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Global evidence for the effects of conservation actions to manage ditches for biodiversity

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Executive Summary

Introduction

This report collated global scientific studies on the effects of ditch management actions on biodiversity. The report reviews 48 potential conservation and management actions, with evidence available for 35 of these actions drawn from 97 studies, around 70% of which were conducted in Europe with the majority being from the Netherlands (17) or the United Kingdom (16).

The evidence covered impacts on plants, invertebrates, amphibians, birds, and habitat condition. The purpose of this report is to present scientific evidence to inform decision making rather than providing prescriptive management guidance. Many of the actions and evidence relate to agri-environment scheme activities.

Key Messages

Ditches are an important biodiversity feature within agricultural and drained landscapes. Their ecological value is highly dependent on management type, intensity and surrounding land use. Across the evidence base, several consistent themes emerged:

- Less intensive, less frequent management generally supports higher biodiversity.
- Reducing chemical inputs, creating habitat diversity and restoring natural water regimes deliver the greatest benefits.
- Outcomes are context dependent, influenced by nutrient levels, hydrology and historical management.

This report also explores the role of agri-environment schemes and their potential impact on ditches and ditch biodiversity. Agri-environment schemes pay farmers to adopt less intensive ditch and bank management techniques (e.g. reduce mowing, reduce fertiliser inputs, reduce grazing intensity).

The evidence in this report shows mixed and context dependant outcomes and suggests that many agri-environment schemes are not well tailored to highly modified lowland landscapes such as the Fens.

Where actions supported by agri-environment schemes align with the evidence

This report shows that several management actions promoted through agri-environment schemes are supported by the scientific evidence:

- Reduced intensity and frequency of management is consistently associated with improved outcomes for plants, invertebrates, and amphibians.
- Buffer strips and reduced chemical inputs are among the most effective actions for improving water quality and supporting plant diversity.

- Amphibians show the strongest positive response, with higher abundance and diversity in agri-environment scheme managed ditches. Reduced disturbance and lower chemical inputs improve breeding and larval survival.
- Agri-environment schemes often increase emergent vegetation cover and are generally more vegetated overall than conventionally farmed ditches.
- Targeted ditch cleaning can benefit amphibians by improving breeding habitat provided recovery time is adequate.

Limitations of scheme options in Fen landscapes

- Plant species richness under agri-environment schemes management is often similar to or lower than conventional management, and often lower than in nature reserves, indicating that supported actions through the current schemes alone are insufficient to drive nature recovery. The reasons for this remain poorly understood and require further investigation.
- Nutrient levels can remain high despite attempts to reduce pollution levels locally suggesting diffuse pollution from surrounding farmland can overwhelm local interventions. This highlights the limitations in highly connected Fenland water systems, where actions can negatively affect downstream habitats.
- Amphibians benefited from agri-environment schemes (though this is based on only one study), while benefits for plants and birds are inconsistent and context dependant (based on 14 studies). Given that ditches and waterways provide habitat for a wide range of specialist plant and bird species, further research is needed to identify which interventions are most beneficial.
- Many of the most effective actions identified, such as ditch reprofiling, pool creation, water level raising, reconnection of ditches and peatland rewetting are not routinely supported or are difficult to deliver under standard Countryside Stewardship (CS) and Sustainable Farming Incentive (SFI) options. The requirements for upfront investments can act as a significant barrier, particularly for smaller scale farms.

The report highlights that substantial evidence gaps remain, with many uncertainties around the impacts of different management actions, highlighting the need for further investigation into the effectiveness of ditch management techniques and how to improve agri-environment schemes.

1. The Conservation Evidence project

Conservation Evidence is a free, authoritative information resource designed to support decisions about how to maintain and restore global biodiversity. (https://www.conservationevidence.com/content/page/24).

We summarise evidence from the scientific literature (studies) about the effects of conservation actions such as methods of habitat or species management. We produce synopses of evidence that review the effectiveness of all actions that could be implemented to conserve a species group or habitat or to tackle a particular conservation issue.

The Conservation Evidence project has four main parts:

1. The **synopses** of the evidence captured for the conservation of particular species groups or habitats. Synopses bring together the evidence for each possible action. They are freely available online (www.conservationevidence.com/synopsis/index).
2. An ever-expanding **database of summaries** of previously published scientific papers, reports, reviews or systematic reviews that document the effects of actions. This resource comprises over 8,871 pieces of evidence, all available in a searchable database on the website www.conservationevidence.com.
3. **What Works in Conservation,** which is an assessment of the effectiveness of actions by expert panels, based on the collated evidence for each intervention for each species group or habitat covered by our synopses. This is available as part of the searchable database and is published as an updated book edition (www.conservationevidence.com/content/page/79).
4. An online, **open access journal** *Conservation Evidence* publishes new pieces of research on the effects of conservation management actions. All our papers are written by, or in conjunction with, those who carried out the conservation work and include some monitoring of its effects (www.conservationevidence.com/collection/view).

Table 1. *The purpose of Conservation Evidence*

Conservation Evidence **does**	Conservation Evidence **does not**
• Bring together scientific evidence captured by the Conservation Evidence project (over 8,854 studies so far) on the effects of actions to conserve biodiversity	• Include evidence on the basic ecology of species or habitats, or threats to them
• List all realistic actions for the species group or habitat in question, regardless of how much evidence for their effects is available	• Make any attempt to weight or prioritize actions according to their importance or the size of their effects

- Describe each piece of evidence, including methods, as clearly as possible, allowing readers to assess the quality of evidence
- Work in partnership with conservation practitioners, policymakers and scientists to develop the list of actions and ensures we have covered the most important literature

- Weight or numerically evaluates the evidence according to its quality
- Provide recommendations for conservation problems, but instead provides scientific information to help with decision-making

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1.1 Methods

For detailed methods used in the Conservation evidence project, please refer to our most recently published synopsis on Eel Conservation, the PDF of which can be found at https://www.conservationevidence.com/synopsis/index. Please also refer to the methods page on the website (https://www.conservationevidence.com/content/page/111).

For specific details about this project, see below.

Creating the list of actions

A comprehensive list of conservation actions was developed by searching the literature, particularly The Drainage Channel Biodiversity Manual (Buisson et al. 2008). The list was also checked by Conservation Evidence to ensure that it followed the standard structure. The aim is to include all actions that have been carried out or advised to support biodiversity in ditches, whether evidence for the effectiveness of an action is available or not.

Literature searches

Literature was obtained from the Conservation Evidence discipline-wide literature database. The Conservation Evidence discipline-wide literature database is compiled using systematic searches of journals (by screening all titles and abstracts) and organisational reports ('grey literature'). Relevant publications describing studies of conservation actions for all species groups and habitats were saved from each journal and added to the database (see above links for the specific inclusion criteria).

To collate studies related to ditch management, the Conservation Evidence literature database was searched using the following terms: “ditch”, “dyke”, “field drain” and “catchwater”.

Due to time constraints, journal searches could not be updated for all journals. Therefore, we selected the three journals with the most publications relevant to ditches and updated the screenings until the year specified:

- Agriculture, Ecosystems and Environment (2024)
- Biological Conservation (2023)
- Conservation Evidence (2024)

The final list of evidence sources searched is published in this document (see Appendices 1–3) and the full list of journals and report series is published online (https://www.conservationevidence.com/journalsearcher/synopsis).

Synthesising the evidence

All relevant publications identified through literature searches were condensed into 200–250-word summaries and group by action. These summaries are further summarised in the key messages for each action. Publications already summarised in previous Conservation Evidence synopses were also incorporated, with links provided to their original summaries on the website. All summaries can be accessed and searched on the Conservation Evidence website.

We found **48** conservation and/or management interventions that could be carried out to conserve biodiversity in ditches. We found evidence for the effects on biodiversity for **35** of these interventions. The evidence was reported as **96** summaries (**55** summarised specifically for this report) from **60** relevant publications**.**

1.2 Acknowledgements

This report is part of a Lowland Agricultural Peat Water Discovery Pilot (LAPDWP) project funded by the Environment Agency and Defra. The project is led by FenlandSOIL, (www.fenlandsoil.org), in partnership with the Centre for Landscape Regeneration, led by the University of Cambridge.

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We would also like to thank those who have contributed to the Conservation Evidence project (www.conservationevidence.com/content/page/24).

2. Summary of findings

In this section, we summarise some of the key learnings from the various potential actions involved in ditch management.

2.1 Ditch maintenance

Actions include ditch cleaning (action 3.1), changing cleaning/cutting frequency (3.2, 3.3), changing season of cleaning/cutting (3.4, 3.5), removing cuttings (3.6), grazing (3.8), leaving headwaters untouched (3.9) and paying farmers to cover conservation, such as through agri-environment schemes (3.7). Key Findings:

- Vegetation responses are variable, cleaning can reduce emergent plant cover while increasing floating or aquatic plant cover, depending on the cleaning method used (1 study, action 3.1).
- Ditch-scoop and mowing basket support higher plant richness (1 study, action 3.1).
- Ditches dredged by pull shovel can support rarer submerged/floating species than other dredging methods (1 study, action 3.1).
- Cleaning ditches can temporarily reduce invertebrate richness and disturb vegetation, but communities often recover to a similar level within 2–4 years however results can vary by cleaning method (2 studies, action 3.1).
- Amphibians respond positively to ditch cleaning, with increased abundance of frogs and toads, more spawning activity, and higher tadpole numbers in cleaned ditches two years after disturbance; however, this can vary species to species (2 studies, action 3.1).
- Later mowing (1st Jul and 1st Sep) significantly increases vegetation seed setting and results in higher diversity compared to conventional cutting regimes, but there was no difference in the emergent plant community when cut at different times of year (2 studies, action 3.5).
- Earlier cleaning of ditches, between Jul–Sep as opposed to Sep–Oct, can result in a higher abundance of amphibian larvae (1 study, action 3.4).
- Removing cuttings is associated with higher plant diversity compared to conventional management (1 study, action 3.6).
- Reducing the frequency of ditch cleaning can increase the presence of caddisfly larvae (1 study, action 3.2).

More Evidence Required:

- Further research required on the effects of cutting frequency on ditch bank vegetation, the effects of grazing livestock on ditch banks and the effects leaving headwaters untouched.

2.2 Managing pollution

Actions include restrictions on pesticides and herbicides (action 4.1), fertiliser (4.2), spoil disposal (4.3), adding minerals (4.4), planting vegetation (4.5, 4.6), altering flow (4.7) and creating interception pools (4.8). Key Findings:

- Restricting chemical inputs reduces pressure on aquatic plant species and invertebrates (2 studies, action 4.1).
- Slower flow rates increase submerged vegetation but decrease floating vegetation (1 study, action 4.7).
- Slower flow rates can increase pollution removal rate (1 study, action 4.7).

More Evidence Required:

- Further research on evaluating the effects of reducing or restricting fertiliser application near ditches, disposal of ditch spoil on ditch banks, planting reedbeds to reduce pollution and excavating pools to intercept pollution.

2.3 Habitat restoration and creation

Actions include excavating and reprofiling ditches (actions 5.1 and 5.2), creating pools (5.3, stabilising banks (5.4), deepening channels (5.5), creating washlands (5.6), buffer strips (5.7) and adding shells (5.8). Key Findings:

- Excavating ditches has mixed results with the successful return of key species such as Norfolk Hawker dragonflies but can also lead to colonisation by invasive species such as water soldier in the short term (2 studies, action 5.1).
- Reprofiling ditches shows no measurable vegetation benefits even after several years (1 study, action 5.2).
- Buffer strips can increase plant richness and enhance dragonfly diversity along ditch banks (1 study, action 5.7).
- Evidence suggests that organically managed ditches without buffers have higher species richness and diversity than conventionally managed ditches with or without buffer strips (1 study, action 5.7).
- Excavating pools produces mixed ecological outcomes, with vegetation and invertebrate richness often lower than in natural pools, but some groups such as farmland birds show localised increases (9 studies, action 5.3).
- Amphibian responses to excavated pools are variable with tadpole numbers sometimes higher than in ditches but generally lower than in natural pools, indicating that created pools provide usable but not optimal breeding habitat (1 study, action 5.3).

More Evidence Required:

- Further evidence required on the effects of stabilising ditch banks, deepening ditch channels and creating washlands.

2.4 Vegetation management

Actions include introduction of aquatic or bankside vegetation (actions 6.1 and 6.2), planting trees (6.4), removing trees (6.5) and coppicing/pollarding (6.6). Key Findings:

- Introducing aquatic vegetation can increase plant diversity and improve structure (1 study, action 6.1).
- Tree removal along ditches can increase vegetation abundance but shows mixed results for amphibians. More evidence is required to establish effects on vegetation, amphibian and invertebrate abundance and diversity (3 studies, action 6.5).

More Evidence Required:

- Further research required into introducing bankside vegetation, planting trees near ditches and coppicing /pollarding trees on ditch banks.

2.5 Species management

Actions include creating escape routes for wildlife (e.g mammals falling into steep sided ditches, action 7.1). Key Findings:

- Simple structures like ramps can reduce wildlife mortality (1 study, action 7.1).

2.6 Water management

Actions include damming (action 8.1), reconnecting ditches (8.2), installing weirs and sluices (8.3), raising water levels (8.4, 8.8), filling/blocking ditches (8.5, 8.6) and rewetting peatland (8.7). Key Findings:

- Damming ditches can lead to increased bird abundance (2 studies) but the effects on other wetland biodiversity are mixed (13 studies, action 8.1).
- Blocking/filling ditches can increase vegetation cover, including bryophytes, grasses and sedges, returning them to natural, undisturbed levels within 3 years (3 studies, action 8.4).
- Reconnecting ditches can increase abundance of fish species (1 study, action 8.2).
- Raising water levels through controlled release has a positive effect on abundance of lapwing and redshank pairs (1 study, action 8.4).

More Evidence Required:

- More evidence required on the effects of installing weirs or sluices in ditches.

2.7 Managing problematic plant species

Evidence covers water hyacinth (actions 9.1, 9.2 and 9.3), curly water weed (9.4, 9.5), Canadian water weed (9.6), New Zealand pigmyweed (9.7), parrots feather (9.8) and floating pennywort (9.9). Key Findings:

- Physical removal is often effective short term but labour intensive (1 study, action 9.1).
- Herbicides can work but have ecological risks (1 study, action 9.3).
- Covering invasive species may be effective in increasing native species abundance in some species (1 study, action 9.4).
- Cutting can supress but rarely eradicates invasive aquatic plants (2 studies, actions 9.5 and 9.6).

2.8 Managing other invasive species

Includes methods like altering banks to prevent crayfish burrows (action 10.1) and releasing fish to control mosquitos (10.2). Key Findings:

- Reprofiling banks can deter invasive crayfish (1 study, action 10.1)
- Using fish for mosquito control is effective but may disrupt ecosystems (1 study, action 10.2).

2.9 Practitioner insights

The following examples were highlighted from those living and working in the landscape through a series of site visits in the Fens, organised by the Centre for Landscape Regeneration in 2023. Real world experience highlighted:

- Reprofiling ditches at Stodmarsh allowed rapid reedbed regeneration, with strong reed growth within two years (11.1).
- Plastic piling is a cheap, quick and durable method for blocking ditches, easier to install than wood and effective for rewetting projects (11.2).
- Cutting ditches once a year, on only one side, creates long wildlife corridors, increases breeding by reed and sedge warblers, attracts cuckoos, reduces water vole predation and cuts management costs (11.3).
- Keeping old dykes instead of filling them in provides valuable bird habitat, supporting large numbers of reed and sedge warbles on farmland (11.4).

2.10 Overall conclusions

- Less intensive, less frequent management generally supports richer assemblages of plants and amphibians.
- Amphibians can benefit from cleaning and clearing vegetation, especially where breeding habitat is provided.

- Agri-environment schemes show mixed results, with some positive impacts on plant richness and amphibian diversity but not consistently across all schemes.
- Restoration efforts like excavation, reprofiling and rewetting are among the most beneficial actions for biodiversity but are underrepresented and harder to access in current schemes.
- The evidence base includes studies conducted globally, such as bacterial studies in China and invasive species research from New Zealand. Whilst these contribute valuable information, their applicability to UK lowland peat landscapes may be limited.
- Given the hydrological connectivity of the Fenland systems, scheme design should also place greater emphasis on coordinated, landscape scale delivery rather than isolated farm level actions.

3. Ditch maintenance

Ditch maintenance involves routine actions such as dredging or cutting, to keep channels functioning. While essential for drainage and flood management, these activities can disturb habitats and wildlife. This chapter covers approaches that minimise ecological impacts while maintaining ditch performance.

3.1 Clean ditches

- **Eleven studies** evaluated the effects of cleaning ditches on vegetation, invertebrates and amphibians. The studies were in the Netherlands[1a,1b,2,5a,5b] and Estonia[3a,3b,4a,4b,7] and the UK[6].

VEGETATION (4 STUDIES)

- **Richness/diversity (1 study):** One replicated study of farmland ditches in the Netherlands[2] found that cleaning with a ditch-scoop or mowing-basket led to higher emergent aquatic plants richness than when cleaning with a mowing-drum. The study also found that ditches dredged by pull-shovel supported more rare submerged/floating species than other dredging methods.
- **Abundance (3 studies):** Two replicated, before-and-after, site comparison studies of commercial forest ditches in Estonia[3a,4a] found that cleaning ditches increased aquatic plant cover but decreased Sphagnum moss cover[4a]. One site comparison study of farmland ditches in the Netherlands[1] found that cleaning ditches decreased emergent plant cover, had no effect on submerged plant or algae cover, and increased floating aquatic plant cover but only when using a mowing basket.

INVERTEBRATES (3 STUDIES)

- **Richness/diversity (2 studies):** Two before-and-after studies (one replicated, site comparison) in farmland ditches and commercial forest ditches in the Netherlands[1b] and Estonia[4a] found that invertebrate richness and diversity was lower eight days after[1b] and one year after cleaning[4a], but returned to pre-cleaning levels 2–4 years after cleaning[4b]. One of the studies found results varied by cleaning method[1b].
- **Abundance (2 studies):** One replicated, before-and-after, site comparison study of commercial forest ditches in Estonia[4a] found that 2–4 years after cleaning ditches, invertebrate abundance was lower than before. One replicated, site comparison study of farmland ditches in the Netherlands[5a] found the equipment used to clean ditches affected the presence of caddisfly larvae but not dragonfly larvae.

AMPHIBIANS (4 STUDIES):

- **Abundance (4 studies):** Two replicated, before-and-after, site comparison studies of commercial forest ditches in Estonia[3b,7] found that two years after cleaning ditches the abundance of common frogs and moor frogs had increased, but the proportion of moor frog tadpoles decreased, and the abundance of spawning clumps and tadpoles was higher in cleared than uncleared sites[7]. One controlled, before-and-after study of farmland ditches in the UK[6] found that after cleaning ditches the number of common toad increased. One replicated, site comparison study of farmland ditches in the Netherlands[5b] found the equipment used to clean ditches did not affect amphibian larvae presence.

Background

Ditches may be cleaned to maintain water flow, prevent siltation, or restore habitat (Herzon & Helenius 2008). Cleaning typically involves removing accumulated sediment, debris, and dense vegetation using machinery (e.g. by dredging) or manual methods. This process can maintain habitat suitability for aquatic vegetation and wildlife.

However, cleaning can also be a major disturbance, directly removing plants and invertebrates and habitat for other species. The frequency, method, and timing of cleaning can therefore have strong effects on the recovery and composition of aquatic and bankside communities. Clearing material from only the middle of the ditch pay prevent bank damage and erosion (Mayer *et al*. 2017).

See '*Reduce frequency of ditch cleaning*'.

Herzon M. & Helenius J. (2016) Agricultural drainage ditches, their biological importance and functioning. *Biological Conservation*, 141, 1171–1183.

Mayer L., Moodie I., Carson C., Vines K., Nunns M., Hall K., Redding M., Sharman P. & Bonney S. (2017) *Good Ecological Potential in Fenland Waterbodies: A Guide to Management Strategies and Mitigation Measures for achieving Good Ecological Potential in Fenland Waterbodies.* Association of Drainage Authorities & Environment Agency.

Vegetation

A site comparison study in 1977–1978 in pasture in Utrect, Netherlands (1a) found that cleaning ditches did not change the cover of submerged aquatic plants, decreased the cover of emergent plants, increased the cover of floating aquatic plants (but only when using a mowing basket), and did not change the cover of filamentous algae (mostly), and there were differences in species composition depending on the cleaning method. Average cover of floating aquatic plants was higher in cleaned than uncleaned ditches, but only when using a mowing-basket (mowing-basket: 18%; ditch-scoop: 3–4%; manual: 5%; uncleaned: 5%). Average cover of emergent species was lower in cleaned (mowing-basket: 11%; ditch-scoop: 8–9%; manual: 11%;) than uncleaned ditches (36%). Average cover of submerged plants did not differ between cleaned (mowing-basket: 43%; ditch-scoop: 45–58%; manual: 46%) and uncleaned ditches (70%). Average cover of filamentous algae did not differ between cleaned (mowing-basket: 22%; ditch-scoop: 21–32%; manual: 39%) and uncleaned ditches (23%) for most cleaning methods, but cover was significantly lower when using a ditch-scoop specifically when ground water discharge was obviously present (2%). There were significant differences in the occurrence of individual species between different methods of cleaning (data not provided, see paper for details). Ditches were cleared of aquatic and bank vegetation and mud using either a ditch-scoop (with or without discharging groundwater into ditches), mowing-basket, or manual equipment. They were compared to uncleaned ditches. In 1977, vegetation was surveyed along 5-m-long transects on both banks. Aquatic vegetation was surveyed in a 10–18 m^2 area across the full width of the ditch. In 1978, vegetation was surveyed over a 10 m distance with the water line as a boundary.

A replicated study in 1994–1996 in ditches on 84 farms in North Holland, Utrect, and South Holland, Netherlands (2) found that the type of machinery used to clean and dredge ditches affected the vegetation community, with ditches cleaned by ditch-scoop or mowing-basket supporting the highest number of emergent aquatic plants, and ditches dredged by pull-shovel supporting more rare and declining species of submerged and floating vegetation. Emergent plant species richness and rare and declining species (recorded as nature-value index) were significantly higher when cleaning with a ditch-scoop or mowing-basket than a mowing-drum (based on statistical model results). For submerged and floating vegetation the nature-value index depended on dredging method, declining in the order: pull-shovel > punched pull-shovel > suction pipe. Ditches (2–10 m wide, 1–2 m deep) were cleaned once/year in July–October. Three types of cleaning machine were compared: ditch-scoop, mowing-basket, mowing-drum. Three types of dredging were compared: pull-shovel, punched-pull shovel, suction pipe. A total of 240 ditches that had been under the same management regime for ≥5 years were surveyed in May–June 1994–1996. Vegetation was surveyed from 25 plots (2 × 2.5 m) evenly spread along a 150 m transect in each ditch.

A replicated, before-and-after, site comparison study in 2013–2017 in three commercial forests in Tartu County, Estonia (3a; same study site as 4) reported that cleaning ditches, along with creating pools, increased the cover of semi-aquatic plants. Results are not based on statistical tests. Cover of semi-aquatic plants in ditches was 35% after cleaning compared to 15% before. Brushwood was removed from ditch banks (no further information provided) in two sites in spring 2014 and one site in 2017. In 2015, pools (18–64 m^2, depth: 1.2–1.8 m) were excavated within some ditches ('ditch enlargements'). Aquatic plant cover was estimated annually from 2013–2017 (no details provided).

A replicated, before-and-after, site comparison study in 2013–2018 in three commercial forests in Tartu County, Estonia (4a; same study site as 3) reported that cleaning ditches increased aquatic plant cover to levels higher than in natural pools, but decreased Sphagnum moss cover to zero. Results are not based on statistical tests. Before cleaning ditches, aquatic plant cover was 15% and Sphagnum moss cover was 17%. After cleaning, aquatic plant cover was 45% and Sphagnum moss cover was 0%. In comparison, natural pools had 37% aquatic plant cover and 5% Sphagnum moss cover. Ditches were cleaned in 2015 or 2017 ('ditch network maintenance', no further information provided). Ten ditches were surveyed in each of three drained sites. Ten 'natural' pools in each of three undrained sites were used as a comparison. Aquatic plant (including algae) and moss cover were estimated in late May or June each year from 2013–2018 in ditches and 2015–2016 in natural pools (no further methods provided).

Invertebrates

A before-and-after study in 1977–1978 in pasture in Utrect, Netherlands (1b) found that cleaning ditches decreased invertebrate species richness and that richness was influenced by cleaning method. Eight days after cleaning, average invertebrate species richness was lower than before cleaning when using either a ditch-scoop (before: 41 species; after: 32 species) or mowing-basket (before: 42 species; after: 28 species). However, when only considering invertebrates from aquatic samples, there was no significant change in species richness (data not provided). The number of species differed significantly between cleaning methods (ditch-scoop without discharge: 1 species; ditch-scoop with discharge: 11 species; mowing-basket: 2 species, see paper for individual species list). Ditches were cleared of aquatic and bank vegetation and mud using either a ditch-scoop or mowing-basket. Sampling stations were selected where the type of management had stayed the same for three years. Invertebrates were sampled in autumn 1978 just before and one week after cleaning. Invertebrates were sampled with a net (20 × 30 cm, 0.5 mm mesh) pushed through the vegetation along the bottom and banks over a 5 m distance.

A replicated, site comparison study in 1994–1996 in 240 ditches on 84 dairy farms in the Netherlands (5a) found that cleaning ditches affected the presence of caddisfly (Trichoptera) larvae, but not dragonfly (Odonata) larvae, depending on the cleaning equipment used. The chance of finding caddisfly larvae varied depending if ditches were cleaned with a mowing-basket (20–81%), followed by a ditch-scoop (22–60%), and a mowing-drum (19–27%), though this also depended on the timing of cleaning. There was no change in the presence of dragon fly larvae (data not reported). Ditches are cleaned every year on the farms. Ditches (2–10 m wide, 10–200 cm deep) cleaned in July–mid-September or September–October were compared. Ditches were cleaned with a ditch-scoop, mowing basket or mowing drum. Sampling was undertaken once between May–June in 1994–1996 before cleaning. Larvae were sampled with a pond net (20 × 30 cm; mesh size 0.5 mm) over a 100 m section in each ditch (twenty 1-m samples per section). The number of larvae per species was counted.

A replicated, before-and-after, site comparison study in 2013–2018 in three commercial forests in Tartu County, Estonia (4b; same study site as 3) found that cleaning ditches initially decreased invertebrate species richness, abundance and diversity after one year, but species richness and diversity increased after 2–4 years, while abundance remained low. Average species richness and diversity decreased one year after cleaning (before: 70 species/plot; one year: 30 species/plot, diversity reported as Shannon index) but returned to pre-cleaning levels 2–4 years after (65 species/plot). Average abundance was lower after cleaning but this was not statistically tested (before: 3,530 individuals/plot; one year after: 1,450 individuals/plot; 2–4 years after: 2,613 individuals/plot). Pools in undrained sites had 61 species and 2,321 individuals/plot. Ditches were cleaned in 2015 or 2017 (‘ditch network maintenance’, no further information provided). Ten ditches were surveyed in each of three drained sites. Ten ‘natural’ pools in each of three undrained sites were used as a comparison. Invertebrate were sampled in late May or June each year from 2013–2018 in ditches and 2015–2016 in natural pools (no further methods provided).

Amphibians

A controlled, before-and-after study in 1999–2012 of seven ditches in pasture in Suffolk, UK (6) found that common toad *Bufo bufo* numbers increased after cleaning ditches. Numbers of adults counted three to seven years after management (after 3–4 years toad maturation) were significantly higher than in the subsequent five years once management ceased (563 vs 245). The year after ditch clearance, large numbers of tadpoles were seen and toadlets increased from 10s–100s to 1,000s in one of the dredged ditches. In comparison, highly vegetated unmanaged ditches supported few or no tadpoles through to metamorphosis. Ditch dredging was undertaken in five of seven ditches in 1999. Monitoring was undertaken three times in March by eggs counts, torchlight surveys, netting ditches and counting breeding adults.

From the Amphibian Synopsis, see here: https://www.conservationevidence.com/actions/749

A replicated, site comparison study in 1994–1996 in 240 ditches on 84 dairy farms in the Netherlands (5b) found that the machine used to clean (dredging) ditches did not affect the presence of amphibian larvae. The chance of finding amphibian larvae did not differ whether ditches were dredged with a suction pipe, pull-shovel, or punched pull-shovel. Ditches are cleaned every year on the farms. Ditches (2–10 m wide, 10–200 cm deep) were dredged with a suction pipe, pull-shovel, or punched pull-shovel either between April–August or September–March. Sampling was undertaken once between May–June before farmers started cleaning the ditches. Larvae were sampled with a pond net (20 × 30 cm; mesh size 0.5 mm) over a 100 m section in each ditch (twenty 1-m samples per section). The number of larvae per species was counted.

A replicated, before-and-after, controlled study in 2014–2015 in a forest wetland complex in Kõpu, Estonia (7) found that clearing ditch vegetation and cutting trees resulted in higher abundance of moor frog *Rana arvalis* and common frog *Rana temporaria* spawning clumps and tadpoles compared to uncleared sites. Before clearing vegetation, the average number of spawning clumps and tadpoles did not significantly differ between cleared (3 clumps/site, 3 tadpoles/site) and uncleared sites (2 clumps/site, 2 tadpoles/site). Six months after clearing, the average number of spawn clumps and tadpoles was higher in cleared (12 clumps/site, 8 tadpoles/site) than uncleared sites (1 clumps/site, <1 tadpoles/site). After clearing, a total of 48 males were observed in cleared sites compared to 0 in uncleared sites, whereas before only one male was observed in both cleared and uncleared in sites (these differences were not statistically tested). In August–December 2014, overgrowth was mechanically removed from the ditch corridor in 16 ditch sections (100-m-long). In most sections, trees were logged from one side with some left lying across the ditch. Sixteen unmanipulated ditch sections were used as a comparison. In spring 2014 (before) and 2015 (after), amphibians were counted visually at each site. Sites where breeding activity was identified were re-visited and dip-netted for tadpoles in June (20 sweeps/100m).

A replicated, before-and-after, site comparison study in 2014–2017 in three commercial forests in Tartu County, Estonia (3b; same study site as 4) reported that cleaning ditches, along with creating pools, increased the abundance of common frogs *Rana temporaria* and moor frogs *Rana arvalis* after two years, but decreased the proportion of moor frog tadpoles. Results are not based on statistical tests. After ditch cleaning, frog occurrence and abundance were higher (4 frogs/10 net sweeps; 47% of samples) than before (1 frog/10 net sweeps; 23%). Of tadpoles that were possible to identify to species, a smaller proportion were identified as moor frogs after ditch cleaning (40%) than before (76%). Brushwood was removed from ditch banks (no further information provided) in two sites in 2014 and one site in 2017. In 2015, pools (18–64 m^2, depth: 1.2–1.8 m) were excavated within some ditches ('ditch enlargements'). All waterbodies were surveyed for frogs and dip-netted for tadpoles (10 sweeps/waterbody) before (year not stated) and after cleaning ditches (July 2017).

(1) Beltman B. (19987) Effects of weed control on species composition of aquatic plants and bank plants and macrofauna in ditches. *Hydrobiological Bulletin*, 21: 171–179. http://dx.doi.org/10.1007/BF02255443

(2) Twisk W., Noordervliet M.A.W. & ter Keurs W.J. (2003) The nature value of the ditch vegetation in peat areas in relation to farm management. *Aquatic Ecology*, 37, 191–209. http://dx.doi.org/10.1023/A:1023944028022

(3) Remm L., Vaikre M., Rannap R. & Kohv M. (2018) Amphibians in drained forest landscapes: Conservation opportunities for commercial forests and protected sites. *Forest Ecology and Management*, 428, 87–92. https://doi.org/10.1016/j.foreco.2018.06.038

(4) Vaikre M., Remm L., Rannap R. (2020) Forest ditch maintenance impoverishes the fauna of aquatic invertebrates: Opportunities for mitigation. *Journal of Environmental Management*, 274, 111188. https://doi.org/10.1016/j.jenvman.2020.111188

(5) Twisk W., Noordervliet M.A.W. & ter Keurs W.J. (2000) Effects of ditch management on caddisfly, dragonfly and amphibian larvae in intensively farmed peat areas. *Aquatic Ecology*, 34, 397–411. https://doi.org/10.1023/A:1011430831180

(6) Beebee T. (2012) Decline and flounder of a Sussex common toad (Bufo bufo) population. *The Herpetological Bulletin*, 121, 6-16. Available at: https://www.thebhs.org/publications/the-herpetological-bulletin/issue-number-121-autumn-2012/4-2-decline-and-flounder-of-a-sussex-common-toad-i-bufo-bufo-i-population/file

(7) Soomets E., Lõhmus A. & Rannap R. (2017) Brushwood removal from ditch banks attracts breeding frogs in drained forests. *Forest Ecology and Management*, 384, 1–5. http://dx.doi.org/10.1016/j.foreco.2016.10.023

3.2 Reduce frequency of ditch cleaning

- **Three studies** evaluated the effects of reducing the frequency of ditch cleaning on vegetation, invertebrates and amphibians. The studies were in Germany[1] and the Netherlands[2a,2b].

VEGETATION (1 STUDY)

- **Abundance (1 study):** One replicated, site comparison study in marshes Germany[1] found that cover and number of seedlings of mud bank species was lower, but purple-moor grass cover was higher, in ditches that had not been dredged for at least two years compared to those dredged one year ago, whereas the cover of reeds, shrubs, trees, and the number of seedings did not differ.

- **Community composition (1 study):** One replicated, site comparison study in marshes Germany[1] found that ditches dredged once, two, three, or more than three years previously had different species composition on ditch banks, but not in the ditch water.

INVERTEBRATES (1 STUDY)

- **Abundance (1 study):** One replicated, site comparison study in farmland ditches in the Netherlands[2b] found reducing the frequency of ditch cleaning increased the presence of caddisfly larvae but not dragonfly larvae.

AMPHIBIANS (1 STUDY)

- **Abundance (1 study):** One replicated, site comparison study in farmland ditches in the Netherlands[2b] found reducing the frequency of ditch cleaning increased the presence of amphibian larvae.

Background

Ditch wildlife has been shown to be affected by agricultural management practices including ditch cleaning (e.g. van Strien *et al*. 1991, Twisk *et al*. 2000, 2003). Frequent or intensive cleaning can remove aquatic plants, displace or kill invertebrates and fish, disturb sediments, and simplify habitat structure (Herzon & Helenius 2008).

Reducing the frequency of ditch cleaning may allow vegetation to establish more stable communities and provide refuges, food resources, and habitat complexity for wildlife.

van Strien A.J., van der Burg T., Rip W.J. & Strucker R.C.W. (1991) Effects of mechanical ditch management on the vegetation of ditch banks in Dutch peat areas. *Journal of Applied Ecology*, 28, 501– 513.

Twisk W., Noordervliet M.A.W. & Ter Keurs W.J. (2000) Effects of ditch management on caddisfly, dragonfly and amphibian larvae in intensively farmed peat areas. *Aquatic Ecology*, 34, 397–411.

Herzon M. & Helenius J. (2016) Agricultural drainage ditches, their biological importance and functioning. *Biological Conservation*, 141, 1171–1183.

Vegetation

A replicated, site comparison study in 2011–2013 in agricultural marshes in Schleswig-Holstein, Germany (1) found that reducing the frequency of ditch cleaning changed the plant species composition on ditch banks, but not ditch water, decreased the cover of reeds (Phragmitetea), increased the cover purple–moor-grass *Molinietalia caeruleae*, but did not change the cover of other species groups or the total number of seedlings. Plant species composition on ditch banks differed among ditches dredged one, two, three, or more than three years previously, but composition in ditch water did not significantly differ (reported as statistical model results). Average cover of mud bank species (Bidentetea) was lower in ditches dredged two (5%), three (4%), or more than three years earlier (7%) compared to ditches dredged one year earlier (19%). Cover of purple –moor-grass also differed with time since dredging (one: 12%; two: 25%; three: 35%; >3 years: 20%). Cover of reeds (50–87%), woody species (5–39%), and trees/shrubs (no data) did not significantly differ. The number of seedlings did not significantly differ with time since dredging (9,900–14,800 seedlings/year), except mud bank species, which had fewer seedlings in ditches dredged three or more years earlier (1,800–2000 seedlings/year), than two years earlier (4,400 seedlings/m^2). Ditches were dredged with a 1-m wide pull shovel when the soil was frozen, and categorised by time since last dredging (one, two, three, or >3 years). In 2011–2013, vegetation was surveyed along one 50-m section of each of 110 ditches (mostly bordered by grassland). Soil seed bank samples (100 cm^2) were taken from ditch banks of 60 ditches in summer 2013.

Invertebrates

A replicated, site comparison study in 1994–1996 in 240 ditches on 84 dairy farms in the Netherlands (2a) found that reducing the frequency of dredging increased the presence of caddisfly (Trichoptera) larvae, but not dragonfly (Odonata) larvae. The presence of caddis fly larvae was higher in ditches that had not been dredged for two years or more compared to ditches that had been dredged within 1–2 years. There was no change in the presence of dragon fly larvae (data not reported). Ditches are cleaned every year on the farms. Ditches (2–10 m wide, 10–200 cm deep) were dredged one, two, three, or four years previously. Sampling was undertaken once between May–June in 1994–1996 before farmers started cleaning the ditches. Larvae were sampled with a pond net (20 × 30 cm; mesh size 0.5 mm) over a 100 m section in each ditch (twenty 1-m samples per section). The number of larvae per species was counted.

Amphibians

A replicated, site comparison study in 1994–1996 in 240 ditches on 84 dairy farms in the Netherlands (2b) found that reducing the frequency of dredging increased the presence of amphibian larvae. The presence of amphibian fly larvae was higher in ditches that had not been dredged for three years or more, compared to ditches that had been dredged within 1–3 years. Ditches are cleaned every year on the farms. Ditches (2–10 m wide, 10–200 cm deep) were dredged one, two, three, or four years previously. Sampling was undertaken once between May–June in 1994–1996 before farmers started cleaning the ditches. Larvae were sampled with a pond net (20 × 30 cm; mesh size 0.5 mm) over a 100 m section in each ditch (twenty 1-m samples per section). The number of larvae per species was counted.

(1) Rasran L. & Vogt K. (2018) Ditches as species-rich secondary habitats and refuge for meadow species in agricultural marsh grasslands. *Applied Vegetation Science*, 21, 21–31. https://doi.org/10.1111/avsc.12337
(2) Twisk W., Noordervliet M.A.W. & ter Keurs W.J. (2000) Effects of ditch management on caddisfly, dragonfly and amphibian larvae in intensively farmed peat areas. *Aquatic Ecology*, 34, 397–411. https://doi.org/10.1023/A:1011430831180

3.3 Change frequency of cutting/mowing ditches

- **Two studies** evaluated the effects of changing the frequency of cutting/mowing ditches on vegetation. The studies were in the Netherlands[1,2].

VEGETATION (3 STUDIES)

- **Community composition (1 study):** One replicated, randomized, paired, controlled study in farmland ditches in the Netherlands[1] found that cutting once, twice or three times per year did not change the plant community in the ditch channel or the emergent wetland zone.
- **Richness/diversity (1 studies):** One replicated, randomized, paired, controlled study of farmland ditches in the Netherlands[1] found that cutting ditches once, twice or three times/year resulted in similar overall plant species richness.
- **Survival (1 study):** One replicated, controlled study of farmland ditches in the Netherlands[2] found that ditch banks cut once, twice of three times per year had similar plant survival and establishment.
- **Reproduction (1 study):** One replicated, controlled study of farmland ditches in the Netherlands[2] found that ditch banks cut once, twice or three times per year had similar levels of plant reproduction (flowering/seed-setting).

Background

Ditch cutting or mowing is a common management practice to maintain habitat structure and prevent them from becoming overgrown or drying out. Regular cutting can help control dominant species, maintain open water areas, and regulate light and nutrient availability. These factors can influence the composition of both plant and animal communities living in and around ditches.

However, the frequency, and intensity, of ditch cutting are important, as different plant species vary in their tolerance to disturbance (Connell 1978).

See also '*Change season of cutting/mowing'.*

Connell, J.H. (1978) Diversity in tropical rain forests and coral reefs. *Science*, 199, 1302–1310.

Vegetation

A replicated, randomized, paired, controlled study in 1989–1991 of four farmland ditches in the Netherlands (1) found that vegetation cutting had similar effects on the aquatic plant community in the ditch and in the emergent wetland zone, whether it was done once, twice or three times/year. The overall plant community composition was statistically similar under each cutting frequency in three of three years (data reported as statistical model results). Aquatic macrophyte richness was statistically similar under each cutting frequency in 12 of 12 comparisons (for which one cut: 6–14; two cuts: 6–14; three cuts: 7–14 species/ditch). Plant species richness in the emergent wetland zone was similar under each cutting frequency in 10 of 12 comparisons (for which one cut: 10–49; two cuts: 8–48; three cuts: 9–49 species/ditch). The study also identified four common aquatic macrophytes and 16 common emergent and terrestrial plant species whose cover was significantly affected by the frequency of cutting in at least one ditch (data not reported). Between 1989 and 1991, vegetation was cleared from three 20 m sections of each ditch: one section each May; one section each May and July; one section each May, July and September. Vegetation was cut within the ditch and on its margins, then dumped higher up on the ditch banks. Each July, plant species and their cover (excluding mosses) were recorded in the ditch channel and emergent wetland zone bordering each ditch.

From the Marshes and Swamps Synopsis, see here: https://www.conservationevidence.com/actions/3066
From the Aquatic Vegetation Synopsis (not yet published)

A replicated, controlled study of species sown on ditch banks on six farms in the western peat district of the Netherlands (2) found that, overall, there was no significant difference between overall species or species-level germination and establishment, plant survival or reproduction (flowering/seed-setting) under three cutting regimes. However, on high-productivity ditch banks, germination (7% vs 4–5%), establishment (20% vs 7–15%) and reproduction (21–39% vs 15–27%) of many species were higher under 'conventional management' than the three cutting treatments. On low-productivity ditch banks, plants tended to have lower survival under 'conventional management' (60% vs 70–80%) and higher reproduction under 'conventional management' and with the first cut in May (33–40% vs 23–26%). One ditch bank was selected on each farm and was divided into four treatments, each with five replicates: two cuts (July and September), three cuts (June, August, September), two cuts (May, September), 'conventional management' (standard cutting and grazing - varied between 74 farms). A mown/artificial gap (15 × 15 cm) was created for each of the nine species in each plot. Approximately 100 seeds were sown of each species in October 2001. Numbers of seedlings and established plants (≥4 cm) were monitored each month until September 2003. Biomass samples were collected from plots (20 × 50 cm) in July 2001 (pre-treatment biomass) and before each mowing event in 2002–2003; dry weights were recorded.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

(1) Best E.P.H. (1994) The impact of mechanical harvesting regimes on the aquatic and shore vegetation in water courses of agricultural areas of the Netherlands. *Vegetatio (now Plant Ecology)*, 112, 57–71. https://doi.org/10.1007/BF00045100

(2) Blomqvist M.M., Tamis W.L.M., Bakker J.P. & van der Meijden E. (2006) Seed and (micro) site limitation in ditch banks: Germination, establishment and survival under different management regimes. *Journal for Nature Conservation*, 14, 16–33 77. https://doi.org/10.1016/j.jnc.2005.08.003

3.4 Change season of cleaning ditches

- **Two studies** evaluated the effects of changing the season of cleaning ditches on invertebrates and amphibians. The studies were in the Netherlands[1,2].

INVERTEBRATES (1 STUDY)

- **Abundance (1 study):** One replicated, site comparison study of farmland ditches in the Netherlands[1a] found that ditches cleaned between September–October had higher presence of caddisfly larvae, but not dragonfly larvae, than ditches cleaned in July–September.

AMPHIBIANS (1 STUDY)

- **Abundance (1 study):** One replicated, site comparison study of farmland ditches in the Netherlands[1b] found that ditches cleaned between July–September had higher presence of amphibian larvae than ditches cleaned in September–October, but changing the timing of dredging had no effect on larvae presence.

Background

Ditch wildlife has been shown to be affected by agricultural management practices including ditch cleaning (e.g. van Strien *et al*. 1991, Twisk *et al*. 2000, 2003). Frequent or intensive cleaning can remove aquatic plants, displace or kill invertebrates and fish, disturb sediments, and simplify habitat structure (Herzon & Helenius 2008; Mayer *et al*. 2017).

Altering the season when ditches are cleaned and dredged may avoid sensitive periods such as plant flowering or seed production, invertebrate emergence, amphibian breeding, or fish spawning, and may help maintain habitat structure for longer within the year.

van Strien A.J., van der Burg T., Rip W.J. & Strucker R.C.W. (1991) Effects of mechanical ditch management on the vegetation of ditch banks in Dutch peat areas. *Journal of Applied Ecology*, 28, 501– 513

Twisk W., Noordervliet M.A.W. & Ter Keurs W.J. (2000) Effects of ditch management on caddisfly, dragonfly and amphibian larvae in intensively farmed peat areas. *Aquatic Ecology*, 34, 397–411.

Herzon M. & Helenius J. (2016) Agricultural drainage ditches, their biological importance and functioning. *Biological Conservation*, 141, 1171–1183.

Mayer L., Moodie I., Carson C., Vines K., Nunns M., Hall K., Redding M., Sharman P. & Bonney S. (2017) *Good Ecological Potential in Fenland Waterbodies: A Guide to Management Strategies and Mitigation Measures for achieving Good Ecological Potential in Fenland Waterbodies.* Association of Drainage Authorities & Environment Agency.

Invertebrates

A replicated, site comparison study in 1994–1996 in 240 ditches on 84 dairy farms in the Netherlands (1a) found that changing the timing of ditch cleaning and dredging affected the presence of caddisfly (Trichoptera) larvae, but not dragonfly (Odonata) larvae. The chance of finding caddisfly larvae was higher when ditches are cleaned in September–October (19–60%) than July–September (22–81%), though this also depended on the cleaning equipment used. The timing of dredging also affected the presence of caddis fly larvae (see paper). There was no change in the presence of dragon fly larvae (data not reported). Ditches are cleaned every year on the farms. Ditches (2–10 m wide, 10–200 cm deep) were cleaned with a ditch-scoop, mowing basket or mowing drum either in July–mid-September or September–October. Ditches were dredged with a suction pipe, pull-shovel, or punched pull-shovel either between November–August or September–October. Sampling was undertaken once between May–June 1994–1996 before farmers started cleaning the ditches. Larvae were sampled with a pond net (20 × 30 cm; mesh size 0.5 mm) over a 100 m section in each ditch (twenty 1-m samples per section). The number of larvae per species was counted.

Amphibians

A replicated, site comparison study in 1994–1996 in 240 ditches on 84 dairy farms in the Netherlands (1b) found that changing the timing of ditch cleaning, but not ditch dredging, affected the presence of amphibian larvae. Ditches cleaned between July–September had a higher presence of amphibian larvae (77%) than ditches cleaned between September–October (57%). The timing of dredging did not significantly affect larvae presence. Ditches are cleaned every year on the farms. Ditches (2–10 m wide, 10–200 cm deep) were cleaned with a ditch-scoop, mowing basket or mowing drum either in July–mid-September or September–October. Ditches were dredged with a suction pipe, pull-shovel, or punched pull-shovel either between April–August or September–March. Sampling was undertaken once between May–June before farmers started cleaning the ditches. Larvae were sampled with a pond net (20 × 30 cm; mesh size 0.5 mm) over a 100 m section in each ditch (twenty 1-m samples per section). The number of larvae per species was counted.

(1) Twisk W., Noordervliet M.A.W. & ter Keurs W.J. (2000) Effects of ditch management on caddisfly, dragonfly and amphibian larvae in intensively farmed peat areas. *Aquatic Ecology*, 34, 397–411. https://doi.org/10.1023/A:1011430831180

3.5 Change season of cutting/mowing ditches

- **Two studies** evaluated the effects of changing the season of cutting/mowing on vegetation in ditches. The studies were in the Netherlands[1,2].

VEGETATION (2 STUDIES)

- **Richness/diversity (1 study):** One replicated, randomized, paired, controlled study in farmland ditches in the Netherlands[1] found no difference in species richness of aquatic macrophytes and emergent plants when cutting in May or November.
- **Community composition (1 study):** One replicated, randomized, paired, controlled study in farmland ditches in the Netherlands[1] found that cutting in May or November resulted in a similar plant community in the ditch and the emergent wetland zone.

Background

Ditch wildlife has been shown to be affected by agricultural management practices such as mowing regimes (e.g. van Strien *et al*. 1989). The ecological impacts of ditch cutting can vary greatly depending on the time of year it is carried out.

Altering the season when ditches are cut may avoid sensitive periods such as plant flowering or seed production, invertebrate emergence, amphibian breeding, or fish spawning, and may help maintain habitat structure for longer within the year.

van Strien A.J, van Der Linden, J., Melman, T.C.P & Noordervliet, M.A.W. (1989) Factors affecting the vegetation of ditch banks in peat areas in the western Netherlands. *Journal of Applied Ecology*, 26, 989–1004.

Vegetation

A replicated, randomized, paired, controlled study in 1989–1991 of four farmland ditches in the Netherlands (1) found that vegetation cutting had similar effects on the plant community in the ditch of the emergent wetland zone, whether it was done in May or November. The season of cutting had no significant effect on plant community composition in three of three years for aquatic macrophytes and two of three years for emergent vegetation (data reported as statistical model results). The season of cutting had no significant effect on aquatic macrophyte richness in 9 of 12 comparisons (May-cut: 7–14; November-cut: 7–13 species/ditch). In the other three comparisons, November-cut plots had higher richness (8–12) than May-cut plots (6–8). The season of cutting had no significant effect on emergent plant species richness in 11 of 12 comparisons (May-cut: 10–49; November-cut: 8–47 species/ditch). The study also identified three common aquatic macrophyte species and 18 common emergent and terrestrial plant species for which cover was significantly affected by the season of cutting, in at least one of the four ditches (data not reported). The study used four agricultural ditches. Between 1989 and 1991, vegetation was cleared from two 20-m-long sections of each ditch: one section each May and one section each November. Vegetation was cut within the ditch and on its margins, then dumped higher up on the ditch banks. Each July, plants (excluding mosses) and their cover were recorded in the permanently flooded ditch channel.

From the Marshes and Swamps Synopsis, see here: https://www.conservationevidence.com/actions/3070
From the Aquatic Vegetation Synopsis (not yet published)

A replicated study of 24 pastoral ditches in 2008 in the Netherlands (2) found that delaying twice yearly mowing dates resulted in higher plant diversity. The highest number of seed-setting species was recorded following mowing on 1 July and 1 September, which was 126% higher than under the conventional regime of mowing on 1 June and 1 August. The effect of mowing date differed between plant species. Species richness was significantly higher and biomass significantly lower on ditches in nature reserves compared to those under long-term agri-environment schemes (>16 years), short-term agri-environment schemes (<6 years) and conventional management. Plots were mown twice on a unique combination of an early (15th May, 1st June, 15th June, 1st July) and late date (1st August, 15th August, 1st September, 15th September). Before mowing, presence of species, target species with ripe seeds and biomass was recorded in 16 plots under different biannual mowing treatments within six randomly selected ditches under each of the four management systems: nature reserves, long-term agri-environment schemes, short-term agri-environment schemes and conventional farms.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

(1) Best E.P.H. (1994) The impact of mechanical harvesting regimes on the aquatic and shore vegetation in water courses of agricultural areas of the Netherlands. *Vegetatio (now Plant Ecology)*, 112, 57-71. https://doi.org/10.1007/BF00045100
(2) Leng X., Musters C.J.M. & de Snoo G.R. (2011) Effects of mowing date on the opportunities of seed dispersal of ditch bank plant species under different management regimes. *Journal for Nature Conservation*, 19, 166–174. https://doi.org/10.1016/j.jnc.2010.11.003

3.6 Remove vegetation cuttings from ditch banks

- **One study** evaluated the effects of removing vegetation cuttings from ditch banks on vegetation. The study was in the Netherlands[1].

VEGETATION (1 STUDY)

- **Richness/diversity (1 study):** One replicated, site comparison study in the Netherlands[1] found that farms where cuttings were removed from ditch banks (and establishing buffer strips) had higher plant diversity compared to conventionally managed farms but not compared to organic farms with where cuttings were not removed.

Background

Cutting or mowing vegetation along ditches is a common management practice, but leaving the cut material on the banks can have unintended ecological and hydrological effects. Removing cuttings helps prevent them from smothering existing bankside vegetation and reduces the risk of material being washed into the channel, where it may cause downstream blockages (e.g. at culverts) (Buisson et al. 2008).

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

Vegetation

A replicated, site comparison study from 1999 to 2004 in the Netherlands (1) found that removing ditch cuttings, along with establishing buffer strips, affected plant diversity. The study does not distinguish between removing cuttings and establishing buffer strips. Diversity was significantly higher on farms with 'ecologically managed' ditches where cuttings were removed and organic farms where cuttings were not removed (converted to organic less than 5 years ago: 32 plant species/400 m^2, converted more than 5 years ago: 36–52 plant species/400 m^2) than conventional farms where cuttings were not removed (26–34 species/400 m^2). On ecologically managed farms plant diversity increased significantly over six years (up to 27%), there was a small shift to less common plant species and a decrease in the number of nitrogen rich species and Ellenberg nitrogen-values. There tended to be more nitrogen poor species on ecologically managed and organic farms compared to conventional farms. Four ecologically managed farms (mown once in September and cuttings removed), 18 conventional and 20 organic arable farms were studied. Cutting date varied on conventional and organic farms, but cuttings were never removed, ditches on both farm-types did not have buffer field margin strips. On ecologically managed farms, plant species surveys of 100 m of ditch bank spread over the whole farm were undertaken once a year 1999–2004. On 75 organic (in 2001) and conventional (2003) farms, plant species presence was recorded on 10 × 25 m of ditch bank along a transect (May-June).

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

(1) Manhoudt A.G.E., Visser A.J. & de Snoo G.R. (2007) Management regimes and farming practices enhancing plant species richness on ditch banks. *Agriculture, Ecosystems & Environment*, 119, 353–358. https://doi.org/10.1016/j.agee.2006.08.004

3.7 Pay farmers to cover the costs of conservation measures

- **Thirteen studies** evaluated the effects of paying farmers to cover the costs of conservation measures on vegetation, amphibians and birds. The studies were in the Netherlands[1–5,7], the UK[6,9–12] and Estonia[8].

VEGETATION (8 STUDIES)

- **Richness/diversity (6 studies):** Four of five replicated, controlled studies (one before-and-after) in the Netherlands[3–5,7] and UK[6] found that farmland ditches under agri-environment schemes had similar richness of ditch bank plants[4,5], aquatic plants[6] and water-dispersed plants[7] to ditches not in the schemes, but species richness[4] was lower than in nature reserves in two of the studies[4,7]. One of the studies found ditch bank plant richness increased over time for wind and water-dispersed species[5]. The other study found that farmland ditches under agri-environment schemes had higher plant species richness of ditch banks than ditches not in the schemes[3]. One replicated, paired, site comparison study in the Netherlands[2] found that farmland ditches under agri-environment schemes had a decrease in ditch bank plant richness over 10 years, but target plant richness did not differ.
- **Abundance (4 studies):** Three of four replicated, site comparison studies in the Netherlands[1a,3] and Estonia[8] found that farmland ditches under agri-environment schemes had higher emergent plant cover[1a], higher abundances of 11 of 17 plant species[3], and a higher proportion of fields with vegetated ditches[8] than ditches not in the schemes, though one of the studies found no difference in the cover of submerged or floating plants[1a]. The other study[4] found that farmland ditches under agri-environment schemes had similar plant biomass to ditches not in the schemes, but lower biomass than nature reserves.
- **Community composition (1 study):** One replicated, paired, site comparison study in the Netherlands[2] found that farmland ditches under agri-environment schemes had an increase in grass:broadleaved plant ratio over 10 years.

AMPHIBIANS (1 STUDY)

- **Richness/diversity (1 study):** One replicated, site comparison study in the Netherlands[1b] found that farmland ditches under agri-environment schemes had higher amphibian diversity than conventionally managed ditches.
- **Abundance (1 study):** One replicated, site comparison study in the Netherlands[1b] found that farmland ditches under agri-environment schemes had higher amphibian abundance (including green frogs) than conventionally managed ditches.

BIRDS (5 STUDIES)

- **Abundance: (4 studies):** Three studies in the UK[9-11]found that farmland ditches managed under agri-environment schemes had mixed effects on bird abundance depending on the species, with increases found for linnet[10], reed bunting[10,12], blue tits[11] dunnocks[11] and common white throat[11], decreases found for skylark[10], grey partridge[10], tree sparrow[12], and no change in abundance for other species monitored[12].

Background

Ditch bank biodiversity is declining in agricultural landscapes and so management is required to maintain and increase species diversity. However, implementing conservation actions can be costly for landowners, either because of the direct management costs or due to the loss of income from other possible land uses, such as farming. Payments may be offered by Governments or inter-Governmental schemes to compensate landowners for these costs, and encourage more wildlife-friendly habitat management and creation on private land. In Europe, agri-environment schemes (AES) are an integral part of the European Common Agricultural Policy (CAP) and Member States devise their own AES prescriptions to suit their agricultural economies and environmental contexts. In relation to ditch banks, schemes often focus on reducing intensity of management, such as mowing, grazing of fertilizer use.

This section includes evidence about the success of agri-environment or conservation incentive policies overall, since AES often represent many different conservation actions.

Vegetation

A replicated, site comparison study of 18 agri-environment scheme-managed and 24 conventionally managed ditches within pasture and perpendicular to eight nature reserve borders in the western peat district of the Netherlands (1a) found that emergent plant cover was significantly higher in agri-environment than conventional ditches but no difference was found for submerged and floating vegetation or floating algae (reported as statistical model results). Farmers managing ditches under agri-environment schemes are encouraged to reduce grazing/mowing intensity, reduce fertilizer inputs, and not to deposit mowing cuttings or sediments from ditch cleaning on the ditch banks. Percentage cover of aquatic plants was estimated in ditches in April-May and/or May-July 2008 just inside reserves and at four distances (0–700 m) from reserve borders.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

A replicated, paired, site comparison study of ditch banks on six dairy farms in the western peat district of the Netherlands (2) found that agri-environment scheme ditch management did not result in increased plant diversity or decreased productivity over 10 years. The total number of plant species on ditch banks under agri-environment scheme management decreased significantly between the periods 1993–1995 (31 species) and 2000–2003 (29 species); numbers of target plant species did not differ (7 species). Productivity on agri-environment scheme ditch banks measured as grass/broadleaved plant ratio increased significantly (1993–1995: 0.37; 2000–2003: 0.44) and Ellenberg nitrogen values increased in four and decreased in two farms (1993–1995: 5.82; 2000–2003: 5.92). Differences between agri-environment scheme and surrounding ditch banks tended to decrease over the study period. Plant diversity data were obtained from agri-environment scheme ditch banks in July-August 1993–1995 and May 2000–2003 (42 repeatedly sampled plots) and non-agri-environment scheme ditch banks surrounding five of the farms (78 plots/year). Five replicate biomass samples were taken from agri-environment scheme ditch banks in mid-May 2000–

2002 (9–72 plots) before grazing and mowing. Two productivity measures were also derived from botanical data: grass/broadleaved plant ratios and Ellenberg nitrogen-values.
From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

A replicated, site comparison study in 2006–2007 in agricultural land in South Holland, Netherlands (3; same study site as 5, 7) found that ditch banks managed under agri-environment schemes had higher species richness, and higher abundance of most species, than ditch banks not in the schemes. Average species richness in agri-environment ditch banks was significantly higher than in ditch banks not in the schemes (5.0 vs 4.6 species). Of 17 species, 11 had a higher abundance, one had a lower abundance, and five showed no difference in agri-environment ditch banks compared to ditch banks not in the schemes (reported as statistical model results). Under agri-environment scheme management, no application of fertilizer, manure or dredged sludge was made on the first metre of the ditch bank but mowing and grazing were allowed. Twenty-six ditch banks across two sites managed under agri-environment schemes for 6–12 years were compared to 36 ditch banks not under the schemes. In May/June 2006–2007, vegetation was analysed (no methods provided) and presence/absence of 25 target plants were recorded in fourteen 10-m-long plots (approximate width 1.25 m ± 0.09 m) along each ditch bank. The 25 target plants were selected by the Dutch government as easily identifiable species that correlated with plant species richness along ditch banks.

A replicated, controlled study in 2008 in pastureland and nature reserves in South Holland, Netherlands (4) found that ditch banks managed under agri-environment schemes had similar plant species richness and biomass to conventionally managed farms, but lower species richness and higher biomass than nature reserves. Total plant species richness and biomass did not significantly differ between agri-environment (6 species, 797–803 g/m^2) and conventional farms (5 species, 865 g/m^2) but species richness was lower, while biomass was higher, compared to nature reserves (7 species, 635 g/m^2). There was no difference in species richness and biomass between short (6 species, 803 g/m^2) and long-term agri-environment management (6 species, 797 g/m^2). Ditch banks under four management types were compared: nature reserves, short term agri-environment schemes (<6 years), long term agri-environment scheme (>16 years), and conventional management (farmers choose freely). Nature reserves have limited grazing/mowing. Agri-environment management recommended late June/early July mowing, no fertilizer use, low stocking rates, and deposition of dredged material on ditch banks. Vegetation was sampled from six sites/management type. Each site contained sixteen 10 m plots. Vegetation was cut from two 0.1 m^2 quadrats/plot (cut 3 cm above ground), then dried, weighed, and species recorded.

A replicated, controlled study in 2000–2009 in agricultural land in South Holland, Netherlands (5; same study site as 7) found that ditch banks managed under agri-environment schemes had similar plant species richness as control ditch banks, though species richness increased changed over time depending on dispersal strategy. Target species richness did not significantly differ between managed (4.1–4.9 species/year) and control ditch banks (0–4 species/year). Richness also did not differ for species dispersed by water (managed: 2

species/year; control: 0–3/year), wind (<1 species/year for both), animals (<0.1 species/year for both), or without long-distance dispersal (managed: 2 species/year; control: 0–2/year). Over nine years, richness increased for wind- (4.7%/year) and water-dispersed species (2.5%/year), did not change for animal-dispersed species, and decreased for species with no dispersal (1.1%/year), regardless of management. Under agri-environment scheme management, no application of fertilizer, manure or dredged sludge on the first metre of ditch banks but mowing and grazing were allowed. Between June–August 2000–2009, plants were recorded by farmers across 20 farms by farmers in 153 managed plots (100 × 1 m; one plot per kilometre of managed ditch banks). Control plots were surveyed in the year those farms first started agri-environment management. Twenty-five target plants were selected by the Dutch government as easily recognised species that correlated with plant species richness along ditch banks.

A replicated, before-and-after, site comparison study in 2005–2012 of farmland ditches in England, UK (6) found that managing ditches under an agri-environment scheme had no significant effect on the frequency of aquatic vegetation, or vegetation species richness. After six years, 15–34% of ditches managed under agri-environment rules contained floating macrophytes. There were 1.5 native aquatic macrophyte species/20 m. There were 6.1–6.5 total plant species/ditch (aquatic, emergent and terrestrial). These values did not significantly differ from ditches not managed under agri-environment rules: 14% with floating macrophytes, 2.0 native aquatic macrophyte species/20 m, and 6.4 total plant species/ditch. Additionally, there was no clear change over time in the proportion of managed ditches that contained aquatic macrophytes: 15% (submerged) and 12% (floating) just before or just after the agri-environment scheme began, then 13% (submerged) and 16% (floating) five years later (statistical significance not assessed). The "Entry Level Stewardship" agri-environment scheme began in 2005/2006. Rules for ditch management included leaving at least half of the vegetation in the ditch if cleaning to prevent flooding, and carrying out this cleaning during winter. Vegetation in and along ditches was surveyed in 2005/2006, 2011 and 2012. Surveys included 52–170 ditches/year managed under agri-environment rules, and 16–17 ditches/year on farms not participating in the scheme.
From the Aquatic Vegetation Synopsis (not yet published)

A replicated, site comparison study in 1998–2009 in agricultural land in South Holland, Netherlands (7; same study site as 5) found that ditch banks managed under agri-environment schemes had a lower species richness of water-dispersed plants than those in nature reserves. Of 25 target species, the number of water-dispersed species was lower in agri-environment scheme ditch banks (2.0–2.4 species/year) than nature reserve ditch banks (1.6–4.8 species/year), though richness increased over nine years in both. Total plant species richness (not just target species) did not change over time in either management type (see paper for details). Agri-environment schemes, established in 2000, required that no application of fertilizer, manure or dredged sludge was made on the first metre of ditch banks but mowing and grazing were allowed. Plants on agri-environment ditch banks were recorded by 63 farmers across 1,494 quadrats (100 × 1 m) in 2000, 2005, and 2009 (25% of records were verified by specialists). Data for nature reserves came from 122 quadrats (50 x 1 m), each surveyed at least twice between 1998 and 2009. Nature reserve ditch banks were managed either by grazing without fertilisation, or by fertilizing with manure. The 25 target species were selected by the Dutch government as easily identifiable species that correlated with plant species richness along ditch banks.

A replicated, controlled study in 2020–2021 in 74 arable fields and 11 grasslands in Central and South Estonia (8) found that fields on farms managed organically had more ditches with tall vegetation and trees than fields managed conventionally, but there was no difference between environmentally friendly and conventionally managed fields. The proportion of fields with vegetated ditches was higher in organic fields (48%) than in conventionally managed fields (19%) but did not differ between environmentally friendly (31%) and conventional fields. Two agri-environment management types, organic and environmentally friendly, were compared with conventional farming. Organic farms used organic fertilizers and crop rotations with legumes, while environmentally friendly farms limited synthetic fertilizer use.

Amphibians

A replicated, site comparison study of 42 managed ditches within pasture in the Western Peat District of the Netherlands (1b) found that amphibian diversity and abundance was significantly higher in agri-environment scheme compared to conventionally managed ditches. Adult green frog *Rana esculenta* numbers in conventional ditches declined with distance from reserves; this was not the case in agri-environment scheme ditches. Farmers managing ditches under agri-environment schemes are encouraged to reduce grazing/mowing intensity and reduce fertilizer inputs compared to conventional management, and not to deposit mowing cuttings or sediments from ditch cleaning on the ditch banks. Monitoring was undertaken along 18 agri-environment and 24 conventionally managed ditches in April–July 2008. Ditches were perpendicular to eight nature reserve borders and monitoring was just inside reserves and at four distances from reserve borders (0–700 m). Three methods were used during each sampling period: five minute counts, 20 dip net samples and two overnight funnel traps.

From the Amphibian Synopsis, see here: https://www.conservationevidence.com/actions/749
From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

Birds

A replicated site comparison of 2,046, 1 km squares of agricultural land across England in 2005 and 2008 (9; same study site as 10, 11) found that management of hedges and ditches under Entry Level Stewardship did not have clear impacts on farmland bird species. Management had significant positive impacts on five species in at least one region of England, but these effects were often very weak and four of the same species showed negative responses in other regions. The other five 'hedgerow' species investigated were never positively associated with boundary management. Generally, effects appeared to be more positive in the north of England.

From the Bird Synopsis, see synopsis PDF: https://www.conservationevidence.com/synopsis/index

A large site comparison study of 2,046, 1 km² plots of lowland farmland in England (10; same study as site as 9, 11) found that three years after the 2005 introduction of the Countryside Stewardship Scheme and Entry Level Stewardship Scheme, there was no consistent association between the length of 76 ditches managed according to the agri-environment scheme on a plot and farmland bird numbers. There were higher numbers of linnet *Carduelis cannabina* and reed bunting *Emberiza schoeniclus*, which are known to nest in ditch bank vegetation, in plots with ditches managed according to the Countryside Stewardship Scheme and Entry Level Stewardship compared to other plots. However, this difference was not observed for other species also expected to benefit from ditch management, including yellowhammer *Emberiza citrinella* and yellow wagtail *Motacilla flava*. Between 2005 and 2008, Eurasian skylark *Alauda arvensis* and grey partridge *Perdix perdix* declines were greater in plots with lengths of ditch management than other plots. For example, grey partridges showed decreases of 1.3 birds for each 0.08 km of ditch on pastoral farmland. The 2,046, 1 km² lowland plots were surveyed in both 2005 and 2008 and classified as arable, pastoral or mixed farmland. Eighty-four percent of plots included some area managed according to Entry Level Stewardship or the Countryside Stewardship Scheme. In both survey years, two surveys were conducted along a 2 km pre-selected transect route through each 1 km² square.
From the Bird Synopsis, see here: https://www.conservationevidence.com/actions/177
From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

A replicated study in February 2008 across 97, 1 km2 plots in East Anglia, England (11; same study site as 9, 10) found that four farmland birds showed strong positive responses to field boundaries (hedges and ditches) managed under agri-environment schemes. These species were blue tit *Parus (Cyanistes) caeruleus*, dunnock *Prunella modularis*, common whitethroat *Sylvia communis* and yellowhammer *Emberiza citrinella*. Six other species showed weak or negative responses: Eurasian blackbird *Turdus merula*, song thrush *Turdus philomelos*, Eurasian bullfinch *Pyrrhula pyrrhula*, long-tailed tit *Aegithalos caudatus*, winter wren *Troglodytes troglodytes*, and Eurasian reed bunting *Emberiza schoeniclus*. The boundaries were classed as either hedges, ditches or hedges and ditches and most were managed under the Entry Level Stewardship scheme.
From the Bird Synopsis, see here: https://www.conservationevidence.com/actions/177
From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/135

A study in 2002–2010 in lowland farmland across the UK (12) found that an agri-environment scheme requiring that ditches be kept open led to mixed results for bird population growth rates depending on the species and landscape type. Reed bunting *Emberiza schoeniclus* population growth rate increased with ditch management in mixed farmland, but not in arable or pastoral landscapes. Tree sparrow *Passer montanus* growth rate decreased with ditch management in pastoral farmland, but showed no significant change in arable or mixed farmland. Corn bunting *Emberiza calandra*, yellowhammer *Emberiza citrinella* and yellow wagtail *Motacilla flava* showed no significant change in any landscape type. Spatial data on farms with Environmental Stewardship agreements (which required ditches to be kept open, with restrictions on cutting and grazing of adjacent vegetation) were obtained from a government agency (Natural England). Bird abundance data were obtained from a volunteer-based survey (BTO/JNCC/RSPB Breeding Bird Survey). Data were selected specifically from lowland farmland surveyed for at least two years between 2002–2010.

(1) Maes J., Musters C.J.M. & Snoo G.R.D. (2008) The effect of agri-environment schemes on amphibian diversity and abundance. *Biological Conservation*, 141, 635-645. https://doi.org/10.1016/j.biocon.2007.12.018

(2) Blomqvist M.M., Tamis W.L.M. & de Snoo G.R. (2009) No improvement of plant biodiversity in ditch banks after a decade of agri-environment schemes. *Basic and Applied Ecology*, 10, 368–378. https://doi.org/10.1016/j.baae.2008.08.007

(3) Leng X., Musters C.J.M., de Snoo G.R. (2009) Restoration of plant diversity on ditch banks: Seed and site limitation in response to agri-environment schemes. *Biological Conservation*, 142, 1340–1349. https://doi.org/10.1016/j.biocon.2009.01.019

(4) Leng X., Musters C.J.M. & de Snoo G.R. (2011) Effects of mowing date on the opportunities of seed dispersal of ditch bank plant species under different management regimes. *Journal for Nature Conservation*, 19, 166–174. https://doi.org/10.1016/j.jnc.2010.11.003

(5) van Dijk W.F.A., Schaffers A.P., Leewis L., Berendse F. & de Snoo G.R. (2014) Temporal effects of agri-environment schemes on ditch bank plant species. *Basic and Applied Ecology*, 14, 289–297. http://dx.doi.org/10.1016/j.baae.2013.04.001

(6) FERA (2013) Monitoring the Impacts of Entry Level Stewardship. Natural England Commissioned Report No. 133. Available at: https://publications.naturalengland.org.uk/publication/5518902616391680

(7) van Dijk W.F.A., van Ruijven J., Berendse F. & de Snoo G.R. (2014) The effectiveness of ditch banks as dispersal corridor for plants in agricultural landscapes depends on species' dispersal traits. *Biological Conservation*, 171, 91–98. http://dx.doi.org/10.1016/j.biocon.2014.01.006.

(8) Tilgar V., Elts J., Tätte K. & Marja R. (2024) Linking farming practices and landscape elements to nest predation of an iconic farmland wader. *Agriculture, Ecosystems & Environment*, 373, 109095. https://doi.org/10.1016/j.agee.2024.109095

(9) Davey C., Vickery J., Boatman N., Chamberlain D., Parry H. & Siriwardena G. (2010a) Regional variation in the efficacy of Entry Level Stewardship in England. *Agriculture Ecosystems & Environment*, 139, 121–128. https://doi.org/10.1016/j.agee.2010.07.008

(10) Davey C.M., Vickery J.A., Boatman N.D., Chamberlain D.E., Parry H.R. & Siriwardena G.M. (2010b) Assessing the impact of Entry Level Stewardship on lowland farmland birds in England. *Ibis*, 152, 459–474. https://doi.org/10.1016/j.agee.2010.07.008

(11) Davey C.M., Vickery J.A., Boatman N.D., Chamberlain D.E. & Siriwardena G.M. (2010) Entry Level Stewardship may enhance bird numbers in boundary habitats. *Bird Study*, 57, 415–420. https://doi.org/10.1080/00063657.2010.505642

(12) Baker D.J., Freeman S.N., Grice P.V. & Siriwardena G.M. (2012) Landscape-scale responses of birds to agri-environment management: a test of the English Environmental Stewardship scheme. *Journal of Applied Ecology*, 49, 871–882. https://doi.org/10.1111/j.1365-2664.2012.02161.x

3.8 Allow grazing on ditch banks

- We found no studies that evaluated the effects of allowing grazing on ditch banks on biodiversity.

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

Background

Grazing along ditch banks is a traditional management practice that can influence vegetation structure and habitat quality. Unlike cutting, which removes biomass rapidly, grazing reduces vegetation more gradually and creates a varied sward that can support a wider range of invertebrates. Dung from grazing animals can further enhance invertebrate abundance. Light trampling by livestock, particularly cattle, can produce shallow, disturbed margins that favour emergent plants, annual wetland-edge species, and specialist invertebrates, and may also provide foraging habitat for wading birds (Buisson *et al*. 2008).

Caution: if grazing pressure is too high, trampling can increase bank erosion, add sediment to the ditch, and elevate nutrient levels.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

3.9 Leave headwaters untouched

- We found no studies that evaluated the effects of leaving headwaters untouched on biodiversity.

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

Background

Headwaters and the uppermost sections of drainage channels are often managed less intensively than lower sections, particularly where flood risk is low. Reducing or avoiding activities such as ditch cleaning, vegetation cutting, or channel reshaping allows these areas to develop into more mature and structurally complex habitats. Over time, unmanaged headwaters can form linear marshland with dense stands of sedges, reeds, or other wetland plants, and may retain deeper pools created by past management (Buisson *et al*. 2008). Some long-term management may still be needed to prevent complete succession.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

4. Managing pollution

Ditches often receive nutrients, sediments, and other pollutants from surrounding land. Excess inputs can degrade water quality and alter plant and animal communities. This chapter includes actions that reduce pollution at its source or intercept it before it enters the ditch system.

4.1 Reduce or restrict pesticide or herbicide application near ditches

- **Two studies** evaluated the effects of reducing or restricting pesticide or herbicide application near ditch banks on vegetation and invertebrates. Both studies were in the Netherlands[1,2].

VEGETATION (1 STUDY)

- **Richness/diversity (1 study):** One replicated, controlled, paired study of farmland ditches in the Netherlands[1] found ditch banks adjacent to unsprayed field edges of wheat, but not sugar beet or potato crops, had higher plant richness diversity than edges sprayed with pesticides.

INVERTEBRATES (1 STUDY)

- **Richness/diversity (1 study):** One replicated, controlled, paired study of farmland ditches in the Netherlands[2] found that ditch banks adjacent to unsprayed field edges had higher butterfly richness than field edges sprayed with herbicides and insecticides.

Background

In conventional farming, a wide range of chemicals are commonly applied for pest control, such as herbicides, insecticides or fungicides, but these can have lethal or sub-lethal effects on non-target farmland wildlife (Wan *et al*. 2025). Restricting pesticide spraying, for example in a margin of crop at the edge of the field, may reduce the negative impacts on farmland wildlife.

Wan N.F., Fu L., Dainese M., Kiær L.P., Hu Y-Q., Xin F., Goulson D., Woodcock B.A., Vanbergen A.J., Spurgeon D.J., Shen S. & Scherber C. (2025) Pesticides have negative effects on non-target organisms. *Nature Communications,* 16, 1360. https://doi.org/10.1038/s41467-025-56732-x

Vegetation

A replicated, controlled paired study in 1991–1992 of ditch banks on arable farms in the Netherlands (1) found higher plant diversity and more important/rare plant species on ditch banks along unsprayed edges of winter wheat compared to those sprayed with pesticides. Ditch banks next to unsprayed edges of winter wheat had 65 plant species and a floristic value of 2,201 (scoring system based on the importance of different plant species in terms of rarity) compared to those sprayed with pesticides (50 species; floristic value 1,181). There was no significant difference on banks along unsprayed and sprayed edges of sugar beet *Beta vulgaris* (species: 48 and 41, floristic values: 3,616 and 3,029 respectively) and potato crops (species:

46 and 41, floristic values: 1,961 and 1,864 respectively). Frequency and cover of species and floristic value of vegetation was recorded in two plots on each ditch, one along a sprayed and one an unsprayed edge of sugar beet (seven), potato (eight) and winter wheat (20) fields in June-July.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/652

Invertebrates

A replicated, controlled, paired study of arable field edges from 1990 to 1992 in the Netherlands (2) found that ditch banks adjacent to unsprayed field margins had greater richness of butterflies (Lepidoptera) than ditch banks adjacent to sprayed margins. Numbers of butterfly species were higher on ditch banks adjacent to unsprayed (18–20) than sprayed margins (9–11). Also, numbers of butterfly species were significantly higher in the unsprayed field margins (6-7/300 m²) compared to sprayed margins (1–2/300 m²). Density did not differ between 3 m (6/300 m²) and 6 m (7/300 m²) unsprayed margins. The number of insect groups in the upper vegetation was higher in the unsprayed (12-14) than sprayed margins (8–11). The predominant groups were flower-visiting insects, such as hoverflies (Syrphidae) and ladybirds (Coccinellidae). Insect density was also significantly higher in unsprayed (3 m: 53/100 m, 6 m: 31/100m) compared to sprayed margins (3 m: 20/100m, 6 m: 12/100m). Margins 3 m × 100 m and 6 m × 400 m were left unsprayed by herbicides and insecticides and compared to sprayed edges in the same field. Butterflies were sampled on 3 m (eight farms) and 6 m (six farms) margins 11 times between mid-May-July. Insects in the upper parts of plants were sampled twice/plot at the end of June with a sweep net.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/652

(1) de Snoo G.R. & van der Poll R.J. (1999) Effect of herbicide drift on adjacent boundary vegetation. *Agriculture, Ecosystems and Environment*, 73, 1–6. https://doi.org/10.1016/S0167-8809(99)00008-0

(2) de Snoo G.R. (1996) Enhancement of non-target insects: indications about dimensions of unsprayed crop edges. Pages 209-219 in: K. Booij & L.d. Nijs (eds.) Arthropod Natural Enemies in Arable Land II - Survival, Reproduction and Enhancement: Acta Jutlandica 71:2, Natural Science Series, 10. Aarhus University Press, Aarhus, Denmark.

4.2 Reduce or restrict fertilizer application near ditches

- We found no studies that evaluated the effects of reducing or restricting fertilizer application near ditches on biodiversity.

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

Background

Runoff from agricultural land is a major source of nutrients, particularly nitrogen and phosphorus, which can enter ditches. Excessive nutrient input can alter the competitive balance among plants, leading to domination by a single species (Tilman *et al*. 1999) or algal blooms (Smith *et al*. 2006), altering the composition of aquatic plant and animal communities. Applying less fertilizer to land/water near ditches could reduce these problems.

Smith V.H., Joye S.B. & Howarth R.W. (2006) Eutrophication of freshwater and marine ecosystems. *Limnology and Oceanography*, 51, 351–355.
Tilman E.A., Tilman D., Crawley M.J. & Johnston A.E. (1999) Biological weed control via nutrient competition: potassium limitation of dandelions. *Ecological Applications*, 9, 103–111.

4.3 Reduce or restrict disposal of ditch spoil on ditch banks

- We found no studies that evaluated the effects of reducing or restricting the disposal of ditch spoil on ditch banks on biodiversity.

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

Background

Dredging or desilting of ditches often produces sediment that is subsequently deposited on ditch banks. While this is a common management practice, dumping nutrient-rich or fine sediments on banks can smother existing vegetation, alter bank structure, increase compaction, and reduce the availability of microhabitats for invertebrates and other wildlife. Reducing or restricting the disposal of dredged sediments on ditch banks can help reduce these impacts.

4.4 Add minerals (zeolites) to neutralize pollutants

- **One study** evaluated the effects of adding minerals (zeolites) to neutralize pollutants on bacteria. The study was in China[1].

BACTERIA (1 STUDY)

- **Richness/diversity (1 study):** One replicated, controlled study of experimental ditches in China[1] found that adding zeolites had no effect on overall bacterial diversity, but decreased bacterial diversity when using a measure that emphasized rare species.
- **Abundance (1 study):** One replicated, controlled study of experimental ditches in China[1] found that adding zeolites decreased abundance of some bacterial species groups, including Alphaproteobacteria and Nitrospira.

Background

Zeolites are naturally occurring or synthetic aluminosilicate minerals with a porous structure that allows them to adsorb and trap pollutants (Smith *et al*. 1987; Lang *et al*. 2024). When added to aquatic systems, such as ditches, ponds, or wetlands, zeolites can bind and remove pollutants including ammonium, heavy metals, and phosphorus (Velarde *et al*. 2023; Lang *et al*. 2024). This can help to improve water quality, particularly in areas affected by agricultural or industrial runoff.

Lang Q., Lu P., Yang X. & Valentin V. (2024) Zeolites for the environment. *Green Carbon*, 2, 12–32. https://doi.org/10.1016/j.greenca.2024.02.007
Smith J.V. (1984) Definition of a zolite. *Zeolites*, 4, 309–310. https://doi.org/10.1016/0144-2449(84)90003-4

Velarde L., Nabavi M.S., Escalera E., Antti M-E. & Akhtar F. (2023) Adsorption of heavy metals on natural zeolites: A review. *Chemosphere*, 328, 138508. https://doi.org/10.1016/j.chemosphere.2023.138508

Bacteria

A replicated, controlled study in 2018 in nine experimental ditches in Shanghai, China (1) found that adding zeolite minerals did not increase bacterial diversity and decreased abundance of some species groups. In all three cases, bacterial diversity did not significantly differ between ditches with and without zeolites (Shannon index, which considers richness and evenness). However, when using a measure that emphasizes rare species (Chao1 index), diversity was lower in ditches with zeolites in two of three comparisons. There were differences in the abundances of species groups. For example, ditches with zeolites had lower abundances of Alphaproteobacteria (3.6–5.7%) and Nitrospira (3.8–5.8%) than ditches without zeolites (Alphaproteobacteria: 4.1–5.5%; Nitrospira: 4.6–6.8 %). Pollutant removal rates did not significantly differ between ditches with zeolites (nitrogen: 45–60%; phosphorus: 52–69%) and ditches without zeolites (nitrogen: 24–52%; phosphorus: 24–52%). In June 2018, five nylon bags (1 m long, and 0.4 m depth) filled with zeolite substrate (4–6 mm diameter) were placed every 5 m along three concrete ditches (30 × 1 m). Three ditches did not receive zeolites. All ditches had a 30 cm soil layer and were planted with aquatic vegetation (*Vallisneria natans*). Water from a nearby river receiving farmland runoff was pumped into the ditches daily and ammonia chloride was added (250 g/day) to increase nitrogen concentration to 2.1–3.9 mg/L and phosphorus concentrations of 0.1–0.3 mg/L. From June–August 2018, water samples were collected every seven days to measure nitrogen and phosphorus concentrations. Bacterial communities were surveyed at the end of the experiment from 10 soil samples/ditch (0–10 cm depth).

(3) Cui N., Zhang X., Cai M., Zhou L., Chen G. & Zou G. (2020) Roles of vegetation in nutrient removal and structuring microbial communities in different types of agricultural drainage ditches for treating farmland runoff. *Ecological Engineering*, 155, 105941. https://doi.org/10.1016/j.ecoleng.2020.105941

4.5 Plant aquatic vegetation to reduce pollution

- **One study** evaluated the effects of planting aquatic vegetation to reduce pollution on bacteria. The study was in China[1].

BACTERIA (1 STUDY)

- **Richness/diversity (1 study):** One replicated, controlled study of experimental ditches in China[1] found that ditches planted with submerged aquatic vegetation had a more diverse and unique bacterial community compared to unplanted ditches.
- **Abundance (1 study):** One replicated, controlled study of experimental ditches in China[1] found that planting submerged vegetation increased abundance of some bacterial species groups, including Alphaproteobacteria and Nitrospira.

Background

Runoff from agricultural fields presents a major threat to ditch ecosystems through the introduction of nutrients. Aquatic vegetation can help mitigate these effects by absorbing and retaining pollutants from the water column. For example, a study in farmland ditches found plant uptake was responsible for 26% of nitrogen removal and 14% of phosphorus removal (Vymazal & Březinová 2018).

Planting or encouraging the growth of submerged, floating, or emergent vegetation may therefore enhance the natural purification capacity of ditches.

Vymazal J. & Březinová T.D. (2018) Removal of nutrients, organics and suspended solids in vegetated agricultural drainage ditch. *Ecological Engineering*, 118, 97–103.

Bacteria

A replicated, controlled study in 2018 in six experimental ditches in Shanghai, China (1) found that planting submerged aquatic vegetation increased bacterial diversity, changed the bacterial community composition and increased abundance of some species groups, though pollution removal rate did not increase. In all three cases, bacterial diversity was higher in planted than unplanted ditches (based on Shannon and Chao1 diversity indices). Furthermore, bacterial communities were distinct between planted and unplanted ditches (data reported as graphical analysis). For example, planted ditches had a greater abundance of Alphaproteobacteria (3.6–5.7%) and Nitrospira (3.8–5.8%) than unplanted ditches (Alphaproteobacteria: 2.5–3.3%; Nitrospira: 0.6–1.2%). Pollutant removal rates did not significantly differ between planted (nitrogen: 45–60%; phosphorus: 52–69%) and unplanted ditches (nitrogen: 44–63%; phosphorus: 64–70%) in all three cases**.** In June 2018, submerged macrophytes (*Vallisneria natans*) were planted at ~50 seedlings/m^2 in three experimental concrete ditches (30 × 1 m). Three ditches were left unplanted. All ditches had a 30 cm soil layer and added zeolites (aluminosilicate minerals). Water from a nearby river receiving farmland runoff was pumped into the ditches daily and ammonium chloride was added (250 g/day) to increase nitrogen concentration, resulting in nitrogen concentrations of 2.1–3.9 mg/L and phosphorus concentrations of 0.1–0.3 mg/L. From June–August 2018, water samples were collected every seven days to measure nitrogen and phosphorus concentrations. Bacterial communities were surveyed at the end of the experiment from 10 soil samples/ditch (0–10 cm depth).

(1) Cui N., Zhang X., Cai M., Zhou L., Chen G. & Zou G. (2020) Roles of vegetation in nutrient removal and structuring microbial communities in different types of agricultural drainage ditches for treating farmland runoff. *Ecological Engineering*, 155, 105941. https://doi.org/10.1016/j.ecoleng.2020.105941

4.6 Plant reedbeds to reduce pollution

- We found no studies that evaluated the effects of planting reedbeds to reduce pollution in ditches on biodiversity.

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

Background

Reedbeds (*Phragmites australis*) can be planted along ditches to reduce sediment and nutrient pollution from diffuse sources such as agricultural runoff. Dense stands slow water flow, allowing sediments to settle and nutrients, particularly nitrogen and phosphorus, to be absorbed by plants or associated microbes, which can help suppress downstream algal growth (Buisson *et al*. 2008).

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

4.7 Alter flow rate in ditches to reduce pollution

- **Two studies** evaluated the effects of altering flow rate in diches to reduce pollution on vegetation and bacteria. The studies were in the Netherlands[1] China[2].

VEGETATION (1 STUDY)

- **Abundance (1 study):** One replicated, site comparison study of sewage treatment ditches in the Netherlands[2] found that slow flow rates resulted in lower biomass of floating aquatic vegetation but higher biomass of submerged vegetation, than high flow rates.

BACTERIA (1 STUDY)

- **Richness/diversity (1 study):** One randomized, replicated, site comparison study of experimental ditches in China[2] found that high, medium and low flow rates had similar bacterial diversity.
- **Abundance (1 study):** One randomized, replicated, site comparison study of experimental ditches in China[2] found that high, medium and low flow rates had similar abundance of different bacteria species groups.

Background

Altering flow rates (or 'hydraulic loading rate') can enhance nutrient removal in ditches. For example, lower flow rates, or higher water retention times, can promote nitrogen removal by increasing the time available for biochemical interactions and thus denitrification (microbial process whereby nitrogen is removed from aquatic systems) (Baker *et al*. 2015).

Flow rates can be altered by installing weirs or other flow control structures, altering the gradient of the ditch bed, widening or narrowing the ditch channel, or via pumps.

Baker B.H., Kröger R., Brooks J.P., Smith R.K. & Prince-Czarnecki J.M. (2015) Investigation of denitrifying microbial communities within an agricultural drainage system fitted with low-grade weirs. *Water Research*, 87, 193–201. https://doi.org/10.1016/j.watres.2015.09.028

Vegetation

A replicated, site comparison study in 1997 in a wetland at a sewage treatment plant in Texel, Netherlands (1) found that ditches with slow flow rates (higher water retention times) had lower biomass of floating vegetation but higher biomass of submerged aquatic vegetation than ditches with high flow rates (lower water retention time). Biomass of floating vegetation (duckweeds *Lemna* spp. and macroalgae) was lower in ditches with a retention time of 9.3 days (5 g/m²) than in those with a retention time of 0.8 days (50 g/m²). In contrast, submerged vegetation had higher shoot biomass in ditches with a 9.3-day retention time (199 g/m²) than in those with a 0.8-day retention time (42 g/m²). In April 1997, water flow rate was experimentally varied in four ditches using rectangular and V-notch weirs. Two ditches were set to a retention time of 0.8 days and two to 9.3 days. Previously, all ditches had a 0.8-day retention time. Each flow treatment included one ditch with reeds *Phragmites* spp. and one with bullrush *Typha* spp. In October 1997, reed and bulrush shoots were harvested 0.15 m above the water surface from 1 × 1 m plots spaced evenly along each ditch. In August 1997, submerged macrophytes were collected from the upper 30% of the water column in 0.4 × 0.4 m plots. Samples were dried and weighed.

Bacteria

A randomized, replicated, site comparison study in 2018 in nine experimental ditches in Shanghai, China (2) found that altering water flow in ditches had no effect on bacterial diversity and abundance, though pollution removal rate was higher at low and medium flow compared to high flow. Bacterial diversity did not significantly differ between ditches with high, medium, or low flow rates (reported as diversity indices). Abundances of bacterial groups also showed no significant differences at different flow rates, including Alphaproteobacteria (high: 2.5–4.1%; medium: 3.0–5.5%; low: 3.3–5.7%) and Nitrospira (high: 0.6–4.6%; medium: 1.2–5.5%; low: 0.6–6.8%). Pollutants were removed at a significantly higher rate in low-flow (nitrogen: 52–63%; phosphorus: 52–70%) and medium-flow ditches (nitrogen: 46–60%; phosphorus: 45–69%) compared to high-flow (nitrogen: 24–45%; phosphorus: 24–64%). From June–August 2018, nine concrete ditches (30 × 1 m) with perforated sides (to maintain soil contact) and a 30 cm soil layer at the bottom were each randomly assigned one of three 'hydraulic loading rates' (representing water retention times of one, two, or four days): high-flow (11.76 m^3/d), medium-flow (5.88 m^3/d) and low-flow (2.94 m^3/d). Water from a nearby river receiving farmland runoff was pumped into the ditches daily and ammonium chloride was added (250 g/day) to increase nitrogen concentration, resulting in nitrogen concentrations of 2.1–3.9 mg/L and phosphorus concentrations of 0.1–0.3 mg/L. From June–August 2018, water samples were collected every seven days to measure nitrogen and phosphorus concentrations. Bacterial communities were surveyed at the end of the experiment from ten soil samples/ditch (0–10 cm depth).

(1) Toet S., Van Logtestijn R.S.P., Kampf R., Schreijer M. & Verhoeven J.T.A. (2004) The effect of hydraulic retention time on the removal of pollutants from sewage treatment plant effluent in a surface-flow wetland system. *Wetlands,* 25, 375–391. https://doi.org/10.1672/13
(2) Cui N., Zhang X., Cai M., Zhou L., Chen G. & Zou G. (2020) Roles of vegetation in nutrient removal and structuring microbial communities in different types of agricultural drainage ditches for treating farmland runoff. *Ecological Engineering*, 155, 105941. https://doi.org/10.1016/j.ecoleng.2020.105941

4.8 Excavate pools to intercept pollution

- We found no studies that evaluated the effects of excavate pools to intercept pollution into ditches on biodiversity.

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

Background

Runoff from agricultural fields presents a severe threat to the ecosystem of ditches (Herzon & Helenius 2008). Excavating pools within or next to ditches can prevent pollutants entering ditches or downstream water bodies. Such 'interception ponds', or 'attenuation ponds' are designed to intercept polluted water and sediment and slow the flow of water, allowing suspended sediments and associated pollutants to settle out (Williams *et al*. 2020).

By reducing sediment and nutrient loads, such pools can improve water quality in connected ditches, streams, rivers, and wetlands. They may also create areas of open water that support aquatic vegetation and provide habitat for invertebrates, amphibians, and other wildlife.

See also '*Excavate pools*'.

Herzon M. & Helenius J. (2016) Agricultural drainage ditches, their biological importance and functioning. *Biological Conservation*, 141, 1171–1183.
Williams P., Biggs J., Stoate C., Szczur J., Brown C. & Bonney S. (2020) Nature based measures increase freshwater biodiversity in agricultural catchments. *Biological Conservation*, 244, 108515. https://doi.org/10.1016/j.biocon.2020.108515

5. Habitat restoration and creation

Many ditch networks are uniform and lack the structural features that support diverse wildlife. Restoring or creating habitat, such as pools, or altering the ditch profile, can increase variation in water depth, flow, and vegetation. This chapter includes actions that restore or create habitat features within ditch systems.

5.1 Excavate ditches

- **Two studies** evaluated the effects of excavating ditches on vegetation and invertebrates. The studies were in the UK[1a,b].

VEGETATION (1 STUDY)

- **Abundance (1 study):** One study in a marsh in the UK[1a] reported that over half of excavated ditches were colonized by water soldier within nine years.

INVERTEBRATES (1 STUDY)

- **Abundance (1 study):** One study in a marsh in the UK[2b] reported that over half the length of a newly excavated ditch was colonised by Norfolk hawkers within two years, and seven of 12 excavated ditches were colonised over 12 years.

Background

Excavating new ditches creates open water channels in previously unchanneled areas, providing habitat for wildlife. Shallow margins and gently sloping banks can support vegetation establishment, while deeper sections provide refuge for aquatic organisms. New ditches can also intercept runoff and reduce nutrient accumulation. Careful design is needed to avoid erosion, downstream pollution, or habitat disruption.

Vegetation

A study in 1986–1999 in a marsh in Norfolk, UK (1a) reported that over half the length of newly excavated ditches was colonized by water soldier *Stratiotes aloides*. Ditches were created in 1986, 1996 and 1998. By 1997, water soldier had colonized 200 m of 550 m of excavated ditch (40%), and by 1999 the species had colonized 330 m of 560 m (59%). Overall, since 1986, when the first ditches were excavated, 890 m of 1,600 m of new ditches (55%) had been colonized by water soldier. In 1986, 1996, and 1998, new ditches were excavated during winter (560 m in 1986, 550 m in 1996, and 560 m in 1998) and connected to existing ditches. The study did not report details of sampling methods.

Invertebrates

A study in 1986–1998 in a marsh in Norfolk, UK (1b) reported that seven of twelve excavated ditches were colonised by Norfolk hawkers *Aeshna isosceles*. Two years after the first ditch excavation, Norfolk hawkers colonised 360 m of 560 m (64%) of new ditch. Altogether, Norfolk hawkers were present in seven out of 12 excavated ditches created over a 12-year period (data not reported). In 1986, 1996, and 1998, ditches were excavated in the winter months (560 m in 1986, 550 m in 1996 and 560 m in 1998) and linked to ditches already used by Norfolk hawkers. The study did not report details of sampling methods.

(1) Southwood R., Taylor P. & Daguet C. (2005) Creation of dykes on grazing marshes and effects on the Norfolk hawker *Aeshna isosceles* dragonfly at Ludham and Potter Heigham Marshes NNR, Norfolk, England. *Conservation Evidence*, 2, 137–138. https://conservationevidencejournal.com/reference/pdf/2196

5.2 Reprofile ditches

- **One study** evaluated the effects of reprofiling ditches on vegetation. The study was in the UK[1].

VEGETATION (1 STUDY)

- **Abundance (1 study):** One replicated, controlled study of peatland ditches in the UK[1] found that reprofiling (and damming) had no effect on sphagnum moss and sedge abundance over five years.
- **Condition (1 study):** One replicated, controlled study of peatland ditches in the UK[1] found that reprofiling (and damming) had no effect on the leaf length of sedges (mostly hare's-tail cottongrass) over five years.

Background

Reprofiling ditches involves altering their cross-sectional shape or slope. Ditch banks are often steep and uniform in shape, which can limit their habitat diversity. Reshaping ditch profiles (e.g., creating gently sloping banks, shallow margins, or berms) can provide gradual transition from wetland and marginal communities to drier grassland (Buisson *et al*. 2008; see Mayer *et al*. 2017).

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

Mayer L., Moodie I., Carson C., Vines K., Nunns M., Hall K., Redding M., Sharman P. & Bonney S. (2017) *Good Ecological Potential in Fenland Waterbodies: A Guide to Management Strategies and Mitigation Measures for achieving Good Ecological Potential in Fenland Waterbodies.* Association of Drainage Authorities & Environment Agency.

Vegetation

A replicated, controlled study in 2010–2015 in peatland in North Wales, UK (1) found that reprofiling, along with damming, ditches had no effect on the abundance of sphagnum mosses *Sphagnum* spp. or the abundance and leaf length of sedges (mostly hare's-tail cottongrass *Eriophorum vaginatum*) compared to unmodified ditches. Over five years, sphagnum abundance (reprofiled: 9–33%/year; control: 18–71%/year) and sedge abundance (reprofiled: 63–97%/year; control: 82–95%/year) did not significantly differ between reprofiled and unmanipulated (control) ditches. Average leaf length of hare's-tail cottongrass also did not significantly differ (reprofiled: 24–36 cm/year; control: 24–38 cm/year). In February 2011, four ditches were reprofiled by removing vegetation, compressing peat to destroy natural pipes, and partially infilling ditches with nearby peat and re-vegetating. Peat dams were constructed at regular intervals using peat from adjacent borrow pits**.** Four reprofiled/dammed ditches were compared with four unmodified control ditches. Plant abundance was estimated annually in August–October 2010–2015 in twenty-four 1 × 1 m quadrats placed 2 m east and west of each ditch. Height and width of sedges was measured. The sphagnum group comprised, in order of abundance: *Sphagnum capillifolium*, *Sphagnum fallax* and *Sphagnum papillosum.*

(1) Green S.M. Baird A.J., Holden J., Reed D., Birch K. & Jones P. (2017) An experimental study on the response of blanket bog vegetation and water tables to ditch blocking. *Wetlands Ecology and Management*, 25: 703–716. https://doi.org/10.1007/s11273-017-9545-z

5.3 Excavate pools

- **Ten studies** evaluated the effects of excavating pools in or next to ditches on vegetation, invertebrates, amphibians, and birds. The studies were in the UK[1a,b,c,5], USA[2a,b] and Estonia[3a,b,4a,b].

VEGETATION (6 STUDIES)

- **Richness/diversity (4 studies):** One of two controlled studies in salt marsh ditches in the USA[2a,b] found that excavated pools had lower plant species richness than sites without pools[2a]. The other study found no difference in the vegetation community[2b]. One controlled, replicated study in farmland in the UK[1a] found that ditch-fed excavated pools had higher plant diversity than control sites. One replicated, site comparison study in farmland in the UK[5] found that excavated ponds (to intercept pollution) had similar plant species richness to natural ponds but higher richness than ditches.
- **Abundance (3 studies):** Two replicated, site comparison studies of commercial forest ditches in Estonia[3a,4a] reported that pools excavated within or next to ditches had lower cover of aquatic plants and moss[3a] than natural pools two years after excavation. One controlled, replicated study in the UK[1a] found that ditch-fed excavated pools had lower grass cover than control sites.

INVERTEBRATES (2 STUDIES)

- **Richness/diversity (1 studies):** One replicated, site comparison in commercial forest ditches in Estonia[4b] reported that in pools excavated within or next to ditches invertebrate species richness was lower than in natural pools.
- **Abundance (2 studies):** One replicated, site comparison in commercial forest ditches in Estonia[4b] reported that in pools excavated within or next to ditches invertebrate abundance was lower than in natural pools. One controlled, replicated study in the UK[1b] found that ditch-fed excavated pools had higher abundance of adult flies, but lower

abundance of fly and butterfly/moth larvae, and lower abundance of grass-active invertebrates, than control sites.

AMPHIBIANS (1 STUDY):

- **Abundance (1 study):** One replicated, controlled study in commercial forest ditches in Estonia[3b] found that excavating pools had mixed effects on moor frog and common frog abundance compared to natural pools, depending on the abundance measure.

Birds (1 STUDY):

- **Abundance (1 study):** One replicated, controlled, paired study in the UK[1c] found that ditch-fed excavated pools were visited by birds more than control sites.

Background

Many ditch systems are designed in a uniform way, lacking habitat variability compared to natural waterbodies. As a result, they may support fewer and less diverse species (Rosenvald *et al*. 2014). One way to mitigate the uniformity is to excavated pools within or alongside ditches with the aim of increasing habitat diversity (Mayer *et al*. 2017; Vaikre *et al*. 2010). Deeper or wider sections create areas of slow-moving or standing water that can act as refuges. Pools can be created at ditch junctions, ditch corners, or at dead-ends (Mayer *et al*. 2017). Over time, such structural diversity could help support a more complex and resilient ditch ecosystem.

Rosenvald R., J¨arvekülg R. & L˜ohmus, A. (2014) Fish assemblages in forest drainage ditches: degraded small streams or novel habitats? *Limnologica*, 46, 37–44. https://doi.org/10.1016/j.limno.2013.12.004

Mayer L., Moodie I., Carson C., Vines K., Nunns M., Hall K., Redding M., Sharman P. & Bonney S. (2017) *Good Ecological Potential in Fenland Waterbodies: A Guide to Management Strategies and Mitigation Measures for achieving Good Ecological Potential in Fenland Waterbodies.* Association of Drainage Authorities & Environment Agency.

Vaikre M., Remm L., Rannap R. (2020) Forest ditch maintenance impoverishes the fauna of aquatic invertebrates: Opportunities for mitigation. *Journal of Environmental Management*, 274, 111188. https://doi.org/10.1016/j.jenvman.2020.111188

Vegetation

A replicated, controlled study of 10 surface pools (scrapes) in arable field margins in Leicestershire, UK (1a) found that vegetation was more heterogenous (diversity and height), grass cover lower and bare ground more extensive in the scrapes than the control areas (data not provided). Scrapes in field corners, excavated with a JCB 360 tracked digger, were fed with water from a nearby ditch. Sampling involved a botanical quadrat (0.25–0.5 m^2) survey. Data was obtained between April 2005–March 2007 in spring–summer. Cost (UK£ reported in 2007): £48.

From farmland synopsis, see here: https://www.conservationevidence.com/actions/153

A controlled study in 2004–2011 in a salt marsh in Massachusetts, USA (2a) found that excavating pools, along with filling/blocking ditches, led to lower plant species richness compared to sites without pools. Results are not based on statistical tests. One species was observed in sites with berms and pools (cordgrass *Spartina alterniflora*, 100% frequency), whereas five species were observed in sites without pools: blackgrass *Juncus gerardii* (100%), cordgrass *Spartina patens* (50%), silverweed *Argentina anserina* (75%), sea milkwort *Glaux maritima* (62%) and cordgrass *Spartina alterinaflora* (12%). In 2004, saltmarsh restoration comprised filling/blocking ditches and excavating pools (no methods provided). The study does not distinguish between the effects of these actions. Three 50-m radius sites with pools and berms were compared to three ditched sites without pools. The centre of each site was within 5 m of a randomly selected pool or ditch. In July 2011, plants were surveyed in eight randomly located 1 m^2 plots/treatment.

A controlled study in 2003–2011 in a salt marsh in New Jersey, USA (2b) found that excavating pools in ditches did not change the vegetation community compared to ditches without excavated pools. Results are not based on statistical tests. The same three species were recorded at sites with and without pools at similar frequencies: desert saltgrass *Distichlis spicata* (with and without pools: 25%), cordgrass *Spartina alterniflora*: (with pools: 87%; without pools: 50%) and cordgrass *Spartina patens*: (with pools: 37–50%: without pools: 50%). In 2003, pools and radial ditches were constructed with spoil deposited in a thin layer on the marsh surface (no further methods provided). Three 50-m radius sites with pools, centred within 5 m of a randomly selected pool or ditch, were compared to three sites without pools. In July 2011, plants were surveyed in eight randomly located 1 m^2 plots/treatment.

A replicated, site comparison study in 2013–2017 in two commercial forests in Tartu County, Estonia (3a; same study site as 4) reported that pools excavated within and next to ditches had a lower coverage of semi-aquatic plants than ditches and natural pools after two years. Results are not based on statistical tests. Cover of semi-aquatic plants was 11% in excavated pools compared to 35% in ditches and 25% in natural pools. In 2015, twenty-nine pools were excavated across two sites. Thirteen were excavated within ditches ('ditch enlargements', 18–64 m^2, depth: 1.2–1.8 m) and sixteen were excavated next to ditch corridors (25–100 m^2, depth: 1.2–1.7 m). Twenty existing water bodies (10 ditches, 10 pools, > 4m^2, >15 cm deep) at each site were used as a comparison. Aquatic plant cover was estimated annually from 2013–2017 (no details provided).

A replicated, site comparison study in 2013–2018 in three commercial forests in Tartu County, Estonia (4a; same study site as 3) reported that pools excavated within or next to ditches had less aquatic plant and moss cover than natural pools. Results are not based on statistical tests. Aquatic plant and *Sphagnum* moss cover was lower in created pools within ditches (aquatic plants: 13%; *Sphagnum*: 0%) and next to ditches (aquatic plants: 6%; *Sphagnum*: 2%) than natural pools (aquatic plants: 37%; *Sphagnum*: 5%). In 2015 or 2017, across three sites, 28 pools were created within ditches ('ditch enlargements', 18–64 m^2) and 28 pools were created next to ditches (25–100 m^2). Thirty natural pools across three undrained sites were used as a comparison. Aquatic plant (including algae) and moss cover was estimated in late May or June each year from 2013–2018 in created pools and 2015–2016 in natural pools (no further methods provided).

A replicated, site comparison study in 2013–2018 in farmland in Leicester, UK (5) found that ponds excavated to intercept pollution run-ff into ditches did not differ in aquatic plant species richness or rare species richness compared to natural ponds five years after they were created. The average number of species in excavated ponds (6.8 species/site) did not significantly differ from natural ponds (7.3 species/site), but was significantly higher than in ditches (3.6 species/site). The total number of aquatic plant species across all ditches was 33 in created ponds, 67 in natural ponds, and 27 in ditches (differences not statistically tested). The average number of rare species did not differ between interception ponds (0.1 species/site) and natural ponds (0.9 species/site). No rare species were found in ditches. In 2013–2014, two types of 'interception' ponds were created in two study areas: run-off ponds (to intercept run-off in to ditches) and flood-storage ponds (filled by ditches during periods of high-water flow). Eight run-off ponds (0.04 ha) and nine flood storage ponds (0.08–0.13 ha) were compared to sixty-five natural (0.5–2.4 ha). Each August 2014–2018, aquatic plants were recorded visually by walking or wading along pond margins, or using a grapnel thrown from the bank. Twenty sites were surveyed from each pond type in each area. All study areas were under agri-environment schemes.

Invertebrates

A replicated, controlled study of 10 ten excavated surface pools (scrapes) in arable field margins in Leicestershire, UK (1b) found that surface-active adult flies (Diptera) were more abundant but fly larvae less abundant in the scrapes than the controls. Butterly and moth (Lepidoptera) larvae were less abundant in scrapes than controls in 2006, but not 2006. Numbers of invertebrates active in the grass layer were lower in scrapes than nearby unmanipulated plots. Scrapes in field corners, excavated with a JCB 360 tracked digger, were fed with water from a nearby ditch. Sampling involved fixed/floating traps for emerging aquatic insects and pitfall traps and sweep-netting for terrestrial invertebrates. Data was obtained between April 2005–March 2007 in spring–summer. Cost (UK£ reported in 2007): £48.

From farmland synopsis, see here: https://www.conservationevidence.com/actions/153

A replicated, site comparison study in 2013–2018 in three commercial forests in Tartu County, Estonia (4b; same study site as 3) reported that pools excavated within or next to ditches had lower invertebrate species richness and abundance than natural pools. Results are not based on statistical tests. Average species richness and abundance was lower in created pools within ditches (42 species/plot, 1,327 individuals/plot) and next to ditches (53 species/plot, 1764 individuals/plot) than natural pools (61 species/plot, 2,321 individuals/plot). In 2015 or 2017, across three sites, 28 pools were created within ditches ('ditch enlargements', 18–64 m^2) and 28 pools were created next to ditches (25–100 m^2). Thirty natural pools across three undrained sites were used as a comparison. Invertebrates were sampled in late May or June each year from 2013–2018 in created pools and 2015–2016 in natural pools (no further methods provided).

Amphibians

A replicated, site comparison study in 2014–2017 in two commercial forests in Tartu County, Estonia (3b; same study site as 4) found that excavating pools within and next to ditches had mixed effects on abundance of moor frog *Rana arvalis* and common frog *Rana temporaria* tadpoles depending on the abundance measure used. Tadpole abundance (number per 10 net sweeps) was higher in excavated pools (four tadpoles) than in ditches (one tadpole), but lower than in natural pools (10 tadpoles). However, tadpole occurrence (proportion of pools containing tadpoles) was lower in excavated pools (25%) than in ditches (47%) but higher than in natural pools (4%). The proportion of tadpoles identified as moor frogs was higher in excavated pools (49%) than in ditches (40%) but lower than in natural pools (100%). The number of spawn clumps per site ranged from 19–102 in excavated pools, 164–244 in ditches, and 5–115 in natural pools. There was no significant difference in the occurrence of frog spawn and tadpoles between pools excavated within ditches and those excavated next to ditches (based on a statistical model). In 2015, twenty-nine pools were excavated across two sites. Thirteen were created within ditches ('ditch enlargements', 18–64 m², depth: 1.2–1.8 m) and sixteen next to ditch corridors (25–100 m², depth: 1.2–1.7 m). Twenty existing waterbodies (10 ditches, 10 pools; >4 m², >15 cm deep) at each site were used as comparisons. All waterbodies were surveyed for frogs and dip-netted for tadpoles (10 sweeps/waterbody) before (year not stated) and after pool creation (July 2017).

Birds

A replicated, controlled, paired study of eight excavated ditch-fed paired ponds in field corners in arable field margins in Leicestershire, UK (1c) found that bird visit rates were significantly higher in ditch-fed paired ponds (1 visit/month) than dry controls (0.5 visits/month), particularly in the summer months. Paired ponds in field corners, excavated with a JCB 360 tracked digger, were fed with water from a nearby ditch. Control sites were selected upstream of the ponds. Sampling involved bird observations (45 minutes, 1–2/month) between April 2005-March 2007. Cost (UK£ reported in 2007): £372.75.

From farmland synopsis, see here: https://www.conservationevidence.com/actions/153

(1) Defra (2007) Wetting up farmland for birds and other biodiversity. Defra BD1323.

(2) Elsey-Quirk T. & Adamowicz S.C (2016) Influence of physical manipulations on short-term salt marsh morphodynamics: examples from the North and Mid-Atlantic Coast, USA. *Estuaries and Coasts*, 39, 423–439. https://doi.org/10.1007/s12237-015-0013-9

(3) Remm L., Vaikre M., Rannap R. & Kohv M. (2018) Amphibians in drained forest landscapes: Conservation opportunities for commercial forests and protected sites. *Forest Ecology and Management*, 428, 87–92. https://doi.org/10.1016/j.foreco.2018.06.038

(4) Vaikre M., Remm L., Rannap R. (2020) Forest ditch maintenance impoverishes the fauna of aquatic invertebrates: Opportunities for mitigation. *Journal of Environmental Management*, 274, 111188. https://doi.org/10.1016/j.jenvman.2020.111188

(5) Williams P., Biggs J., Stoate C., Szczur J., Brown C. & Bonney S. (2020) Nature based measures increase freshwater biodiversity in agricultural catchments. *Biological Conservation*, 244, 108515. https://doi.org/10.1016/j.biocon.2020.108515

5.4 Stabilize ditch banks

- We found no studies that evaluated the effects of stabilizing ditch banks on biodiversity.

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

Background

Stabilizing ditch banks aims to protect banks from scour, slippage, or erosion, and to repair areas where damage has occurred. Unstable banks can lead to sedimentation, loss of vegetation, and reduced habitat quality for aquatic and semi-aquatic species. Natural materials such as wattle, shrubs, trees, and stones can be used, as well as prefabricated products like concrete mats or biodegradable fibre mats with vegetation (Buisson *et al*. 2008). Methods used to stabilize may vary by material, site conditions, and bank slope.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

5.5 Deepen the ditch channel

- We found no studies that evaluated the effects of deepening the ditch channel on biodiversity.

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

Background

Increasing the depth of the central channel slows the spread of emergent plants into the middle of ditches, maintaining open water and the carrying capacity of the watercourse. Shallower margins are retained for emergent vegetation, supporting invertebrates and providing potential fish spawning areas (Buisson *et al*. 2008). Over-deepening can increase habitat diversity and may be a suitable alternative to herbicide treatment, though it may be less effective for highly aggressive species.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

5.6 Create washlands

- We found no studies that evaluated the effects of creating washlands on biodiversity.

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

Background

Washlands are areas, often enclosed by embankments, designed to temporarily store floodwaters from drainage channels. They are typically located upstream of land that is prone to flooding, allowing excess water to be held temporarily and released slowly. Water enters the washland either by overtopping the ditch channel or through controlled sluices, reducing the risk of downstream flooding.

Beyond flood management, washlands have the potential to provide conservation benefits. Managing the land with extensive summer grazing supports wet grassland habitats, which have declined across many regions. Such habitats benefit a range of wildlife, including breeding birds, invertebrates, and plants, and provide winter feeding areas for waders and wildfowl (Buisson *et al*. 2008). Careful design and management of washlands may therefore combine flood mitigation with biodiversity enhancement.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

5.7 Establish buffer strips alongside ditches

- **Three studies** evaluated the effects of establishing buffer strips alongside ditches on vegetation and invertebrates. The studies were in the Netherlands[1,2a,2b].

VEGETATION (2 STUDIES)

- **Richness/diversity (2 studies):** One replicated study of farmland ditches in the Netherlands[1] found that ditches with buffer strips had higher plant diversity than conventionally managed ditches without buffers, but not higher than organically managed ditches without buffers. One replicated study of farmland ditches in the Netherlands[2a] found that, four years after planting 3-m-wide field margins with grasses, the number of plant species of adjacent ditch banks increased, while the number of agricultural weeds decreased.

INVERTEBRATES (1 STUDY)

- **Richness/diversity (1 study):** One replicated study of farmland ditches in the Netherlands[2b] found that, four years after planting 3-m-wide field margins with grasses, butterfly and dragonfly diversity of adjacent ditch banks increased.

Background

Buffer strips are areas of land adjacent to ditches where agricultural management is reduced or altered. These strips may be left unmanaged, mown less frequently, or planted with grasses and wildflowers to create habitat for wildlife. Buffer strips are typically created in agreement with landowners, often as part of agri-environment schemes.

Vegetation

A replicated site comparison study from 1999 to 2004 in the Netherlands (1) found that establishing buffer strips, along with removing cuttings affected plant diversity. The study does not distinguish between removing cuttings and establishing buffer strips. Diversity was significantly higher on farms with ecologically managed ditches buffered with ≥ 3 m-wide field margin strips (36–65 plant species/400 m^2) and organic farms without buffers (converted to organic less than 5 years ago: 32 plant species/400 m2, converted more than 5 years ago: 36–52 plant species/400 m^2) than conventional farms without buffers (26–34 species/400 m^2). On ecologically managed farms with buffers plant diversity increased significantly over six years (up to 27%), there was a small shift to less common plant species and a decrease in the number of nitrogen rich species and Ellenberg nitrogen-values. There tended to be more nitrogen poor species on ecologically-managed and organic farms compared to conventional farms. Four ecologically managed farms (mown once in September, cuttings removed, buffer strips), 18 conventional and 20 organic arable farms were studied. Cutting date varied on conventional and organic farms, but cuttings were never removed, ditches did not have buffer field margin strips. On ecologically managed farms, plant species surveys of 100 m of ditch bank spread over the whole farm were undertaken once a year 1999–2004. On 75 organic (in 2001) and conventional (2003) farms, plant species presence was recorded on 10 × 25 m of ditch bank along a transect (May-June).

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/120

A series of three replicated trials in the Netherlands (2a) found that the number of plant species in field margins and adjacent ditch banks increased in the four years following establishment of 2–3 m-wide sown grass and wildflower field margins. More field margins and ditch banks showed a decline in cover of agricultural weeds following margin establishment. Ninety field margins at least 2 m-wide were established on 21 farms across the Netherlands and monitored for two to six years. On 20 of the farms, 107 ditch banks alongside 3 m wide field margins were also monitored. Most margins were planted with grasses. All margins and ditch banks were mown at least once a year and cuttings removed. Plant species richness was measured in permanent quadrats or sections. Transect counts were either every week, or two to five times during summer.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/246

Invertebrates

A series of three replicated trials in the Netherlands (2b) found that the butterfly (Lepidoptera) and dragonfly (Odonata) diversity in field margins and adjacent ditch banks increased in the four years following establishment of 2–3 m-wide sown grass and wildflower field margins. For both butterflies and dragonflies, more than half the transects showed increased species diversity in field margins, in the two to eight years following the establishment of margins. Ninety field margins at least 2 m-wide were established on 21 farms across the Netherlands and monitored for two to six years. On 20 of the farms, 107 ditch banks alongside 3 m wide field margins were also monitored. Most margins were planted with grasses. All margins and ditch banks were mown at least once a year and cuttings removed. Butterflies were counted in 50 m transect counts along field margins on six farms, and dragonflies on five farms. Transect counts were either every week, or two to five times during summer.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/246

(1) Manhoudt A.G.E., Visser A.J. & de Snoo G.R. (2007) Management regimes and farming practices enhancing plant species richness on ditch banks. *Agriculture, Ecosystems & Environment*, 119, 353–358. https://doi.org/10.1016/j.agee.2006.08.004

(2) Musters C.J.M., Alebeek F.V., Geers R.H.E.M., Korevaar H., Visser A. & Snoo G.R.D. (2009) Development of biodiversity in field margins recently taken out of production and adjacent ditch banks in arable areas. Agriculture, *Ecosystems & Environment*, 129, 131–139. https://doi.org/10.1016/ j.agee.2008.08.003

5.8 Add shells to ditches

- **One study** evaluated the effects of adding shells to ditches on invertebrates. The study was in Japan[1].

INVERTEBRATES (1 STUDY)

- **Richness/diversity (1 study):** One replicated, controlled study in an experimental concrete ditch in Japan[1] found that cages with Asian clam shells had higher invertebrate species richness than cages without, and richness was highest when a mixture of large and small shells was used.

Background

Adding empty mollusc shells to the bed of ditches may enhance habitat complexity and provide microhabitats for aquatic invertebrates. Shell additions can act as hard substrate in otherwise soft-bottomed ditches, stabilising the sediment surface and creating sheltered spaces for colonisation by invertebrates. Research on freshwater mussel shells has shown that dead shells can support macroinvertebrate richness, particularly predators and filter-feeders, by providing structural complexity and surfaces for attachment (von Wesendonk *et al*. 2025).

However, potential risks should be carefully considered. Shells from non-native bivalves, such as Asian clams, may alter substrate structure, and in some cases their historic accumulation has been linked to negative effects on native mussels (Szarmach *et al*. 2024).

Szarmach D., Wiśniewski K., Kobak J., Lichocka K., Jermacz Ł., Kakareko T., Sousa R. & Poznańska-Kakareko M. (2024) Impact of habitat engineering by invasive Corbicula clams on native European unionid mussels. *Science of the Total Environment*, 948, 174764. https://doi.org/10.1016/ j.scitotenv.2024.174764

von Wesendonk M., Pander J., Ożgo M. & Geist J. (2025) Habitat functions of freshwater mussel shells for riverine macroinvertebrates. *Science of the Total Environment*, 1000, 1 80407. https://doi.org/ 10.1016/j.scitotenv.2025.180407

Invertebrates

A replicated, controlled study in 2021 in an experimental concrete ditch in Miyakonojo, Japan (1) found that adding Asian clam *Corbicula* shells to ditches increased invertebrate species richness. Invertebrate species richness was higher in cages with shells (3.3–5.3 species) than without (2.0 species). Species richness was highest when a mixture of large and small clam shells was used (5.3 species), compared to only large (3.3 species) or only small shells (4.0 species). The gastropod *Semisulcospira libertine* was the most abundant species (55%; with shells: 16–21 individuals; without shells: 10 individuals). Other taxa included shrimp *Neocaridina* spp. and *Asellus hilgendorfii*, and insect larvae such as non-biting midges (Chironomidae). In April 2021, shells from dead Asian clams were collected from a ditch, cleaned in a laboratory, dried, and measured. Sixteen cages (23 × 11 cm, 0.2 cm mesh) with open tops were buried 5 cm into the substrate of an experimental concrete ditch (30 m long, 1–4 m wide) designed to mimic agricultural ditches. Each cage received one of four treatments: large shells (28–38 mm), small shells (13–21 mm), a mixture of large and small shells (15–40 mm), or no shells (control). Cages were left in place for 28 days (May–June 2021), after which cage contents were sieved (0.5 mm mesh) and counted.

(1) Nakano M. (2023) Effect of Asian clam shells on aquatic fauna in an artificial ditch. *Aquatic Sciences*, 85, 18. https://doi.org/10.1007/s00027-022-00918-8

6. Vegetation management

Aquatic and bankside vegetation can support biodiversity in ditch ecosystems. This chapter covers actions that enhance or maintain plant communities, such as planting new vegetation to increase diversity, or coppicing or pollarding trees to prevent excessive shading and maintain open, functioning channels.

6.1 Introduce aquatic vegetation into ditches

- **One study** evaluated the effects of introducing aquatic vegetation into ditches. The study was in the UK[1].

VEGETATION (1 STUDY)

- **Abundance (1 study):** One study in a marsh ditch in the UK[1] found that planting turions (buds) of grass-wrack pondweed established within one year and became the dominant species, and the cover of other aquatic plants increased after two years.

Background

Aquatic vegetation can be introduced into ditches by directly planting whole plants, introducing vegetation fragments (e.g. roots, rhizomes, bulbs/tubers), or transplanting blocks of vegetation (i.e. multiple plants and the sediment they are growing in).

It is important to avoid damaging donor sites when collecting material and to ensure that transplanted vegetation does not include invasive or otherwise problematic species.

Vegetation

A study in 2006–2008 in a marsh in Norfolk, UK (1) reported that grass-wrack pondweed *Potamogeton compressus* turions (buds) introduced into a ditch established within one year, and the cover of other aquatic plants increased after two years. Results are not based on statistical tests. Grass-wrack pondweed successfully established within one year of planting and became the dominant species. In the second year, pondweed density was lower than the previous year, but the cover of other species increased (other pondweeds, charophytes *Chara* spp., and water milfoil *Myriophyllum* spp.; data not provided). In October 2005, grass-wrack pondweed turions were collected from an existing ditch and stored in dark conditions in freshwater. In spring 2006 and 2007, twenty–30 turions were directly planted into a newly excavated ditch in a nature reserve marsh. Additional turions were grown in the laboratory (50 turions in plastic pots lined with jute netting and filled with aquatic compost) or outdoors (40 turions in large plastic barrels) before being transplanted into the new ditch in September 2006. In August 2006, silt (including turions) was also mechanically transferred between the old and new ditches. Ditches were monitored regularly from 2006–2008 (methods not specified).

(1) Markwell H.J. & Halls J.M. (2008) Translocation of a nationally scarce aquatic plant, grass-wrack pondweed *Potamogeton compressus*, at South Walsham Marshes, Norfolk, England. *Conservation Evidence*, 5, 69-73. https://conservationevidencejournal.com/reference/pdf/2283

6.2 Introduce bankside vegetation

- We found no studies that evaluated the effects of introducing bankside vegetation on biodiversity.

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

Background

Bankside vegetation can be introduced into ditches by sowing seeds, directly planting whole plants, introducing vegetation fragments (e.g. roots, rhizomes, bulbs/tubers), or transplanting blocks of vegetation (i.e. multiple plants and the sediment they are growing in).

It is important to avoid damaging donor sites when collecting material and to ensure that transplanted vegetation does not include invasive or otherwise problematic species.

6.3 Plant vegetation on top of filled ditches

- **One study** evaluated the effects of planting vegetation on top of filled ditches. The study was in the USA[1].

VEGETATION (1 STUDY)

- **Abundance (1 study):** One study in grassland in the USA[1] reported that five wetland plants planted on a filled drainage ditch reached 13% cover within two years.

Background

Ditches that have been filled can be revegetated by sowing seeds, directly planting whole plants, introducing vegetation fragments (e.g. roots, rhizomes, bulbs/tubers), or transplanting blocks of vegetation (i.e. multiple plants and the sediment they are growing in).

Vegetation

A study in 2015–2017 in prairie grassland in Idaho, USA (1) reported that planting wetland vegetation on filled drainage ditches resulted in establishment of the planted species within two years. After two growing seasons, planted species had 13% cover. Woolly sedge *Carex pellita* dominated the planting (64% of seedlings; 50% of cover), followed by smallwing sedge *Carex microptera* (25% seedlings; 22% cover), panicled bulrush *Scirpus microcarpus* (7% seedlings; 24% cover) and bladder sedge *Carex vesicaria* (4% seedlings; 4% cover). Nebraska sedge *Carex nebrascensis* was planted at very low density (0.3%) and was not recorded in monitored transects. In 2015, a drainage ditch was filled with mineral sediment, compacted, and topped with 15 cm of topsoil. Native wetland species were propagated from local reference sites and planted at four seedlings/m². Vegetation cover was surveyed in 2012 and 2017 in 25 circular plots (1-m radius) and 46 quadrats (1 m²) positioned every 5 m along 25–50 m transects perpendicular to the ditch.

(1) Schook D.M., Borkenhagen A.K., McDaniel P.A., Wagner J.I. & Cooper D.J. (2020) Soils and Hydrologic Processes Drive Wet Meadow Formation and Approaches to Restoration, Western USA. *Wetlands*, 40, 637–653. https://doi.org/10.1007/s13157-019-01200-8

6.4 Plant trees near ditches

- We found no studies that evaluated the effects of planting trees near ditches on biodiversity.

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

Background

Trees can be planted alongside ditches or at a set distance from the channel to provide shade and reduce the growth of emergent and aquatic vegetation (Buisson *et al*. 2008). Shading can limit the expansion of plants that might otherwise impede water flow, offering an alternative to mechanical cutting or mowing. Planting should avoid high-value habitats such as reedbeds or herb-rich grasslands. Trees also provide habitat for birds and invertebrates, increasing corridor diversity.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

6.5 Remove trees

- **Three studies** evaluated the effects of removing trees alongside ditches on vegetation and amphibians. The studies were in Sweden[1] and Estonia[2a,b].

VEGETATION (1 STUDY)

- **Richness/diversity (1 study):** One replicated, before-and-after, controlled study in a fen in Sweden[1] found that, eight years after removing trees from one side of a ditch, plant species richness had not increased.
- **Abundance (1 study):** One replicated, before-and-after, controlled study in a fen in Sweden[1] found that eight years after removing trees from one side of a ditch, vegetation cover of sedges, grasses, Sphagnum moss, bryophytes and wetland vascular plants had increased.

AMPHIBIANS (2 STUDIES):

- **Abundance (2 studies):** Two replicated, before-and-after, controlled studies in forested wetland ditches in Estonia[2a,b] found that removing tree cover from the surrounding area had no effect on the number of tadpoles (mostly brown frogs *Rana* spp.)[2b]. One of the studies found an increase in the number of spawning clumps[2b], while the other study found no change[2a].

Background

Removing trees from ditch banks involves cutting or clearing trees and large shrubs that overhang or grow close to watercourses. This action is typically carried out to reduce leaf litter inputs, maintain water flow, or reduce bank obstruction. Tree removal may also be part of broader habitat management, for example, to restore herbaceous vegetation or open water habitats.

While removing trees can improve light availability and nutrient dynamics in ditches, it may reduce habitat for birds, bats, and invertebrates, and increase the risk of bank erosion if roots are removed. Careful planning is required to balance management objectives with potential ecological impacts. Selective removal may be preferred, see ‘*Coppice or pollard trees on ditch banks*’.

Vegetation

A replicated, before-and-after, controlled study in 2002–2010 in drained fen in Uppland, Sweden (1) found that removing trees, along with damming ditches, increased vegetation cover, but not species richness, after eight years. In sites where trees were removed, average species richness initially increased after three years (before: 8 species; three years after: 11 species) but then decreased after eight years (8 species). The same was true in control sites (before: 6 species; three years after: 8 species; eight years after: 6 species). Vegetation cover increased before vs after removing trees (sedges: <1% vs 2%, grasses: 2 vs 4%, *Sphagnum*: 13 vs 20%, wetland bryophytes: 20 vs 27%, wetland vascular plants: 28 vs 37%). There was no significant change in control sites (sedges: <1%, grasses: <1%, *Sphagnum*: 4%, wetland bryophytes: 9 vs 10%, wetland vascular plants: 11 vs 15%). In sites where tree removal was combined with ditch damming, species richness increased (before: 9 species; after: 11 species) and vegetation cover increased more strongly (sedges: <1% vs 5%, *Sphagnum*: 23 vs 33%, wetland bryophytes: 33 vs 46%). In December 2002–June 2003, in each of three fen sites, all trees were cut and removed from one site along one side of a ditch (500 × 300 m). Trees on the opposite side remained intact. The ditch was dammed in half of the study area. Vegetation cover was estimated annually before (2002) and after tree removal (2003–2005 and 2010). On each side of the ditch, vegetation was surveyed along eight 32-m-long transects perpendicular to the ditch (four of which were in the dammed area). Five 0.5 × 0.5 m plots were surveyed/transect.

Amphibians

A replicated, before-and-after, controlled study in 2014–2020 in a forest wetland complex in Kõpu, Estonia (2a) found that removing tree cover did not change the number of amphibian (mostly brown frogs *Rana* spp.) spawning clumps or tadpoles compared to unmanipulated sites. The average number of spawning clumps did not differ between cut and uncut sites before (cut: 1 clumps/site; uncut: 2 clumps/site) and four years after cutting trees (cut: 3–8 clumps/site/year; uncut: 2–6 clumps/site/year). The average number of tadpoles did not significantly change throughout the study (≤1 tadpoles/site). Species comprised mostly brown frogs *Rana arvalis* and *Rana temporaria* but European newt *Lissotriton vulgaris*, common toad *Bufo bufo* and pool frog *Pelophylax lessonae* were observed in some sites. In August–December 2014, thirty percent of tree cover was removed from forests surrounding 34 ditch sections (100-m-long), and brushwood was removed from ditch banks. Sixty-five unmanipulated ditch sections were used as a comparison. Each spring from 2014–2020, tadpoles were surveyed by 20 dip-net sweeps/section and spawn clumps were counted visually.

A replicated, before-and-after, controlled study in 2014–2020 in a forest wetland complex in Kõpu, Estonia (2b) found that removing tree cover, along with filling/blocking ditches, increased the number of amphibian (mostly brown frogs *Rana* spp.) spawning clumps in restored compared to unrestored sites but had no effect on the number of tadpoles. Before restoration, the average number of spawning clumps did not significantly differ between restored and unrestored sites (one clump/site in both). For four years after restoration, the average number of spawning clumps was higher in restored (7–15 clumps/site/year) than unrestored sites (2–6 clumps/site/year). The average number of tadpoles did not significantly change throughout the study, remaining at <1 tadpole/site. Species comprised mostly brown frogs *Rana arvalis* and *Rana temporaria* but European newt *Lissotriton vulgaris*, common toad *Bufo bufo* and pool frog *Pelophylax lessonae* were observed in some sites. Forty-two 100-m-long ditch sections were restored. In August–December 2014, thirty percent of tree cover was removed from forests surrounding ditches, and brushwood was removed from ditch banks. In autumn/winter of 2015 and 2016 ditch sections were filled with soil from the ditch banks (embankments) using an excavator. Sixty-five unmanipulated ditch sections were used as a comparison. Each spring from 2014–2020, tadpoles were surveyed by 20 dip-net sweeps/section and spawn clumps were counted visually.

(1) Hedberg P., Kotowski W., Saetre P., Mälson K., Rydin H. & Sundberg S. (2012) Vegetation recovery after multiple-site experimental fen restorations, *Biological Conservation*, 147, 60–67. https://doi.org/10.1016/j.biocon.2012.01.039

(2) Soomets E., Lõhmus A. & Rannap R. (2023) Restoring functional forested peatlands by combining ditch-blocking and partial cutting: An amphibian perspective. *Ecological Engineering*, 192, 106968. https://doi.org/10.1016/j.ecoleng.2023.106968

6.6 Coppice or pollard trees on ditch banks

- We found no studies that evaluated the effects of coppicing or pollarding willow trees on ditch banks on biodiversity.

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

Background

Coppicing or pollarding trees near ditches involves cutting trees at a specified height to manage growth and improve access for maintenance (Buisson *et al*. 2008). Coppicing is the rotational cutting of young trees close to the ground, allowing regrowth from the base or 'stool'. Pollarding, particularly of willows, typically removes upper branches at ~2 m to reduce the risk of large limbs falling into the ditch while maintaining bank-stabilising roots.

Both techniques provide structural diversity along ditch margins, that can create habitat and cover for invertebrates and birds (e.g., moorhens) and maintaining the characteristic wetland landscape. Coppice material may also be harvested for local use.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

7. Species management

Some actions target the needs of particular species or species groups, such as amphibians, fish, or invertebrates. This chapter includes actions that aid survival, movement, or breeding opportunities for wildlife associated with ditch systems.

7.1 Provide escape routes from ditches

- **One study** evaluated the effects of providing escape routes from ditches on amphibians. The study was in China[1].

AMPHIBIANS (1 STUDY)

- **Movement (1 study):** One replicated study in concrete ditches in China[1] reported that providing escape routes enabled 95% of black-spotted frogs to escape within 8 minutes, but this varied by escape route design.

Background

Amphibians and other small animals may use ditches for drinking, foraging, or as breeding habitat, and they may also need to cross ditches while dispersing through the landscape. Ditches with steep or uniform banks can trap animals, making it difficult or impossible for them to escape back onto land. Escape routes can be installed (e.g. ramps or ladders) with the aim of helping animals to climb out safely.

Amphibians

A replicated study in 2019 in irrigation channels in Jiangsu, China (1) reported that providing escape routes allowed most black-spotted frogs *Rana nigromaculata* to escape ditches and that escape success and time varied depending on the design of the route. Results are not based on statistical tests. Across all designs, an average of 95% of frogs escaped within 0.4–8.4 minutes. Escape success and time varied with route width (15cm: 57–100%, 2– >10 mins; 100 cm: 100%, 1–2 mins) and substrate type (crushed stone: 100%, 1–8 mins; smooth 'reverse-slope': 57–100%, 1–>10 mins). Escape success also varied slightly with slope angle (50°: 93–100%; 55°: 93–100%; 60°: 57–100%) but escape time did not (1– >10 mins). The design with the highest and fastest escape rate had a 55° slope, crushed stone surface, and 100 cm width (100% escaped in 0.7 minutes), while the design with the lowest and slowest escape rate had a 60° slope, reverse-slope surface, and 15 cm width (57% escaped in >10 minutes). Escape routes were installed in the banks of concrete irrigation ditches and varied by slope (50°, 55°, 60°), surface type (smooth surface 'reverse-slope' vs crushed stone embedded in the concrete), and width (15 or 100 cm), resulting in 12 design combinations. A total of 120 frogs were captured in July 2019. Ten frogs (five male, five female) were tested per design. Frogs were placed at the bottom of the ditch and timed for up to 10 minutes to determine escape success. Frogs were stimulated to jump onto the escape route using green bristlegrass (*Setaria viridis*). Each trial was repeated three times.

(1) Bi B., Chen D., Bi L., Rutherfurd I., Luo Z., Chen J. & Tang S. (2020) Design of engineered modifications to allow frogs to escape from irrigation channels. *Ecological Engineering*, 156, 105967. https://doi.org/10.1016/j.ecoleng.2020.105967

8. Water management

Water levels strongly influence the ditch ecosystem. Managing flows and water tables can support wetland species while maintaining drainage functions. This chapter covers actions that modify hydrology to benefit biodiversity not just within ditches but in the surrounding land.

8.1 Dam ditches

- **Fifteen studies** evaluated the effects of damming ditches on vegetation, invertebrates, birds and fish. The studies were in the UK[1a,1b,1c,4a,4b,6,7,10], Sweden[2], USA[3,8,9,11] and Poland[5a,b].

VEGETATION (7 STUDIES)

- **Richness/diversity (4 studies):** Three of four replicated, controlled studies[1a,3,6] (one paired, one before-and-after) in farmland ditches in the UK[1a,6] and salt marsh ditches in the USA[3] found that dammed ditches had lower plant richness[1a,3,6], diversity and eveness[6] than undammed ditches, though one of the studies found the average number of species/per ditch was similar[6]. The other study[5a] found, after damming, the number of plant species increased and the community became more similar to the target habitat.
- **Abundance (5 studies):** Two of five replicated, controlled studies in the UK[1a,4a,b], USA[3] and Sweden[2] found that dammed ditches in farmland[1a] and saltmarshes[3] had lower plant cover[1a,3] and biomass[3] than undammed ditches. Two of the studies found dammed and undammed ditches in peatland had similar abundances of Sphagnum moss[4a,b] and hare's-tail cottongrass[4b]. The other study[2] found after damming, the cover of sedges, Sphagnum moss and wetlands bryophytes increased, but the cover of grasses or vascular plants did not change.
- **Condition (2 studies):** Two replicated, controlled studies in peatland ditches in the UK[4a,b] found, five years after damming, leaf length of hare's-tail cottongrass was similar in dammed and undammed ditches.

INVERTEBRATES (4 STUDIES)

- **Richness/diversity (3 studies):** One of three replicated, controlled studies (one before and after)[5b,8,9] found that damming increased the number of crustacean species and changed invertebrate community composition during wet years. One of the studies found damming decreased invertebrate richness[9], and the other study found damming had no effect on richness and diversity of mites or springtails[5b].
- **Abundance (4 studies):** Two of three replicated, controlled studies in farmland ditches in the UK[1b,7] and fen ditches in Poland[5b] found that dammed ditches had higher invertebrate biomass (mainly flies and emergent aquatic insects) than undammed ditches, but invertebrates active in the grass layer did not differ. The other study found that damming ditches decreased the density of some species of mite but not springtails. One replicated, before-and-after, site comparison study in saltmarsh ditches in USA[8] found that pools creating by damming had a lower invertebrate biomass, but similar density, compared to natural pools.

BIRDS (2 STUDIES)

- **Abundance (2 studies):** Two replicated, controlled, paired studies in farmland ditches in the UK[1c,10] found that dammed ditches had more bird visits than undammed ditches.

FISH (1 STUDY)

- **Condition (1 study):** One replicated, site comparison study in saltmarsh ditches in the USA[11] found that mummichog fish in pools created by damming had lower growth rates, but similar condition, compared to natural pools.

Background

Damming ditches involves installing small barriers or bunds (typically 20–30 cm high) to retain water in ditches that would otherwise dry out during late spring or summer (Buisson *et al*. 2008). Maintaining water in ditches can support the survival of aquatic plants and create moist conditions that benefit soil invertebrates, which in turn provide food for insectivorous birds.

Low bunds are generally inexpensive and, if installed carefully so that piped outfalls are not submerged, will not negatively affect field drainage. Installation may require consent from relevant authorities, such as the Environment Agency or Internal Drainage Boards, depending on local regulations.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

Vegetation

A replicated, controlled, paired study in 2004–2007 of drainage ditches in arable and pastoral areas of Leicestershire, UK (1a; same study site as 7) found that damming ditches resulted in lower plant species richness and cover than undammed ditches. Dammed ditches had a lower cover of grass-like plants (graminoids) both on the bankside (dammed: 30–60%; undammed: 60–70%) and bank top (dammed: 70–72%; undammed: 85–88%). Vascular plant species richness was lower and bare ground cover higher in dammed ditches than undammed ditches in 2005 due to disturbance during creation. In autumn 2004, bunds were built in ditches to retain water (no further information provided). Plastic pipes were incorporated at the top of the bunds to allow out-flow of water once the features became full. Undammed (control) ditches were selected upstream of the bunds. Sampling involved a botanical quadrat (0.25–0.5 m^2) survey. Data was obtained between April 2005–March 2007 in spring–summer.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/121

A replicated, before-and-after, controlled study in 2002–2010 in drained fen in Uppland, Sweden (2) found that damming ditches, along with removing trees, increased the cover of sedges, *Sphagnum* mosses and bryophytes, but not grasses or vascular plants, and there were small changes in species richness. Vegetation cover increased before vs after removing damming ditches for sedges (<1% vs 2%), *Sphagnum* (10% vs 18%) and wetland bryophytes (13% vs 20%) but there was no significant change in cover for grasses (before and after: <1%)

or wetland vascular plants (11% vs 15%). There was no significant change in control sites (sedges: <1%, grasses: <1%, *Sphagnum*: 4%, wetland bryophytes: 9 vs 10%, wetland vascular plants: 11% vs 15%). After three years, average species richness initially increased compared to before restoration in both dammed (after: 10 species; before: seven species) and control sites (after: eight species; before: six species) but decreased after eight years (dammed: eight species; control: six species). Where trees were removed as well as damming ditches, vegetation cover increased more strongly eight years after damming compared to before (sedges: 5% vs <1%, *Sphagnum*: 33% vs 23%, wetland bryophytes: 46% vs 33%), and species richness increased (before: nine species; after: 11 species) In December 2002–June 2003, in each of three fen sites, three dams (made of sheet piled wood with a 2–3-m-long peat plug) were placed along a 150 m stretch of ditch, 50 m apart. Each dam extended 0.5 m below the ditch bottom and 0.5–1.0 m into the sides. A 2–3-m-long plug of peat and soil was deposited upstream of the dam. Trees were removed along one side of the ditch. On each side of the ditch, vegetation was surveyed along eight 32-m-long transects perpendicular to the ditch in 2002–2005 and 2010. Five 0.5 × 0.5 m plots were surveyed/transect.

A replicated, site comparison study in 2005 in three salt marshes in the Gulf of Maine, USA (3) found that damming ditches (plugging) resulted in lower plant species richness, biomass, cover, diversity and evenness, and a changed community composition compared to unplugged ditches and natural creeks and pools. Plant species richness was lower in ditch-plug habitats than other habitats (ditch-plug: 1–2 species; non-plugged 3–4 species; natural creeks 4–5 species; pools 3–4 species). Biomass was lower in ditch-plug habitats than other habitats (ditch-plug: 3–9 g/6.25 cm^2; non-plugged: 25–47 g/6.25 cm^2; natural creeks 42–59 g/6.25 cm^2; pools: 36–39 g/6.25 cm^2). Cover was lower in ditch-plug habitats than other habitats (ditch-plug: 13–44%; non-plugged: 80–82%; natural creeks 84–86%; pools: 74–90%). Plant diversity and evenness were also lower in ditch-plug habitats (reported as diversity indices). Species composition significantly differed between habitats. For example, ditch-plugs had a higher proportion of smooth cordgrass *Spartina alterniflora* and marsh samphire *Salicornia europea*, as well as more algal mats and unvegetated areas (see paper for details). Each of three marshes contained four replicates of each habitat type: ditch-plug (no methods provided), non-plugged ditch, natural creek, and pools. In summer 2005, two 20 m transects/replicate, placed on opposite sides and perpendicular to the waterbody, were surveyed. Vegetation was surveyed in 1 m^2 quadrats. Plant clippings were taken from 6.25 cm^2 sub-quadrats, dried and weighed.

A replicated, controlled study in 2010–2015 in peatland in North Wales, UK (4a) found that damming ditches had no effect on the abundance of sphagnum mosses *Sphagnum* spp. or the abundance and leaf length of sedges (mostly hare's-tail cottongrass *Eriophorum vaginatum*). Over five years, there was no significant difference between dammed and undammed ditches for sphagnum abundance (dammed: 5–36%/year; undammed: 18–71%/year) or sedge abundance (dammed: 71–96%/year; undammed: 82–95%/year). Average leaf length of hare's-tail cottongrass also did not significantly differ (dammed: 25–35 cm; undammed: 24–38 cm). In February 2011, peat dams were constructed at regular intervals using peat extracted form borrow pits adjacent to the ditch. This created a sequence of pools behind the dams. Four dammed ditches were compared with four unmodified control ditches Plant presence/absence was recorded annually in August–October 2010–2015 in twenty-four 1 × 1 m quadrats placed 2 m east and west of each ditch. Height and width of sedges was measured. The sphagnum group comprised, in order of abundance: *Sphagnum capillifolium*, *Sphagnum fallax* and *Sphagnum papillosum.*

A replicated, controlled study in 2010–2015 in peatland in North Wales, UK (4b) found that damming ditches, along with reprofiling, had no effect on the abundance of sphagnum mosses *Sphagnum* spp. or the abundance and leaf length of sedges (mostly hare's-tail cottongrass *Eriophorum vaginatum*). Over five years, there was no significant difference between reprofiled and unmodified ditches for sphagnum abundance (reprofiled: 9–33%/year; control: 18–71%/year) or sedge abundance (reprofiled: 63–97%/year; control: 82–95%/year). Average leaf length of hare's-tail cottongrass also did not significantly differ (reprofiled: 24–36 cm; control: 24–38). In February 2011, peat dams were constructed at regular intervals along ditches using peat from adjacent borrow pits**,** and ditches were reprofiled (vegetation removed, peat compressed, and partially infilled). Four reprofiled/dammed ditches were compared with four unmodified control ditches. Plant presence/absence was recorded annually in August–October 2010–2015 in twenty-four 1 × 1 m quadrats placed 2 m east and west of each ditch. Height and width of sedges was measured. The sphagnum group comprised, in order of abundance: *Sphagnum capillifolium*, *Sphagnum fallax* and *Sphagnum papillosum.*

A replicated study in 2010–2014 in a mountain fen in Babiogórski National Park, Poland (5a) found that damming ditches increased the number of plant species, and plant community composition became more typical of the target habitat. Results are not based on statistical tests. The number of plant species near dammed ditches increased from 11 to 16 over three years after damming, with 10 of the 16 (63%) species belonging to the characteristic species combination for the habitat. See paper for cover of individual species. Thirty-two out of 35 survey sites (91%) developed plant communities characteristic of the habitat type. In 2011, two-hundred-and-twenty small wooden dams ('valves') were installed in drainage ditches across three sites (2–7 valves/10 m). Dams were made from dried spruce and ash and filled with dry leaves (up to 0.6 m high). Plants were surveyed in 2011, 2012 and 2014 at 35 sites near the dams. Species composition was compared to the typical plant association for the habitat (*Caltho-Alnetum*).

A replicated, controlled, before-and-after study in 2010–2018 in farmland in Leicester, UK (6) found that damming ditches led to a decrease in the total number of plant species across all ditches and the number of rare species in one ditch, but did not affect the average number of species/ditch. From 2010–2018 (three years before to five years after damming), the total number of emergent plant species across all ditches decreased from 35 to 29 at one site and from 18 to 15 at another. In a site where ditches were not dammed, total richness did not change significantly (before: 18 species; after: 16 species). Average species richness did not change significantly in dammed (before: 4–5 species/ditch; after: 4–6 species/ditch) or undammed sites (before: 4 species/ditch; after: 3 species/ditch). The number of rare species decreased at one of the dammed sites (before: 3 species; after: 2 species), while none were found at the other dammed or undammed sites. In 2013–2014, ditches were dammed with earth bunds in two study areas (no details provided). A third area with undammed ditches was used as a comparison. Aquatic plants were surveyed annually in August before (2010–2012) and after (2014–2018) damming ditches. Plants were recorded visually by walking or wading along ditch margins, or using a grapnel thrown from the bank. Twenty randomly selected sites were surveyed in dammed and undammed ditches in each area. All study areas were under agri-environment schemes.

Invertebrates

A replicated, controlled study of 32 ditches in arable and pastoral land in 2005 in Leicestershire, UK (7; same study site as 1) found that bunded ditches, which dammed water, had significantly greater invertebrate biomass than controls (dry weight: 10 g/m² vs 4 g/m²). Invertebrate families other than flies (Diptera) showed a more mixed response to bunding. Ditches were bunded (small dams placed across ditches) and slightly widened in 5–20 m lengths, with equal length control sections approximately 50 m upstream. Five insect emergence traps (0.5 mm mesh, surface area 0.1 m²) were spaced along each section. Samples were collected every two weeks (April-August 2005), invertebrates identified to family and recorded as biomass estimates.
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A replicated, controlled, paired study in 2004–2007 of drainage ditches in arable and pastoral areas of Leicestershire, UK (1b; same study site as 7) found that that damming ditches resulted in higher invertebrate numbers. The following were significantly greater in bunded (dammed ditches) compared to non-bunded ditches: emergent aquatic insect biomass (1,400 vs 900 individuals/m²), surface-active fly (Diptera) adults (in arable ditches in 2005; 85–100 vs 60–65/sample) and fly larvae and butterfly/moth (Lepidoptera) larvae (in pastoral ditches in 2006). There was no difference for invertebrates active in the grass layer. In autumn 2004, bunds were built in ditches to retain water (no further information provided). Plastic pipes were incorporated at the top of the bunds to allow out-flow of water once the features became full. Control sites were selected upstream of the bunds. Sampling involved fixed/floating traps for emerging aquatic insects and pitfall traps and sweep-netting for terrestrial invertebrates. Data was obtained between April 2005–March 2007 in spring–summer.
From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/121

A replicated, before-and-after, controlled study in 1998–2003 in 20 wetlands in South Carolina, USA (8) found that damming ditches (plugging) changed the invertebrate community composition and increased the number of crustacean species. Before plugging ditches, the invertebrate communities in restored and unrestored wetlands did not significantly differ (reported as graphical analysis). After plugging, community composition changed in restored wetlands during wet years, but did not significantly change during dry years. No significant change in invertebrate community composition was observed before or after in unrestored wetlands. The average number of crustacean species increased in restored (before: 3–35 species/wetlands; after: 12–37 species/wetland) but not unrestored wetlands (before: 13–46 species/wetland; after: 14–34 species/wetland). Common crustacean species were found in more restored wetlands after restoration (5–13 wetlands/species) than before (3–12 wetlands/species), but no significant change was observed in unrestored wetlands before or after restoration (both: 0–4 wetlands/species). The crustacean community changed before and after restoration in restored but not unrestored wetlands (reported as graphical analysis). In 2001, ditches were plugged with clay and soil and compacted. Sixteen restored wetlands (0.3–1.7 ha) were compared with four unrestored wetlands (0.3–3.3 ha). In the wider area, trees were logged, wetlands tree seedlings were planted in 50% of wetlands and grasses small areas (100–300 m^2) of wetlands grasses (southern cutgrass *Leersia hexandra* and maidencane *Panicum hemitomon*) were planted in 12 wetlands. Invertebrates were sampled every two months from 1998–2003, when standing water was present, using sweep netting (1-mm mesh) for larger invertebrates and hand nets (0.1-mm mesh) for micro-crustaceans.

A replicated, before-and-after, site comparison study in 2006 in saltmarsh in Maine, USA (9) found that pools created by damming ditches (plugging) had lower invertebrate species richness and biomass, similar density, and a different species composition compared to natural pools, and reported some differences in invertebrate richness, biomass and density in adjacent marsh before-and-after ditch-plugging. Average invertebrate richness and biomass were lower in ditch-plug pools (1.0–1.2 species; 0.1–0.4 g/m^2) than in natural pools (2.0–2.8 species; 0.5 g/m^2), but density did not differ significantly (ditch-plug: 636–1,110 invertebrates/m^2; natural: 1,190–2,780 invertebrates/m^2). Species composition also differed significantly between pool types (see paper for species proportions). In marsh adjacent to ditch-plug pools, richness (before: 3.4 species; after: 2.6 species), biomass (before: 0.6 g/m^2; after: 0.4 g/m^2), and density (before: 4,410; after: 4,670 invertebrates/m^2) changed after ditch-plugging, although statistical significance was not assessed. Five randomly selected pools created by ditch plugging (no methods provided) were compared to five randomly selected natural pools. One fish exclosure (0.25 m^2 wooden frame, 0.8 mm nylon mesh) was placed in each pool and one on the adjacent marsh surface. In July 2006, sediment cores (7.5 cm diameter, five replicates/pool type) were collected from fish exclosures and sieved to extract invertebrates. One ditch-plug pool and one natural pool were also sampled before the experiment.

A replicated, controlled study in 2010–2014 in a mountain fen in Babiogórski National Park, Poland (5b) found that damming ditches decreased the density of some mite (Acari) groups, but not springtails (Collembola), while overall species richness and diversity did not change. Average density of Gamasida mites (restored: 4 mites/m^2; unrestored: 5 mites/m^2) and Oribatida mites (restored: 21 mites/m^2; unrestored: 39 mites/m^2) was lower in restored than unrestored sites, but there was no significant difference for Actinedida (restored and unrestored: 2 mites/m^2) or Acaridida (restored and unrestored: <1 mite/m^2). Average species richness and diversity of mites (reported as diversity indices) did not significantly differ between restored (7 species) and unrestored sites (21 species). Springtail species richness, density, and diversity also did not differ significantly between restored (four species, 11 individuals/m²) and unrestored sites (11 species, 13 individuals/m²). In 2011, two-hundred-and-twenty small wooden dams ('valves') were installed in drainage ditches (2–7 valves/10 m). Dams were made from dried spruce and ash and filled with dry leaves (up to 0.6 m high). Soil fauna was sampled each spring and autumn from three restored sites (2012–2014) and degraded sites (2010–2012; number of sites not reported). Three random litter and soil cores were taken from each site using a steel corer.

Birds

A replicated, controlled and paired sites study of bunded and non-bunded drainage ditches in arable and pastoral areas of Leicestershire, UK (10), found that bird visit rates were significantly higher in dammed compared to non-dammed ditches (1.0 vs. 0.5 visits/month). Sampling involved bird observations (45 minutes, 1–2/month between April 2005 and March 2007.

From the Bird Synopsis, see here: https://www.conservationevidence.com/actions/180

A replicated, controlled (paired) study in 2004–2007 of wet pasture and dammed and non-dammed drainage ditches in arable and pastoral areas in Leicestershire, UK (1c; same study site as 7), found that bird visit rates were significantly higher in wet pasture (0.2–0.3 visits) than in control dry plots (0.1), particularly in the summer months and in 2006. The authors suggested benefits due to management may increase over time. In autumn 2004, bunds were built in ditches to retain water (no further information provided). Plastic pipes were incorporated at the top of the bunds to allow out-flow of water once the features became full. Control sites were selected upstream of the bunds. Sampling involved bird observations (45 minutes, 1–2/month) between April 2005 and March 2007.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/121
From the Bird Synopsis, see here: https://www.conservationevidence.com/actions/180

Fish

A replicated, site comparison study in 2006 in a saltmarsh in Maine, USA (11) found that pools created by damming ditches (plugging) had lower growth rates of mummichog fish *Fundulus heteroclitus* than natural pools, but condition was similar. Growth rate was lower in ditch-plug pools (0.02 mm/day, 0.03 g/day) than natural pools (0.03 mm/day, 0.04 g/day) but fish condition did not differ significantly (reported as Fulton's condition factor). Five randomly selected pools created by ditch plugging (no methods provided) were compared to five randomly selected natural pools. In July 2006, four marked resident fish were placed in one enclosure in each pool. Enclosures comprised 0.25 m^2 wooden frames with 0.8 mm nylon mesh sides. Fish length and wet weight were measured weekly for five weeks.

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(6) Williams P., Biggs J., Stoate C., Szczur J., Brown C. & Bonney S. (2020) Nature based measures increase freshwater biodiversity in agricultural catchments. *Biological Conservation*, 244, 108515. https://doi.org/10.1016/j.biocon.2020.108515
(7) Aquilina R., Williams P., Nicolet P., Stoate C. & Bradbury R. (2007) Effect of wetting-up ditches on emergent insect numbers. *Aspects of Applied Biology*, 81, 261–262. Available at: https://naturalengland.contentdm.oclc.org/digital/api/collection/p21006coll3/id/1815/download
(8) Batzer D.P., Taylor B.E., DeBiase A.E., Brantley S.E. & Schultheis R. (2015) response of aquatic invertebrates to ecological rehabilitation of Southeastern USA depressional wetlands. *Wetlands*, 35, 803–813. https://doi.org/10.1007/s13157-015-0671-1
(9) Vincent R.E., Dionne M., Burdick D.M. & Hobbie E.A. (2014) Fish productivity and trophic transfer in created and naturally occurring salt marsh habitat. *Estuaries and Coasts*, 38, 1233–1250. https://doi.org/10.1007/s12237-015-9969-8
(10) Anon (2007) Wetting up farmland for birds and other biodiversity, Defra Report BD1323.
(11) Vincent R.E., Dionne M., Burdick D.M. & Hobbie E.A. (2014) Fish productivity and trophic transfer in created and naturally occurring salt marsh habitat. *Estuaries and Coasts*, 38, 1233–1250. https://doi.org/10.1007/s12237-015-9969-8

8.2 Reconnect ditches

- **One study** evaluated the effects of reconnecting ditches on fish[1]. The study was in the Poland[1].

FISH (1 STUDY)

- **Abundance (1 study):** One before-and-after study of a peat bog in Poland[1] found that reconnecting ditches increased the numbers of lake minnow.

Background

Ditches may become hydrologically isolated over time due to infilling, drainage modifications, bank erosion, or the installation of pipes and culverts that restrict flow. This can reduce water movement leading to ditch sections drying out or becoming stagnant and preventing dispersal of aquatic plants and animals. Reconnecting ditches by reopening blocked sections or removing barriers helps re-establish flow and improve ecological connectivity.

Fish

A before-and-after study in 2015–2019 in a peat bog near Wolsztyn, Poland (1) found that after connecting two ditches, along with removing sediment, numbers of lake minnow *Eupallasella percnurus* increased. The study does not distinguish between the effects of connecting ditches and removing sediment. Results were not statistically tested. A greater number of lake minnow were captured in the bog four years after it was restored (total 276 fish; 39 females, 25 males, 212 juveniles age 1+) than before (81 fish, all age 2+). Low numbers were caught 1–2 years after restoration (8–14 fish) and juvenile fish were not captured until the third year. On 29 August 2015, after a drought, a peat bog was restored by connecting two adjacent dried-out peat ditches and removing sediment (total bog area increased from 200 to 400 m^2). Silt was removed from both ditches to a depth of 1–1.5 m. Eighty-one lake minnow were captured from the bog prior to the works, kept in captivity, and returned after 34 days. Invasive carp Carassius spp. captured in 2015–2019 (9–101 fish/year) were exterminated. Lake minnow were monitored annually using baited traps in 2016–2019.

From the Freshwater Fish Synopsis (not yet published)

(1) Wolnicki J. & Sikorska J. (2019) Active protection of lake minnow Eupallasella percnurus in Poland: effective habitat revitalisation at the vanishing Barÿoÿnia Wolsztyÿska site. *Let's Protect Our Indigenous Nature*, 75, 243–253. Available at: http://panel.iop.krakow.pl//uploads/wydawnictwa_artykuly/c16a42c94fe9be4e06f55aa91d98bcfe6dc6a436.pdf

8.3 Install weirs/sluices

- We found no studies that evaluated the effects of installing weirs or sluices in ditches on biodiversity.

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

Background

Weirs and sluices are structures installed in ditches to regulate water levels in the channel. They allow controlled retention or release of water, helping maintain high water tables in wet meadows, marshes, or other wetlands (Buisson *et al*. 2008). This can support aquatic plants, invertebrates, and wetland birds, and can also provide wet barriers to control stock access. Sluices provide fine-scale water management, helping to balance conservation and land-use needs. However, they can reduce ecological connectivity, potentially blocking the movement of fish or other aquatic animals, so bypass flows or fish passes may be required at some sites.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

8.4 Raise water level through controlled release

- **Two studies** evaluated the effects of raising the water level through controlled release on birds. The studies were in the UK[1,2].

BIRDS (2 STUDIES)

- **Abundance (1 study):** One before-and-after study of a marsh in the UK[2] found that raising the water level increased the number of lapwing and redshank pairs and abundance of other winter wildfowl.
- **Behaviour (1 study):** One replicated study of a grassland in the UK[1] found that raising the water level had no effect on lapwing foraging rate.

Background

Water levels are regulated in ditches and drainage channels by weirs and sluices. They allow controlled retention or release of water, helping maintain high water tables in wet meadows, marshes, or other wetlands (Buisson *et al*. 2008). This can help support aquatic plants, invertebrates, and wetland birds, and can also provide wet barriers to control stock access. Sluices provide fine-scale water management, helping to balance conservation and land-use needs. However, they can reduce ecological connectivity, potentially blocking the movement of fish or other aquatic animals, so bypass flows or fish passes may be required at some sites.

Buisson R.S.K., Wade P.M., Cathcart R.L., Hemmings S.M., Manning C.J. & Mayer L. (2008) *The Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management.* Association of Drainage Authorities and Natural England, Peterborough.

Birds

A replicated study from January-March 2002 of 15 northern lapwing *Vanellus vanellus* chicks on one grassland site in the Isle of Islay, UK (1) found that raising water levels in the grassland did not affect lapwing foraging rate. Foraging rate increased with decreasing vegetation height and was greater in ditches than on rigs. Soil moisture, however, did not significantly affect foraging rate after sward height and rig versus ditch effects were factored out. The timing of fertilizer application (to promote grass growth) and water level in ditches was manipulated at the field scale, which resulted in a range of soil moisture levels and vegetation heights. Water level was controlled through sluiced canals that ran along field boundaries and in-field ditches. The authors point out that spring 2002 was particularly wet and may have confounded any effect of added soil moisture.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/121

A before-and-after study of grazing marshes in eastern England (2) found that opening up existing footdrains, creating new ones and reconnecting drains to ditches resulted in an increase in breeding wading bird numbers. Northern lapwing *Vanellus vanellus* numbers increased from 19 pairs in 1993 to 85 pairs in 2003 and common redshank *Tringa totanus* rose from four to 63 pairs. Numbers of winter wildfowl also increased over the period and changes in vegetation communities to those more tolerant of inundation occurred. In 1993, water levels were raised by 45 cm. From 1995, approximately 600 m of footdrains were opened/year; from 2000 onwards, approximately 2,000 m of footdrains were opened or added. Grazing intensity was also reduced from 1.5–2 head of cattle to 0.7 head/ha and fertilizer inputs were stopped.

From the Farmland Synopsis, see here: https://www.conservationevidence.com/actions/121

(1) Devereux C.L., McKeever C.U., Benton T.G. & Whittingham M.J. (2004) The effect of sward height and drainage on common starlings Sturnus vulgaris and northern lapwings *Vanellus vanellus* foraging in grassland habitats. *Ibis*, 146, 115–122. https://doi.org/10.1111/j.1474-919X.2004.00355.x
(2) Smart M. & Coutts K. (2004) Footdrain management to enhance habitat for breeding waders on lowland wet grassland at Buckenham and Cantley Marshes, Mid-Yare RSPB Reserve, Norfolk, England. *Conservation Evidence*, 1, 16–19. https://conservationevidencejournal.com/reference/pdf/2128

8.5 Fill/block ditches

Background

Filling or blocking ditches involves adding soil, sediment, or other material to partially or completely infill a drainage channel. This can reduce water flow, restore natural wetland hydrology, and help reinstate habitats that have been degraded by drainage. Infilled ditches can be planted with vegetation to create wetland plants, grassland, or marsh habitats (see 'Plant vegetation on top of filled ditches').

NOTE: the studies in this section are newly summarised and cover multiple habitats: salt marshes, peatlands, grasslands, forested wetlands. These studies overlap with existing evidence in Conservation Evidence, including: '*Rewet peatland*', '*Fill/block ditches to create conditions suitable for peatland plants*' and '*Raise water level to restore/create freshwater marshes from other land uses*' (see below). For this reason, there are no key messages.

Vegetation

A controlled study in 2004–2011 in a salt marsh in Massachusetts, USA (1) found that filling/blocking ditches, along with excavating pools, led to lower plant species richness compared to unmodified sites. Results are not based on statistical tests. One species of cordgrass was observed in sites with filled/blocked ditches (*Spartina alterniflora*, 100% frequency), whereas five species were observed in unmodified sites: blackgrass *Juncus gerardii* (100%), two species of cordgrass (*Spartina patens* 50%, *Spartina alterinaflora* 12%), silverweed *Argentina anserina* (75%), and sea milkwort *Glaux maritima* (62%). In 2004, restoration comprised plugging ditches and blocking them with small berms (40 m long × 2 m wide × 12 cm high) perpendicular to ditches. Pools were also excavated (no methods provided). The study does not distinguish between the effects of these actions. Three 50-m radius sites with pools and berms were compared to three ditched sites without pools. The centre of each site was within 5 m of a randomly selected pool or ditch. In July 2011, plants were surveyed in eight randomly located 1 m^2 plots/treatment.

A replicated, site comparison study in 2004–2011 in grasslands in Hortobágy National Park, Hungary (2) found that filled ditches led to plant species richness, total vegetation cover, and species composition becoming more similar to reference grasslands over time. Species richness, vegetation total cover and plant community composition in filled ditches were more similar to reference grasslands one, six and eight years after filling (reported as a relative response index). Across all sites, a total of 105 species were recorded in one-year-old filled ditches, 54 in six-year-old filled ditches and 50 in eight-year-old filled ditches, compared to 79 species in reference grasslands. Target forb richness did not significantly differ among filled ditches of different ages. In 2004, 2006 and 2011, ditch embankments were used to fill 8-m-wide ditches in grazed grassland. Three age classes of restored ditches (one, six and eight years since filling) were studied, with nine sites per age class (27 ditches total), each adjacent to one of three grassland types. At each ditch and reference grassland, 18 vegetation plots were surveyed. Reference grasslands were also cattle-grazed.

A replicated, controlled study in 2014–2015 in a salt marsh in Massachusetts, USA (3) found that filled ditches were colonized by smooth cordgrass *Spartina alterniflora* with cover and stem density higher than unfilled ditches. For all three years after filling, average cordgrass cover and stem density was higher in filled (cover: 10–22%, density: 8–18 shoots/0.25 m^2) than unfilled ditches (cover: 1–2%, density: 1–2 shoots/0.25 m^2). No other vascular plants were found growing in the ditch centres. In September–November 2014 and 2015, ditches were filled with hay made from nearby salt marsh grasses. Hay was air-dried for 24 hours, loosely braided, placed in ditches to a depth of 15–20 cm, secured with string, and compacted underfoot. Eight filled and nine unfilled ditches were compared. Vegetation was surveyed in 0.5 m^2 quadrats at ditch centres four times between 2015 and 2017.

A before-and-after study in 2012–2017 in a prairie grassland in Idaho, USA (4) reported that filling ditches, then planting wetland vegetation, decreased the number of plant species, but increased the cover of native plant species. Results were not based on statistical tests. The number of species was higher before restoration (43 species, average abundance 9–87 individuals/species, in five communities) than after (15 species, 2–97 individuals/species, in seven communities, including five planted species). covering 77% of sampled plots. Introduced meadow foxtail *Alopecurus pratensis* was the dominant species before and after restoration. Native plant cover increased from 6% to 8%, while non-native plant cover decreased from 76% to 73%. Common camas *Camassia quamash* cover increased slightly from 1.5% to 1.9%. In 2015, a ditch was cleared with an excavator, filled with mineral sediment, compacted with a roller, and covered with a 15 cm layer of topsoil. Five native wetland species propagated from local reference sites were planted at four seedlings/m^2. Vegetation cover was surveyed in 2012 and 2017 in 25 circular plots (1-m radius) and 46 quadrats (1 m^2) positioned every five m along 25–50 m transects perpendicular to the ditch.

Amphibians

A replicated, before-and-after, controlled study in 2014–2020 in a forest wetland complex in Kõpu, Estonia (5a) found that filling/blocking ditches did not change the number of amphibian spawning clumps or tadpoles (mostly brown frogs *Rana* spp.) compared to unfilled sites. The average number of spawning clumps did not differ between filled and unfilled sites before (filled: 2 clumps/site; unfilled: 2 clumps/site) and four years after filling ditches (filled: 7–20 clumps/site/year; unfilled: 2–6 clumps/site/year). The average number of tadpoles did not significantly change throughout the study (≤1 tadpoles/site). Species comprised mostly brown frogs *Rana arvalis* and *Rana temporaria* but European newt *Lissotriton vulgaris*, common toad *Bufo bufo* and pool frog *Pelophylax lessonae* were observed in some sites. In autumn/winter 2015 and 2016, ten ditch sections were filled with soil from the ditch banks (embankments) using an excavator. Numerous dams made of peat and soil were built to restrict outflows. Sixty-five unmanipulated ditch sections were used as a comparison. Each spring from 2014–2020, tadpoles were surveyed by 20 dip-net sweeps/section and spawn clumps were counted visually.

A replicated, before-and-after, controlled study in 2014–2020 in a forest wetland complex in Kõpu, Estonia (5b) found that filling/blocking ditches, along with removing tree cover, increased the number of amphibian spawning clumps (mostly brown frogs *Rana* spp.) in restored compared to unrestored sites but had no effect on the number of tadpoles. Before restoration, the average number of spawning clumps did not significantly differ between restored and unrestored sites (one clump/site in both). For four years after restoration, the average number of spawning clumps was higher in restored (7–15 clumps/site/year) than unrestored sites (2–6 clumps/site/year). The average number of tadpoles did not significantly change throughout the study, remaining at <1 tadpole/site. Species comprised mostly brown frogs *Rana arvalis* and *Rana temporaria* but European newt *Lissotriton vulgaris*, common toad *Bufo bufo* and pool frog *Pelophylax lessonae* were observed in some sites. In 2014–2016, forty-two 100-m-long ditch sections were restored. In August–December 2014, 30% of tree cover was removed in the forests surrounding ditches, and brushwood was removed from ditch banks. In autumn/winter of 2015 and 2016 ditch sections were filled with soil from the ditch banks (embankments) using an excavator. Sixty-five unmanipulated ditch sections were used as a comparison. Each spring from 2014–2020, tadpoles were surveyed by 20 dip-net sweeps/section and spawn clumps were counted visually.

Invertebrates

A site comparison study in 2011–2016 in peatland in Tatra National Park, Slovakia (6) reported that filling/blocking ditches resulted in lower nematode abundance, biomass and diversity, but similar species richness, in restored compared to unrestored peatlands. Unless stated, statistical significance was not assessed. The total number of nematode species was similar, but abundance was lower in restored peatland (12 species, 330 individuals) than unrestored (peatland forest: 20 species, 581 individuals; peatland meadow: 20 species, 572 individuals). Nematode total biomass was significantly lower in restored peatland (0.16 mg) than unrestored (peatland forest: 0.38 mg; peatland meadow: 0.37 mg). Diversity was also significantly lower in restored peatlands (reported as diversity, ecological and functional indices). The proportion of different trophic groups differed between restored and unrestored peatlands (bacterivores: 51 vs 33–43%, fungivores: 33 vs 8–9%, omnivores: <1 vs 5–8%, plant parasites: 16 vs 38–49%). In 2011, 100 m of drainage ditches were blocked (no methods provided). In 2016, soil samples ($1m^2$, 10–15 cm deep) were collected from ten randomly selected sampling plots in each of three habitats: restored peatland, unrestored peatland forest and unrestored peatland meadow. Nematodes were extracted from 100 g subsamples sieved through 2 mm mesh and soaked in water.

(1) Elsey-Quirk T. & Adamowicz S.C (2016) Influence of physical manipulations on short-term salt marsh morphodynamics: examples from the North and Mid-Atlantic Coast, USA. *Estuaries and Coasts*, 39, 423–439. https://doi.org/10.1007/s12237-015-0013-9
(2) Valkó O., Deák B., Török P., Kelemen A., Miglécz T. & Tóthmérész B. (2017) Filling up the gaps—Passive restoration does work on linear landscape elements. *Ecological Engineering*, 102, 501–508. http://dx.doi.org/10.1016/j.ecoleng.2017.02.024
(3) Burdick D.M., Moore G.E., Adamowicz S.C., Wilson G.M. & Peter C.R. (2020) Mitigating the legacy effects of ditching in a New England salt marsh. *Estuaries and Coasts*, 43, 1672–1679. https://doi.org/10.1007/s12237-019-00656-5
(4) Schook D.M., Borkenhagen A.K., McDaniel P.A., Wagner J.I. & Cooper D.J. (2020) Soils and Hydrologic Processes Drive Wet Meadow Formation and Approaches to Restoration, Western USA. *Wetlands*, 40, 637–653. https://doi.org/10.1007/s13157-019-01200-8
(5) Soomets E., Lõhmus A. & Rannap R. (2023) Restoring functional forested peatlands by combining ditch-blocking and partial cutting: An amphibian perspective. *Ecological Engineering*, 192, 106968. https://doi.org/10.1016/j.ecoleng.2023.106968
(6) Bobuľská L., Demková L., Čerevková A. & Renčo M. (2020) Impact of peatland restoration on soil microbial activity and nematode communities. *Wetlands*, 40, 865–875. https://doi.org/10.1007/ s13157-019-01214-2

8.6 Fill/block ditches to create conditions suitable for peatland plants

Background

Many threats can contribute to the formation of ditches or channels in peatlands (Evans et al. 2005). Deep channels (gullies) may be eroded by humans or livestock repeatedly using set trails and/or by heavy rainfall events. Erosion can be increased by burning and acid rain. Ditches may be deliberately dug to drain peatlands for agriculture, forestry or mining. Peatland vegetation cannot establish in ditches that contain deep water or are regularly disturbed by flowing water.

Ditches could be completely filled to immediately create a surface for plants to grow on. Alternatively, ditches could be blocked with dams: creating shallow pools, encouraging peat deposition and eventually creating new surfaces on which peatland plants can grow. This would mimic natural revegetation processes (Evans *et al.* 2005). This action considers growth of peatland vegetation *within* filled or blocked ditches.

Key peatland types where this action may be appropriate: bogs, fens/fen meadows, tropical peat swamps.

Evans M., Allott T., Crowe S. & Liddaman L. (2005) Feasible locations for gully blocking. Pages 27–76 in: M. Evans, T. Allott, J. Holden, C. Flitcroft & A. Bonn (eds.) *Understanding Gully Blocking in Deep Peat*. Moors for the Future Research Report 4.

There are 3 summarised studies for this action in the Peatland Synopsis, see here: https://www.conservationevidence.com/actions/1805

8.7 Rewet peatland

Background

Peatlands may be drained for activities such as crop cultivation, livestock grazing, natural resource harvesting, road building or urban development. Peatland drainage may also be unintentional e.g. extracting drinking water from below ground lowers the water table over a large area. Drained peat can be too dry and chemically unsuitable for peatland plants (Lamers *et al.* 2002). Raising the water table will rewet the surface peat, creating more suitable conditions for recolonization by peatland plants and less suitable conditions for other species (Money & Wheeler 1999; Ritzema *et al.* 2014). It may be necessary to rewet the area around a peatland too (creating a 'hydrological buffer zone') to prevent water simply draining away from the peatland.

A range of techniques may be used to raise the water table in peatlands e.g. blocking drainage ditches or gullies (using peat, rocks, plastic dams or wooden dams), planting flood-resistant vegetation in ditches to slow water flow, blocking underground channels or peat pipes, building raised embankments or berms (elongated mounds of peat or rows of straw bales) to retain water, inserting dams (e.g. straw bales) below the peat surface to slow subsurface drainage, switching off drainage pumps, or restoring inflows. These interventions are all considered in this section.

Caution: Deep flooding is generally not desirable when restoring peatland vegetation. The water table should be raised to anywhere from just below the peat surface to a few centimetres above, depending on the site. Also, rewetting may increase emissions of greenhouse gasses such as methane (Abdalla et al. 2016).

Key peatland types where this action may be appropriate: bogs, fens/fen meadows, tropical peat swamps.

Abdalla M., Hastings A., Truu J., Espenberg M. & Mander Ü. (2016) Emissions of methane from northern peatlands: a review of management impacts and implications for future management options. *Ecology and Evolution*, 6, 7080–7102.

Lamers L.P., Smolders A.J.P. & Roelofs J.G.M. (2002) The restoration of fens in the Netherlands. *Hydrobiologia*, 478, 107–130.

Money R.P. & Wheeler B.D. (1999) Some critical questions concerning the restorability of raised bogs. *Applied Vegetation Science*, 2, 107–116.

Ritzema H., Limin S., Kusin K., Jauhiainen J. & Wösten H. (2014) Canal blocking strategies for hydrological restoration of degraded tropical peatlands in Central Kalimantan, Indonesia. *Catena*, 114, 11–20.

There are 36 summarised studies for this action in the Peatland Synopsis, see here: https://www.conservationevidence.com/actions/1756

8.8 Raise water level to restore/create freshwater marshes from other land uses

Background

This action involves *one-off* action to raise the water level/table to restore/create marshes from other land uses. This means that intervention should (a) occur at one point in time, after which the water table is not actively managed, and (b) must affect an area that does not retain substantial characteristics of the target habitat. This could be an upland area (e.g. grassland), an unvegetated wetland (e.g. mudflats), or a wetland other than the target type (e.g. swamp, where the habitat used to be a marsh).

Specific techniques to raise water levels include: blocking drainage ditches (using sediment, rocks, plastic dams, wooden dams or vegetation); building raised embankments, berms or levees to retain water; switching off drainage pumps; ceasing groundwater extraction; installing or widening culverts (e.g. under roads and railways, to increase water flow into focal marsh/swamp); removing dams upstream of the focal marsh/swamp; and reprofiling or diverting river channels to raise the water level on floodplains. All of these techniques aim to make soils saturated or flooded, or make them saturated or flooded for longer, so they can support emergent wetland vegetation. The resulting water level may be stable or fluctuating, and may create permanently or seasonally flooded wetlands. Sediment inputs may also increase in line with water inputs.

Caution: This action may have negative effects on habitats elsewhere in the catchment. For example, removing dams upstream of a focal site could drain wetlands or aquatic habitats upstream of the dam. There may also be conflicts with water needs of human populations that need to be managed. Rewetting drained acid sulphate soils – common in coastal areas and salinized inland areas – can lead to acidification, deoxygenation and release of toxic metals (Baldwin 2011).

Baldwin D. (2011) *National Guidance for the Management of Acid Sulfate Soils in Inland Aquatic Ecosystems*, Environment Protection and Heritage Council and the Natural Resource Management Ministerial Council, Australia.

There are 26 summarised studies for this action in the Marshes and swamps Synopsis, see here: https://www.conservationevidence.com/actions/3198

9. Managing problematic plant species

We searched for the problem species listed in Table 1 (below) in the following Conservation Evidence synopses:

- Marshes and Swamp Synopsis (reports outcomes on *native* biodiversity)
- Aquatic Vegetation Synopsis (unpublished, reports outcomes on *native* biodiversity)
- Freshwater Invasives Synopsis (reports outcomes on *invasive/problem* species)

The studies in this chapter report the effects of controlling problem species on the *native* species.

Table 1. Problem species listed in The Drainage Channel Biodiversity Manual (Buisson *et al*. 2008) as being problematic or invasive in UK ditches

Channel or wet margin	Bankside
Australian swamp stonecrop *Crassula helmsii* Canadian pondweed *Elodea canadensis* Curly pondweed *Lagarosiphon major* Floating pennywort *Hydrocotyle ranunculoides* Parrot's-feather *Myriophyllum aquaticum* Water fern *Azolla filiculoides* Water hyacinth *Eichhornia crassipes* Water lettuce *Pistia stratiotes* Water primrose *Ludwigia grandiflora*	Giant rhubarb *Gunnera tinctoria* Giant hogweed *Heracleum mantegazzianum* Himalayan balsam *Impatiens glandulifera* Japanese knotweed *Fallopia japonica*

9.1 Physically remove water hyacinth Eichhornia crassipes

- **One study** evaluated the effects of physically removing water hyacinth on vegetation. The study was in the Brazil[1].

VEGETATION (1 STUDY)

- **Native phytoplankton abundance (1 study):** One before-and-after study of a reservoir in Brazil[1] found that total phytoplankton abundance was higher in the five years after mechanically removing water hyacinth than in the three years before.

A before-and-after study in 1997–2004 in a shallow reservoir in southeastern Brazil (1) found that after removing almost all water hyacinth *Eichhornia crassipes*, there were increases in overall phytoplankton abundance and the relative abundance of blue-green algae. Overall phytoplankton abundance was higher in the five years after hyacinth removal began than in the three years before (e.g. subsurface chlorophyll a before: 10–220 µg/L, with 45 of 67 samples >150 µg/L; after: 10–1,320 µg/L, with 2 of 29 samples >150 µg/L). Blue-green algae comprised a greater proportion of the phytoplankton biovolume after hyacinth removal began than before (e.g. subsurface before: 2–99%, with 49 of 67 samples >90%; after: 17–100%, with 1 of 29 samples >90%). Between June and September 1999, water hyacinth was mechanically removed from the surface of Garças Reservoir (88,000 m^2; 2.1 m average depth). Water hyacinth coverage was reduced from around 70% to <10%. Phytoplankton was sampled monthly before (1997–1999) and after (1999–2004) hyacinth removal. Samples were collected over the deepest part of the reservoir, at five depths spanning the entire water column (4.7 m).

From the Aquatic Vegetation Synopsis (not yet published)

(1) Bicudo, D.D.C., Fonseca B.M., Bini L.M., Crossetti L.O., Bicudi, C.E.D.M. & Araújo-Jesus T. (2007) Undesirable side-effects of water hyacinth control in a shallow tropical reservoir. *Freshwater Biology*, 52, 1120–1133. https://doi.org/10.1111/j.1365-2427.2007.01738.x

9.2 Physically damage water hyacinth Eichhornia crassipes

- **One study** evaluated the effects of physically damaging water hyacinth on vegetation. The study was in Mexico[1].

VEGETATION (1 STUDY)

- **Native phytoplankton abundance (1 study):** One before-and-after study in a reservoir in Mexico[1] reported that after crushing a large stand of water hyacinth, diatom abundance was lower, but euglenid abundance was higher, than before.

A before-and-after study in 1994–1998 in a reservoir in central Mexico (1) reported that after crushing a large stand of water hyacinth *Eichhornia crassipes*, there were changes in the abundance of phytoplankton groups. Statistical significance was not assessed. Two years before intervention, the most abundant phytoplankton groups were diatoms (Bacillariophyta; present in 9 of 12 months; peak abundance: 1,500 cells/ml) and blue-green algae (Cyanophyta; present in 10 of 12 months; peak abundance: 600 cells/ml). In the year after intervention, the most abundant phytoplankton groups were euglenids (Euglenophyta; present in 10 of 11 months; peak abundance: 3,000 cells/ml) and blue-green algae (present in 10 of 11 months, peak abundance: 1,600 cells/ml). Diatoms were scarce (<100 cells/ml) for the first 12 months after intervention began. In the mid-1990s, water hyacinth covered around 70% of the Manuel Avila Camacho reservoir. Between December 1996 and February 1997, water hyacinth was crushed using boats with large paddle wheels. Dead plant material sunk to the bottom of the reservoir. Phytoplankton were identified and counted in surface water samples, taken monthly before (June 1994 to April 1995) and after (May 1997 to April 1998) intervention.

From the Aquatic Vegetation Synopsis (not yet published)

(1) Mangas-Ramírez E. & Elías-Gutiérrez M. (2014) Effect of mechanical removal of water hyacinth (*Eichhornia crassipes*) on the water quality and biological communities in a Mexican reservoir. *Aquatic Ecosystem Health & Management*, 7, 161–168. https://doi.org/10.1080/14634980490281597

9.3 Use herbicide to control water hyacinth Eichhornia crassipes

- **One study** evaluated the effects of using herbicide to control water hyacinth on vegetation. The study was Mexico[1].

VEGETATION (1 STUDY)

- **Native phytoplankton abundance (1 study):** One before-and-after study in a reservoir in Mexico[1] reported that applying herbicide to water hyacinth led to a decline in phytoplankton abundance.

A before-and-after study in 1993 in a reservoir in Mexico City, Mexico (1) reported that herbicide application to control water hyacinth *Eichhornia crassipes* was followed by a temporary decline in phytoplankton abundance. Statistical significance was not assessed. In July–August, the reservoir contained 20–130 million phytoplankton cells/L and 41–110 µg chlorophyll a/L. This was at least six weeks after the most recent herbicide (diquat) application. In September, *one week after* the most recent 2,4-D amine application, there were only 5–30 million phytoplankton cells/L and only 5–20 µg chlorophyll a/L. In October, *four weeks after* the most recent 2,4-D amine application, cell numbers remained low (10–20 million phytoplankton cells/L) but the chlorophyll a concentration had recovered in four of five sites (50–100 µg/L). The study also noted that changes in the relative abundance of phytoplankton groups (data not reported and not statistically tested). In August and September 1993, 2,4-D amine herbicide (Hierbamine™) was applied to control water hyacinth in Guadalupe Reservoir (347 ha). This was part of a broader hyacinth management programme, following mechanical removal of hyacinth and diquat (Reglone™) application in early 1993. The study does not provide evidence for the effects of these interventions. Water samples were collected monthly in July–November 1993, from five sites and up to 5 m depth.

From the Aquatic Vegetation Synopsis (not yet published)

(1) Lugo A., Bravo-Inclán L.A., Alcocer J., Gaytán M.L., Oliva Ma.G., Sánchez Ma.del R., Chávez M. & Vilaclara G. (1998) Effect on the planktonic community of the chemical program used to control water hyacinth (*Eichhornia crassipes*) in Guadalupe Dam, Mexico. *Aquatic Ecosystem Health & Management*, 1, 333–343. https://doi.org/10.1016/S1463-4988(98)00024-4

9.4 Use covers to control curly water weed Lagarosiphon major

- **One study** evaluated the effects of using covers to control water hyacinth on vegetation. The study was Ireland[1].

VEGETATION (1 STUDY)

- **Native plant abundance (1 study):** One replicated, before-and-after study in a lake in Ireland[1] reported that covering water hyacinth with jute matting led to colonization of native macrophytes.

A replicated, before-and-after study in 2008–2010 in a lake in Ireland (1) reported that native submerged macrophytes colonized areas of curly waterweed *Lagarosiphon major* that had been covered with jute matting for at least seven months. Before intervention, the seven study sites were dominated by curly waterweed (6 sites: 100% cover, no other macrophytes; 1 site: also "small stands" of native species and/or exposed lake bed). After intervention, five sites with matting in place for ≥7 months contained 3–5 macrophyte species. All five sites were dominated by native stoneworts *Chara* spp. or *Nitella* spp. (1–2 species/site, 28–72% cover of most abundant species). There were three other native or naturalized species present (1–3 species/site; ≤7% cover/species). Curly waterweed was present at two sites (≤2% cover). Two sites with matting in place for ≤5 months contained no submerged macrophytes. Between August 2008 and October 2009, jute matting was laid over seven sites (100–5,000 m^2) in Lough Corrib (17,800 ha) dominated by curly waterweed. The matting was weighed down or pinned in place. It was never removed. Macrophyte presence and cover were surveyed immediately before intervention, and 4–17 months after (early 2010), in five 0.25-m^2 quadrats/site.

From the Aquatic Vegetation Synopsis (not yet published)

(1) Caffrey J., Millane M., Evers S.L., Moran H. & Butler M. (2006) A novel approach to aquatic weed control and habitat restoration using biodegradable jute matting. *Aquatic Invasions*, 5, 123–129. http://dx.doi.org/10.3391/ai.2010.5.2.01

9.5 Use cutting to control curly water weed Lagarosiphon major

- **One study** evaluated the effects of using cutting to control curly water weed on vegetation. The study was in New Zealand[1].

VEGETATION (1 STUDY)

- **Native plant abundance (1 study):** One replicated, randomized study in a lake in New Zealand[1] reported that cutting strips into beds of invasive curly waterweed increased the cover of a native stonewort species but had no effect on algae biomass.

A replicated, randomized, paired, controlled, before-and-after study in 2004–2005 in a lake in Otago, New Zealand (1) found that cutting strips into beds of invasive curly waterweed *Lagarosiphon major* facilitated colonization of native submerged macrophytes in some plots, but had no significant effect on the biomass of algae growing on plants. After four months, cut plots had lower cover of curly waterweed (75%) than uncut plots (100%). Native macrophytes were present in 4 of 10 cut plots (cover ≤5%). In contrast, uncut plots contained no native macrophytes. The biomass (ash-free dry mass) of algae growing on macrophytes was statistically similar in cut plots (0.015 mg algae/g plant) and uncut plots (0.012 mg algae/g plant). Ten pairs of plots were established in patches of curly waterweed (100% cover) near the shore of Lake Dunstan (where water was <3 m deep). In October 2004, macrophytes were manually cut from three strips (2 m wide, 5 m apart) in one random plot/pair. Cuttings were removed. No macrophytes were cut in the other plots. A diver surveyed the vegetation in February 2005. This included collection of three random plants/plot; algae were washed off these in the laboratory.

From the Aquatic Vegetation Synopsis (not yet published)

(1) Bickel T.O. & Closs G.P. (2009) Impact of partial removal of the invasive macrophyte *Lagarosiphon major* (Hydrocharitaceae) on invertebrates and fish. *River Research and Applications*, 25, 734–744. https://doi.org/10.1002/rra.1187

9.6 Use cutting to control Canadian water weed Elodea canadensis

- **One study** evaluated the effects of using cutting to control Canadian water weed on vegetation. The study was the UK[1].

VEGETATION (1 STUDY)

- **Native species richness/diversity (1 study):** One replicated study in a lake in the UK[1] reported that cut patches of Canadian waterweed were not colonized by any other macrophyte species within one growing season.

A replicated study in 2010 in a shallow lake in Scotland, UK (1) reported that clear-cut patches of Canadian waterweed *Elodea canadensis* were not colonized by any other macrophyte species within one growing season. Canadian waterweed abundance did remain significantly lower in clear-cut patches (6–38% volume inhabited) than uncut plots (37–71% volume inhabited). Other macrophyte species were present elsewhere in the lake. Ten 4-m^2 plots were established on the bottom of Loch Flemington, in patches of Canadian waterweed (≤2 m deep). In summer 2010, a diver cut and removed Canadian waterweed from five of the plots. The other five plots were not cut. The plots were surveyed until October 2010, to identify any plant species other than Canadian waterweed and visually estimate the volume of submerged vegetation.

From the Aquatic Vegetation Synopsis (not yet published)

(1) Gunn I.D.M., Meis S., Maberly S.C. & Spears B.M. (2014) Assessing the responses of aquatic macrophytes to the application of a lanthanum modified bentonite clay, at Loch Flemington, Scotland, UK. *Hydrobiologia*, 737, 309–320. https://doi.org/10.1007/s10750-013-1765-5

9.7 Actions to control New Zealand pigmyweed Crassula helmsii

A link to the summarised evidence for each action on the Conservation evidence website is provided. Note that we found no evidence (before publication) for the second set of actions.

Actions with summarised evidence

- **Chemical control using herbicides**
  Seven studies: https://www.conservationevidence.com/actions/1279
- **Decontamination to prevent further spread:**
  One study: https://www.conservationevidence.com/actions/1308
- **Use a combination of control methods**
  One study: https://www.conservationevidence.com/actions/1313
- **Use dyes to reduce light levels**
  One study: https://www.conservationevidence.com/actions/1293
- **Use grazing**
  Two studies: https://www.conservationevidence.com/actions/1301
- **Use hot foam:**
  Two studies: https://www.conservationevidence.com/actions/1286
- **Use hydrogen peroxide**
  One study: https://www.conservationevidence.com/actions/1281
- **Use lightproof barriers**
  Five studies: https://www.conservationevidence.com/actions/1294
- **Use salt water**
  Three studies: https://www.conservationevidence.com/actions/1288

Actions with no summarised evidence

- **Alter environmental conditions to control plants**
  No studies: https://www.conservationevidence.com/actions/1296
- **Biological control using fungal-based herbicides**
  No studies: https://www.conservationevidence.com/actions/1276
- **Biological control using herbivores:**
  No studies: https://www.conservationevidence.com/actions/1277
- **Bury plants**
  No studies: https://www.conservationevidence.com/actions/1305
- **Dry out waterbodies:**
  No studies: https://www.conservationevidence.com/actions/1303
- **Physical control using manual/mechanical control or dredging**
  No studies: https://www.conservationevidence.com/actions/1278
- **Plant other species to suppress growth of *Crassula helmsii***
  No studies: https://www.conservationevidence.com/actions/1299
- **Public education**
  No studies: https://www.conservationevidence.com/actions/1311

- **Surround with wire mesh**
  No studies: https://www.conservationevidence.com/actions/1307
- **Use flame-throwers:**
  No studies: https://www.conservationevidence.com/actions/1291
- **Use hot water**
  No studies: https://www.conservationevidence.com/actions/1275
- **Use of liquid nitrogen to kill plants**
  No studies: https://www.conservationevidence.com/actions/1282

9.8 Actions to control Parrot's feather Myriophyllum aquaticum

A link to the summarised evidence for each action on the Conservation evidence website is provided. Note that we found no evidence (before publication) for the second set of actions.

Actions with summarised evidence

- **Biological control using herbivores**
  Four studies: https://www.conservationevidence.com/actions/1599
- **Biological control using plant pathogens**
  One study: https://www.conservationevidence.com/actions/1601
- **Reduction of trade through legislation and codes of conduct**
  Two studies: https://www.conservationevidence.com/actions/1604
- **Use of herbicide: 2,4-D**
  Seven studies: https://www.conservationevidence.com/actions/1606
- **Use of herbicides: carfentrazone-ethyl**
  Five studies: https://www.conservationevidence.com/actions/1676
- **Use of herbicides: diquat**
  Three studies: https://www.conservationevidence.com/actions/1680
- **Use of herbicides: endohall**
  Three studies: https://www.conservationevidence.com/actions/1681
- **Use of herbicides: triclopyr**
  Five studies: https://www.conservationevidence.com/actions/1689
- **Use of herbicides: other herbicides**
  Fourteen studies: https://www.conservationevidence.com/actions/1699**Water level drawdown**
  One study: https://www.conservationevidence.com/actions/1585

Actions with no summarised evidence

- **Biological control using fungal-based herbicides**
  No evidence: https://www.conservationevidence.com/actions/1598
- **Decontamination preventing further spread**
  No evidence: https://www.conservationevidence.com/actions/1602
- **Dye application**
  No evidence: https://www.conservationevidence.com/actions/1587

- **Manual harvesting**
  No evidence: https://www.conservationevidence.com/actions/1575
- **Mechanical excavation**
  No evidence: https://www.conservationevidence.com/actions/1570
- **Mechanical harvesting and cutting**
  No evidence: https://www.conservationevidence.com/actions/1568
- **Multiple integrated measures**
  No evidence: https://www.conservationevidence.com/actions/1709
- **Public education**
  No evidence: https://www.conservationevidence.com/actions/1603
- **Removal using water jets**
  No studies: https://www.conservationevidence.com/actions/1572
- **Suction dredging and diver-assisted suction removal**
  No evidence: https://www.conservationevidence.com/actions/1573
- **Use lightproof barriers**
  No evidence: https://www.conservationevidence.com/actions/1576
- **Use of salt**
  No evidence: https://www.conservationevidence.com/actions/1605

9.9 Actions to control Floating pennywort Hydrocotyle ranunculoides

A link to the summarised evidence for each action on the Conservation evidence website is provided. Note that we found no evidence (before publication) for the second set of actions.

Actions with summarised evidence

- **Biological control using co-evolved, host specific herbivores**
  One study: https://www.conservationevidence.com/actions/1123
- **Chemical control using herbicides**
  One study: https://www.conservationevidence.com/actions/1127
- **Combination treatment using herbicides and physical removal**
  One study: https://www.conservationevidence.com/actions/1128
- **Flame treatment**
  One study: https://www.conservationevidence.com/actions/1131
- **Physical removal**
  Two studies: https://www.conservationevidence.com/actions/1126
- **Use of hydrogen peroxide**
  One study: https://www.conservationevidence.com/actions/1129

Actions with no summarised evidence

- **Biological control using native herbivores**
  No studies: https://www.conservationevidence.com/actions/1124

- **Biological control using fungal-based herbicides**
  No studies: https://www.conservationevidence.com/actions/1125
- **Environmental control**
  No studies: https://www.conservationevidence.com/actions/1133
- **Excavation of banks**
  No studies: https://www.conservationevidence.com/actions/1132
- **Public education**
  No studies: https://www.conservationevidence.com/actions/1134
- **Use of liquid nitrogen**
  No studies: https://www.conservationevidence.com/actions/1130

10. Managing other invasive species

Key word searches of our database revealed two additional publications that investigated the control of problematic species specifically in ditch habitat (see below). But see the Conservation Evidence website for actions related to the control of other taxa, including:

- **Invasive *Procambarus* crayfish:** https://www.conservationevidence.com/data/index?synopsis_id%5B%5D=18&terms=Procambarus+crayfish&country%5B%5D=&result_type=interventions#search-results
- **Invasive brown and black bullheads:** https://www.conservationevidence.com/data/index?synopsis_id%5B%5D=18&terms=bullheads&country%5B%5D=&result_type=interventions#search-results
- **Invasive Ponto-Caspian gobies:** https://www.conservationevidence.com/data/index?synopsis_id%5B%5D=18&terms=gobies&country%5B%5D=&result_type=interventions#search-results
- **Invasive Red-eared terrapin *Trachemys scripta*:** https://www.conservationevidence.com/data/index?synopsis_id%5B%5D=18&terms=terrapin&country%5B%5D=&result_type=interventions#search-results
- **Invasive American bullfrog *Lithobates catesbeiana*:** https://www.conservationevidence.com/data/index?synopsis_id%5B%5D=18&terms=American+bullfrog&country%5B%5D=&result_type=interventions#search-results

10.1 Reprofile ditch banks to prevent crayfish burrowing

A replicated, site comparison study in 2019 in drainage ditches in Horssen, Netherlands (1) found that natural bank profiles had fewer red swamp crayfish *Procambarus clarkii* burrows than semi-natural and non-natural bank profiles. The average number of crayfish burrows was significantly lower in natural banks (0.5 burrows/transect) than semi-natural (5.5 burrows/transect) or non-natural banks (9.1 burrows/transect). Drainage ditch banks were rehabilitated to a natural profile (no methods provided). Banks were categorized as natural (< 25° slope, diverse aquatic vegetation), semi-natural (steep with some vegetation) and non-natural (> 40° slope, barely vegetated). In March 2019, when water levels were lowered for maintenance, crayfish burrows were counted along 10 m transects at three sites (18–125/site) using binoculars from the opposite bank.

(1) Lemmers P., van der Kroon R., van Kleef H.H., Verhees J.J.F., van der Velde G. & Leuven R.S.E.W. (2022) Limiting burrowing activity and overland dispersal of the invasive alien red swamp crayfish Procambarus clarkii by sophisticated design of watercourses. *Ecological Engineering*, 185, 106787. https://doi.org/10.1016/j.ecoleng.2022.106787

10.2 Release fish to control mosquitoes

A replicated, before-and-after, controlled study in 2006–2008 in nine urban drainage ditches in La Plata, Argentina (1) found that releasing mosquito fish *Cnesterodon decemmaculatus* reduced the number of mosquito larvae *Culex pipiens*, with greater reductions at higher fish densities. Overall, larval abundance was significantly lower in ditches with fish than in control ditches without fish, and lower where 50–100 fish pairs were released than where 10 pairs were released. Fifteen weeks after release, mosquito larvae were reduced by 99% in ditches with 100 pairs, 73% with 50 pairs, and 47% with 10 pairs. Within one year, larvae were no longer detected in ditches with 50 or 100 pairs, but numbers began to increase again in ditches with 10 pairs. Before the release, larval densities did not significantly differ among ditches (344 larvae/ditch). In January 2006, mosquito fish collected from nearby sites were released into nine ditches at three densities: 100 pairs (13 fish/m^2), 50 pairs (7 fish/m^2), and 10 pairs (1 fish/m^2). Three ditches without fish served as controls. Mosquito larvae were sampled twice weekly from January 2006 to May 2007 and fortnightly from June 2007 to January 2008. Four samples were taken before releasing fish. Larvae were counted from samples in a laboratory.

(1) Tranchida M.C., Pelizza S.A., Bisaro V., Beltrán C., García J.J. & Micieli M.V. (2010) Use of the neotropical fish *Cnesterodon decemmaculatus* for long-term control of Culex pipiens L. in Argentina. *Biological Control*, 53, 183–187. https://doi.org/10.1016/j.biocontrol.2009.11.006

11. Practitioner insights

Scientific articles can be systematically searched for and cited at a global scale, but the knowledge and experience of conservation practitioners is less easy to access and share. Because of this, practitioner experience might be underutilized in broader conservation strategies. To help address this problem, Conservation Evidence is piloting a practitioner insight database that captures and shares practical knowledge, including novel solutions to conservation problems, practical implementation details, costs, and ecological observations.

Insights are gathered through a range of approaches, including email correspondence and interviews. The information is then transcribed and edited and the final version agreed by the practitioner. Many of the initial insights were gathered by organising a network of practitioners in the Fens in the UK. Three site visits were held with various local land managers, including reserve managers and farmers. The intention of these site visits was for practitioners to share knowledge and experience, ask questions and give advice. Each visit was written up as a report, combining practitioner knowledge with scientific information from the Conservation Evidence website. The reports can be viewed at the following links:

Chippenham Fen: https://doi.org/10.33774/coe-2025-fr522
Lady Fen: https://doi.org/10.33774/coe-2025-8lwnh
Ouse Bridge: https://doi.org/10.33774/coe-2025-5q4d0

The insights below specifically relate to ditches, but the full database can be accessed here: https://shorturl.at/3P75V

This project has been granted ethical permission from the University of Cambridge.

11.1 Re-profiling ditches to create reed beds

At Stodmarsh nature reserve, a 4–5 km stretch of ditches were reprofiled to make them less steep. The ditches were 2-m deep with very steep sides. The reprofiling was done with a tracked 360 excavator. The spoil was then spread with a bulldozer and used to create a shallower profile (1 in 20). This created a gradual transition from wet to dry.

The bulldozed spoil left over from the reprofiling was spread across fields behind the ditch (covering roughly 20% of the 70 ha site). A disc harrow was used to till the soil. The soil was kept damp (but not waterlogged) and the reed rhizomes re-grew. Reed started growing from the rhizomes that spring and within 2 years had generated significant blocks of reedbed.

Source: David Rogers[1], Site Manager, RSPB Lakenheath since 2011 but previously Senior Reserves Manager for Natural England in Kent.

11.2 Using plastic piling to block ditches

Plastic piling could be a cheap and efficient method to block ditches. Unlike wood, you can simply push it into the ground with a digger or hammer it with sledge hammers in small ditches. You don't have to dig a trench and then install and build a structure as you do with wood. It is relatively cheap and light to move around a site.

There are some concerns about micro plastics but the suppliers tell me it is UV stabilised for at least 50 years and in reality, probably much longer.

If buried (as we plan to do) it is rot resistant so can sit in wet soils for a long time. Although, I suppose once the ditch has vegetated over it could be worth pulling them out.

Source: Chris Hainsworth[2], senior reserve manager at Chippenham Fen National Nature reserve.

11.3 Cutting ditches once per year, and only on one side, provides habitat for birds

Before 1980 there were no reed warblers *Acrocephalus scirpaceus*, or other birds, nesting successfully in our main drains (ditches) in Deeping Fen as they were cut twice a year on both sides. Because they were being cut twice a year, I applied to be a member of my local drainage board, the Welland and Deepings Internal Drainage Board. I was accepted on to the board and, though they believed it necessary to cut our main drains twice a year, I eventually persuaded them to only cut them once a year. A few years later I asked the engineer of the board if we could trial only cutting one side of our main drains a year, and he agreed. Therefore, since 1980, we only cut the ditches once per year, and since 1984, we only cut one side of the ditches.

We now have a wildlife corridor for 12 miles, the length of our main drains and that has saved the board at least £500,000 over those years. Reed warblers, sedge warblers *Acrocephalus schoenobaenus* and reed buntings *Emberiza schoeniclus* do nest in them now that they are only mown one side each year, as long as there are common reeds growing. This also attracted cuckoos *Cuculus canorus*. For the last 5 years I have been able to hear and see cuckoos every day on my farms in May and June. This year (2025) the first one arrived on 16th April and the last one left on the 5th July. Furthermore, when a drain is being cut or mown, herons follow the machine and if both sides are being cut and a water vole is disturbed a heron will usually get it but if only one side is being cut the water vole escapes into the side that is not being cut.

In the last two years a lot more of our side drains are now only cut one side each year. Quite simple isn't it, less mowing so less cost and more wildlife.

Source: Nicholas Watts[4], farmer in Lincolnshire since 1964

11.4 Keeping unneeded dykes (drainage ditches) instead of filling them in provides habitat for birds

Unnecessary dykes all over the Fens have been filled in to make larger fields. However, I have resisted making huge fields and so have about 10 dykes which don't get cut very often. I have about 140 pairs of Sedge Warblers and 90 pairs of Reed Warblers claiming territories on my farms in these 10 dykes plus all the other dykes that are only mown one side each year.

Source: Nicholas Watts[4], farmer in Lincolnshire since 1964

11.5 Bird species that nest in farmland ditches and their preferences

The species that nest in our drains and their lifestyles are described below.

Reed Warblers *Acrocephalus scirpaceus*: This is the bird that drainage boards are most likely to get in trouble with for destroying nests. They sing for most of the summer and so people know they are present in our reed fringed drains. Reed warblers only weigh about 15 grams but they fly across the Sahara desert to winter about 10 deg N of the Equator. They arrive back in England during the first two weeks of May to breed in reedbeds and our reed fringed drains. The growing reeds are far more flexible than the previous reed stems and so they like to attach their nest to some of the previous years reeds two or three feet above the water. So, by cutting a drain only one side each year you are providing good nesting habitat for reed warblers. They are double brooded, the first nest will be built in early June and the second nest built in the second half of July. Four eggs is a normal clutch which hatch after being sat on for about 12 days. The young are in the nest for eleven or twelve days. They are normally finished nesting by the middle of August and will spend the next few weeks in the reeds growing and fattening for their long journey south.

Sedge Warblers *Acrocephalus schoenobaenus*: Sedge warblers are about the same size as a reed warbler. They migrate to warmer climes in the winter but stay in North Africa. They nest in more tangled vegetation than reed warblers, second or third year reeds or even brambles, arriving with us in April, starting to nest in the second half of May and laying 5 or 6 eggs and the second clutch normally finished by the end of July. They do not nest in drains or dykes that are mown every year, their preferred habitat is a drain or dyke that hasn't been mown for several years and ideally with a few brambles growing in it. Like the reed warbler they are double brooded but normally lay 5 or even 6 eggs and they start nesting about 2 or 3 weeks earlier than reed warblers and have finished nesting by the end of July.

Reed Buntings *Emberiza schoeniclus*: Reed buntings are resident in the British Isles, they can be seen singing from the top of bushes or reeds with their black heads from early April. Like other buntings they do not help their partners very much in raising their families, they seem to need to keep singing most of the summer to protect their territory. Like the sedge warblers, they need tangled vegetation to nest in, again they are double brooded, the first brood starts in early May and the second brood is finished by the end of July.

Mallard *Anas platyrhynchos*: Mallard are one of our earliest nesting birds, they normally start nesting in February and rely on last years unmown vegetation to hide themselves and their nests. They will nest up to 200 meters away from water so do not have to rely on vegetation on drain sides to hide their nest. The ducklings rely on insects and so those early broods as well often fail because of a lack of insects. They will continue to nest right up to July or August if they fail to rear young.

Tufted ducks *Aythya fuligula*: Tufted ducks, unlike mallard, do not start nesting until the end of May. They like a larger watercourse to nest in or next to than mallard, but as they like larger watercourses pike *Esox* spp. often get their ducklings. They hide their nests in last years vegetation close to the waters edge. Their ducklings feed on insects as other ducklings do

Moorhen *Gallinula chloropus*: A bird that used to be seen on every pond and watercourse. They like to build their nest in reeds or brambles over the water away from foxes, stoats and weasels. Those places are not available in well managed IDB drains, therefore they have to nest in the drain sides in last years vegetation but they won't nest until they can hide their nest successfully somewhere so maybe they have declined because in many places they would not be able to nest until June or July. In good habitat they will start to nest in March. They have been in steady decline for the last 50 years partly because of loss of habitat and more recently because there are more crows and magpies around that would take their eggs.

Coot *Fulica atra*: Will only be nesting on our larger watercourses and, like moorhens, like to build their nest in vegetation over water. They are more likely to be found on drains or rivers controlled by the EA where the vegetation is not normally cut. If there is plenty of food around will start nesting in March and continue to produce broods right through the summer. They have also declined over the years because of loss of habitat and also because of the increase of carrion crows which would take their eggs.

Source: Nicholas Watts[5], farmer in Lincolnshire since 1964

(1) Rogers, D. (2024). Reprofiling ditches to create a shallow slope. Conservation Practitioner Insight Database 10.

(2) Hainsworth, C. (2024). Using plastic piling to block ditches. Conservation Practitioner Insight Database 15.

(3) Watts, W. (2025). Cutting ditches once per year, and only on one side, provides habitat for birds. Conservation Practitioner Insight Database 16.

(4) Watts, W. (2025). Keeping unneeded dykes (drainage ditches) provides habitat for birds. Conservation Practitioner Insight Database 18.

(5) Watts, W. (2025). Bird species that nest in farmland ditches and their preferences. Conservation Practitioner Insight Database 19.

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*Anon (2007) Wetting up farmland for birds and other biodiversity, Defra Report BD1323.

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Appendix 1: English journals searched

All English journals (and years) searched for the discipline-wide Conservation Evidence database (339 journals)

Journal	Years searched	Topic
Acrocephalus	2009-2018	All biodiversity
Acta Chiropterologica	1999-2019	All biodiversity
Acta Herpetologica	2006-2018	All biodiversity
Acta Oecologica	1990-2018	All biodiversity
Acta Theriologica	1977-2000	All biodiversity
African Bird Club Bulletin	1994-2017	All biodiversity
Aquatic Journal of African Science	2000-2022	All biodiversity
African Journal of Aquatic Science	2000-2022	All biosiversity
African Journal of Ecology	1963-2016	All biodiversity
African Journal of Herpetology	1990-2018	All biodiversity
African Journal of Marine Science	1983-2018	All biodiversity
African Primates	1995-2012	All biodiversity
African Sea Turtle Newsletter	2014-2018	All biodiversity
African Zoology	1979-2013	All biodiversity
Agriculture, Ecosystems & Environment	1983-2024	All biodiversity
Ambio	1972-2019	All biodiversity
American Journal of Primatology	1981-2019	All biodiversity
American Naturalist	1867-2019	All biodiversity
Amphibia-Reptilia	1980-2018	All biodiversity
Amphibian & Reptile Conservation	1996-2018	All biodiversity
Animal Biology	2003-2013	All biodiversity
Animal Conservation	1998-2021	All biodiversity
Animal Nutrition	2015-2019	All biodiversity
Animal Welfare	1992-2019	All biodiversity
Animals	2011-2019	All biodiversity
Annales Zoologici Fennici	1964-2013	All biodiversity
Annales Zoologici Societatis Zoologicae Botanicae Fennicae Vanamo	1932-1963	All biodiversity
Annual Review of Ecology, Evolution, and Systematics (formerly Annual Review of Ecology and Systematics 1970-2002)	1970-2021	All biodiversity
Annual Review of Entomology	2000-2019	All biodiversity
Antarctic Science	1980-2018	All biodiversity
Anthrozoos	1987-2019	All biodiversity
Apidologie	1958-2009	All biodiversity
Applied Animal Behaviour Science	1984-2019	All biodiversity

Applied Herpetology	2003-2009	All biodiversity
Applied Vegetation Science	1998-2017	All biodiversity
Aquarium Sciences and Conservation	1997-2001	All biodiversity
Aquatic Biology	2007-2023	All biodiversity
Aquatic Botany	1975-2022	All biodiversity
Aquatic Conservation: Marine and Freshwater Ecosystems	1991-2023	All biodiversity
Aquatic Ecology	1968-2023	All biodiversity
Aquatic Ecosystem Health and Management	1998-2023	All biodiversity
Aquatic Invasions	2006-2023	All biodiversity
Aquatic Living Resources	1988-2023	All biodiversity
Aquatic Mammals	1972-2018	All biodiversity
Aquatic Sciences	2022-2023	All biodiversity
Arid Land Research and Management (formerly Arid Soil Research and Rehabilitation 1987-2000)	1987-2022	All biodiversity
Asian Herpetological Research	2010-2018	All biodiversity
Asian Primates	2008-2012	All biodiversity
Asiatic Herpetological Research	1993-2008	All biodiversity
Auk	1980-2016	All biodiversity
Austral Ecology	1977-2019	All biodiversity
Austral Entomology	2014-2019	All biodiversity
Australasian Journal of Herpetology	2009-2012	All biodiversity
Australian Mammalogy	2000-2019	All biodiversity
Avian Conservation and Ecology	2005-2016	All biodiversity
Basic & Applied Herpetology	2011-2018	All biodiversity
Basic and Applied Ecology	2000-2021	All biodiversity
Behavioral Ecology	1990-2013	All biodiversity
Behaviour	1948-2013	All biodiversity
Biawak	2001-2017	All biodiversity
Bibliotheca Herpetologica	1999-2017	All biodiversity
BioControl (formerly Entomophaga until 1998)	1956-2016	All biodiversity
Biocontrol Science and Technology	1991-1996	All biodiversity
Biodiversity	2000-2019	All biodiversity
Biodiversity and Conservation	1994-2021	All biodiversity
Biological Conservation	1981-2023	All biodiversity
Biological Control	1991-2017	All biodiversity
Biological Invasions	1999-2023	All biodiversity
Biology and Environment: Proceedings of the Royal Irish Academy	1993-2017	All biodiversity
Biology Letters	2005-2018	All biodiversity
Biotropica	1990-2019	All biodiversity
Bird Conservation International	1991-2016	All biodiversity

Bird Study	1980-2016	All biodiversity
Boreal Environment Research	1996-2014	All biodiversity
Bulletin of Marine Science	2000-2020	All biodiversity
Bulletin of the Chicago Herpetological Society	1990-2018	All biodiversity
Bulletin of the Maryland Herpetological Society	1980-2015	All biodiversity
Canadian Journal of Fisheries & Aquatic Sciences	1901-2023	All biodiversity
Canadian Journal of Forest Research	1971-2018	All biodiversity
Caribbean Herpetology	2010-2018	All biodiversity
Caribbean Journal of Science	1961-2013	All biodiversity
CCAMLR Science	1985-2016	All biodiversity
CEE (Collaboration for Environmental Evidence) Systematic Reviews	2004-2016	All biodiversity
Chelonian Conservation and Biology	1993-2018	All biodiversity
Chelonian Research Monographs	1996-2017	All biodiversity
Coastal Engineering	2000-2018	All biodiversity
Collinsorum (formerly Journal of Kansas Herpetology)	2012-2018	All biodiversity
Colonial Waterbirds	1983-1998	All biodiversity
Community Ecology	2000-2012	All biodiversity
Conservation Biology	1987-2021	All biodiversity
Conservation Evidence	2004-2024	All biodiversity
Conservation Genetics	2000-2013	All biodiversity
Conservation Letters	2008-2021	All biodiversity
Contemporary Herpetology	1998-2009	All biodiversity
Contributions to Primatology	1974-1991 (final published volume)	All biodiversity
Coral Reefs	2000-2020	All biodiversity
Cunninghamia	1981-2016	All biodiversity
Current Herpetology (formerly Acta Herpetologica Japonica 1964-1971 and Japanese Journal of Herpetology 1972-1999)	1964-2022	All biodiversity
Dodo	1977-2001	All biodiversity
Ecological and Environmental Anthropology	2005-2008	All biodiversity
Ecological Applications	1991-2022	All biodiversity
Ecological Engineering	2014-2023	All biodiversity
Ecological Entomology	1985-2018	All biodiversity
Ecological Indicators	2001-2007	All biodiversity
Ecological Management & Restoration	2000-2019	All biodiversity
Ecological Restoration	1981-2021	All biodiversity
Ecological Solutions and Evidence (BES)	2020-2021	All biodiversity
Ecology	1936-2021	All biodiversity
Ecology of Freshwater Fish	1992-2023	All biodiversity

Ecology Letters	1998-2019	All biodiversity
Ecosystems	1998-2013	All biodiversity
Emu	1980-2016	All biodiversity
Endangered Species Bulletin	1966-2003	All biodiversity
Endangered Species Research	2004-2019	All biodiversity
Entomologia Experimentalis et Applicata	2015-2018	All biodiversity
Environmental Biology of Fishes	2014-2023	All biodiversity
Environmental Conservation	1974-2021	All biodiversity
Environmental Entomology	1990-2018	All biodiversity
Environmental Evidence	2012-2021	All biodiversity
Environmental Management	1977-2021	All biodiversity
Environmentalist	1981-1988	All biodiversity
Estuaries and Coasts	2013-2022	All biodiversity
Ethology Ecology & Evolution	1989-2014	All biodiversity
European Journal of Soil Science	1950-2012	Soil Fertility
European Journal of Wildlife Research (formerly Zeitschrift für Jagdwissenschaft 1955-2003)	2004-2021	All biodiversity
Evolutionary Anthropology	1992-2014	All biodiversity
Evolutionary Ecology	1987-2014	All biodiversity
Evolutionary Ecology Research	1999-2014	All biodiversity
Fire Ecology	2005-2016	All biodiversity
Fisheries	2017-2023	All biodiversity
Fish & Fisheries	2000-2023	All biodiversity
Fisheries Management & Ecology	1990-2023	All biodiversity
Fisheries Oceanography	1992-2018	All biodiversity
Fisheries Research	1990-2023	All biodiversity
Fisheries Science	2014-2023	All biodiversity
Flora	1991-2017	All biodiversity
Folia Primatologica	1963-2014	All biodiversity
Folia Zoologica	1959-2013	All biodiversity
Forest Ecology and Management	1976-2019	All biodiversity
Freshwater Biology	1975-2022	All biodiversity
Freshwater Science (formerly Freshwater Invertebrate Biology; then Journal of the North American Benthological Society)	1982-2023	All biodiversity
Frontiers in Marine Science	2017-2018	All biodiversity
Frontiers in Psychology	2019	All biodiversity
Functional Ecology	1987-2013	All biodiversity
Genetics and Molecular Research	2002-2013	All biodiversity
Geoderma	1967-2012	Soil Fertility
Gibbon Journal	2005-2011	All biodiversity
Global Change Biology	1995-2017	All biodiversity

Global Ecology and Biogeograph	1991-2014	All biodiversity
Global Ecology and Conservation	2014-2018	All biodiversity
Grass and Forage Science	1980-2017	All biodiversity
Herpetofauna	2003-2007	All biodiversity
Herpetologica	1936-2018	All biodiversity
Herpetological Conservation and Biology	2006-2018	All biodiversity
Herpetological Monographs	1982-2018	All biodiversity
Herpetological Review	1967-2018	All biodiversity
Herpetology Notes	2008-2018	All biodiversity
Herpetozoa	1988-2018	All biodiversity
Human Wildlife Interactions	2007-2021	All biodiversity
Hydrobiologia*	2000-2018	All biodiversity
Hystrix, the Italian Journal of Mammalogy (English, 1994-)	1994-2019	All biodiversity
Ibis	1980-2016	All biodiversity
ICES Journal of Marine Science	1990-2018	All biodiversity
iForest	2008-2016	All biodiversity
Ichthyology & Herpetology (formerly Copeia)	1910-2023	All biodiversity
Ichthyological Exploration of Freshwaters	2014-2023	All biodiversity
Inland Waters	1969-2022	All biodiversity
Insect Conservation and Diversity	2008-2018	All biodiversity
Integrative Zoology	2006-2013	All biodiversity
International Journal of Pest Management (formerly PANS Pest Articles & News Summaries 1969 - 1975, PANS 1976-1979 & Tropical Pest Management 1980-1992)	1969-1979	All biodiversity
International Journal of Primatology	1980-2019	All biodiversity
International Journal of the Commons	2007-2016	All biodiversity
International Journal of Wildland Fire	1991-2016	All biodiversity
International Wader Studies	1970-1972	All biodiversity
International Zoo Yearbook	1960-2019	All biodiversity
Invasive Plant Science and Management	2008-2016	All biodiversity
Israel Journal of Ecology & Evolution	1963-2013	All biodiversity
Italian Journal of Zoology	1978-2013	All biodiversity
Journal for Nature Conservation	2002-2021	All biodiversity
Journal of Animal Ecology	1932-2021	All biodiversity
Journal of Apicultural Research	1962-2009	All biodiversity
Journal of Applied Animal Nutrition	2012-2019	All biodiversity
Journal of Applied Animal Welfare Science	1998-2019	All biodiversity
Journal of Applied Ecology	1964-2021	All biodiversity
Journal of Applied Ichthyology	2014-2023	All biodiversity
Journal of Aquatic Plant Management (formerly Hyacinth Control Journal 1962-1975)	1962-2022	All biodiversity
Journal of Aquatic Sciences	2014-2022	All biodiversity

Journal of Arid Environments	1993-2017	All biodiversity
Journal of Avian Biology (formerly Ornis Scandinavica 1970-1993)	1994-2016	All biodiversity
Journal of Cetacean Research and Management	1999-2018	All biodiversity
Journal of Coastal Research	2015-2018	All biodiversity
Journal of Ecology	1933-2021	All biodiversity
Journal of Ecology & Natural Resources	2017-2019	All biodiversity
Journal of Environmental Management	1973-2021	All biodiversity
Journal of Experimental Marine Biology and Ecology	2000-2018	All biodiversity
Journal of Field Ornithology	1980-2016	All biodiversity
Journal of Fish and Wildlife Management	2014-2023	All biodiversity
Journal of Fish Biology	2013-2023	All biodiversity
Journal of Forest Research	1996-2019	All biodiversity
Journal of Freshwater Ecology	2014-2023	All biodiversity
Journal of Great Lakes Research	1975-2017	All biodiversity
Journal of Herpetological Medicine and Surgery	2009-2018	All biodiversity
Journal of Herpetology	1968-2018	All biodiversity
Journal of Insect Conservation	1997-2018	All biodiversity
Journal of Insect Science	2003-2018	All biodiversity
Journal of Kansas Herpetology	2002-2018	All biodiversity
Journal of Mammalian Evolution	1993-2014	All biodiversity
Journal of Mammalogy	1919-2019	All biodiversity
Journal of Mountain Science	2004-2016	All biodiversity
Journal of Negative Results: Ecology & Evolutionary Biology	2004-2016	All biodiversity
Journal of North American Herpetology	2014-2017	All biodiversity
Journal of Ornithology (formerly Journal für Ornithologie to 2004)	2004-2018	All biodiversity
Journal of Primatology	2012-2013	All biodiversity
Journal of Range Management	1948-2004	All biodiversity
Journal of Raptor Research	1966-2016	All biodiversity
Journal of Sea Research (formerly Netherlands Journal of Sea Research)	1961-2018	All biodiversity
Journal of the Marine Biological Association of the United Kingdom	1887-2018	All biodiversity
Journal of Tropical Ecology	1986-2021	All biodiversity
Journal of Vegetation Science	1990-2017	All biodiversity
Journal of Wetlands Ecology	2008-2020	All biodiversity
Journal of Wetlands Environmental Management	2012-2022	All biodiversity
Journal of Wildlife Diseases	1965-2012	All biodiversity
Journal of Zoo and Aquarium Research	2013-2019	All biodiversity
Journal of Zoo and Wildlife Medicine	1970-2019	All biodiversity

Journal of Zoology	1966-2021	All biodiversity
Kansas Herpetological Society Newsletter	1974-2001	All biodiversity
Knowledge and Management of Aquatic Ecosystems	2008-2023	All biodiversity
Lake and Reservoir Management	1984 -2023	All biodiversity
Lakes & Reservoirs: Science, Policy and Management for Sustainable Use (formerly Lakes & Reservoirs: Research and Management)	2016-2022	All biodiversity
Land Degradation and Development	1989-2016	All biodiversity
Land Use Policy	1984-2012	Soil Fertility
Latin American Journal of Aquatic Mammals	2002-2018	All biodiversity
Lemur News	1993-2012	All biodiversity
Limnologica - Ecology and Management of Inland Waters	1999-2023	All biodiversity
Mammal Research (formerly Acta Theriologica)	2001-2019	All biodiversity
Mammal Review	1970-2019	All biodiversity
Mammal Study	2005-2019	All biodiversity
Mammalia	1937-2019	All biodiversity
Mammalian Biology	2002-2019	All biodiversity
Mammalian Genome	1991-2013	All biodiversity
Management of Biological Invasions	2010-2016	All biodiversity
Mangroves and Salt Marshes	1996-1999	All biodiversity
Marine and Freshwater Research	1980-2023	All biodiversity
Marine Ecology	1980-2018	All biodiversity
Marine Ecology Progress Series	2000-2018	All biodiversity
Marine Environmental Research	1978-2018	All biodiversity
Marine Mammal Science	1985-2019	All biodiversity
Marine Pollution Bulletin	2010-2018	All biodiversity
Marine Turtle Newsletter	1976-2018	All biodiversity
Marsh Bulletin	1992-2017	All biodiversity
Mesoamerican Herpetology	2014-2017	All biodiversity
Mires and Peat	2006-2016	All biodiversity
Natural Areas Journal	1992-2017	All biodiversity
Nature Conservation	2012-2019	All biodiversity
NeoBiota	2011-2017	All biodiversity
Neotropical Entomology	2004-2018	All biodiversity
Neotropical Ichthyology	2014-2023	All biodiversity
Neotropical Primates	1993-2014	All biodiversity
New Journal of Botany	2011-2017	All biodiversity
New Zealand Journal of Marine and Freshwater Research	1967-2022	All biodiversity
New Zealand Journal of Zoology	1974-2021	All biodiversity
New Zealand Plant Protection	2000-2022	All biodiversity
North American Journal of Fisheries Management	1994-2023	All biodiversity
Northwest Science	2007-2016	All biodiversity

Oecologia	1969-2021	All biodiversity
Oikos	1949-2021	All biodiversity
Ornis Scandinavica	1980-1993	All biodiversity
Ornitologi-a Neotropical	1990-2018	All biodiversity
Oryx	1950-2021	All biodiversity
Ostrich	1980-2016	All biodiversity
Pacific Conservation Biology	1993-2021	All biodiversity
Pakistan Journal of Zoology	2004-2013	All biodiversity
Phyllomedusa	2002-2018	All biodiversity
Plant Ecology (formerly Vegetatio 1948-1996)	1948-2007	All biodiversity
Plant Protection Quarterly	2008-2016	All biodiversity
Polish Journal of Ecology	2002-2013	All biodiversity
Population Ecology	1952-2013	All biodiversity
Preslia	1973-2017	All biodiversity
Primate Conservation	1981-2014	All biodiversity
Primates	1957-2013	All biodiversity
Rangeland Ecology & Management (previously Journal of Range Management 1948-2004)	2005-2016	All biodiversity
Raptors Conservation	2005-2016	All biodiversity
Regional Studies in Marine Science	2015-2018	All biodiversity
Reptile Rap - Newsletter of the South Asian Reptile Network (SARN)	1999-2016	All biodiversity
Restoration Ecology	1993-2021	All biodiversity
Riparian Ecology and Conservation	2013-2017	All biodiversity
River Research and Applications	1987-2023	All biodiversity
Russian Journal of Ecology (Springer - translated version)	1993-2013	All biodiversity
Russian Journal of Herpetology	1994-2018	All biodiversity
Russian Journal of Theriology	1988-2017	All biodiversity
Salamandra (English 2005+)	2005-2018	All biodiversity
Slovak Raptor Journal	2007-2016	All biodiversity
Small Ruminant Research	1988-2017	All biodiversity
Soil Biology & Biochemistry	1969-2012	Soil Fertility
South African Journal of Botany	1982-2018	All biodiversity
South African Journal of Wildlife Research	1971-2014	All biodiversity
South American Journal of Herpetology	2006-2018	All biodiversity
Southern Forests	2008-2018	All biodiversity
Testudo	1978-2017	All biodiversity
The Canadian Field-Naturalist (formerly Ottawa Naturalist)	1887-2019	All biodiversity
The Condor	1980-2009	All biodiversity
The Herpetological Bulletin	2008-2018	All biodiversity
The Herpetological Journal	1985-2016	All biodiversity

The Journal of Wildlife Management	1945-2021	All biodiversity
The Open Ornithology Journal	2008-2016	All biodiversity
The Rangeland Journal	1976-2016	All biodiversity
The Southwestern Naturalist	1956-2018	All biodiversity
The Wilson Bulletin	1980-2005	All biodiversity
The Wilson Journal of Ornithology (formerly The Wilson Bulletin)	2006-2016	All biodiversity
Transactions of the American Fisheries Society	2014-2023	All biodiversity
Trends in Ecology and Evolution	1986-2021	All biodiversity
Tropical Conservation Science	2008-2018	All biodiversity
Tropical Ecology	1960-2018	All biodiversity
Tropical Grasslands	1967-2010	All biodiversity
Tropical Zoology	1988-2018	All biodiversity
Turkish Journal of Zoology	1996-2014	All biodiversity
Ursus	1968-2019	All biodiversity
Vietnamese Journal of Primatology	2007-2009	All biodiversity
Wader Study Group Bulletin	1970-1977	All biodiversity
Waterbirds (formerly Colonial Waterbirds)	1999-2016	All biodiversity
Weed Biology and Management	2001-2016	All biodiversity
Weed Research	1961-2017	All biodiversity
West African Journal of Applied Ecology	2000-2016	All biodiversity
West African Journal of Fisheries and Aquatic Sciences	2020-2022	All biodiversity
Western North American Naturalist	2000-2016	All biodiversity
Wetlands	1981-2023	All biodiversity
Wetlands Ecology and Management	1989-2023	All biodiversity
Wildfowl	1948-2018	All biodiversity
Wildlife Biology	1995-2013	All biodiversity
Wildlife Monographs	1958-2013	All biodiversity
Wildlife Research	1956-2012	Bat Conservation
Wildlife Research	1974-2019	All biodiversity
Wildlife Society Bulletin	1973-2019	All biodiversity
Zhurnal Obshchei Biologii	1972-2013	All biodiversity
Zoo Biology	1982-2019	All biodiversity
ZooKeys	2008-2013	All biodiversity
Zoologica Scripta	1971-2014	All biodiversity
Zoological Journal of the Linnean Society	1856-2013	All biodiversity
Zootaxa	2004-2014	All biodiversity

Appendix 2: Non-English journals searched

All non-English journals (and years) searched for the discipline-wide Conservation Evidence database (334 journals in 17 languages)

Journal	Years searched	Language
Journal of Agricultural, Environmental and Veterinary Sciences مجلة العلوم الزراعية والبيئية والبيطرية	2018-2020	Arabic
Journal of Thi-Qar Science مجلة علوم ذي قار	2014-2018	Arabic
Journal of Marine Sciences and Environmental Techniques مجلة علوم البحار والتقنيات البيئية	2016-2019	Arabic
Journal of King Abdulaziz University: Environmental Design Science مجلة جامعة الملك عبد العزيز: علوم تصاميم البيئة	2003-2017	Arabic
Journal of King Abdulaziz University: Marine Sciences مجلة جامعة الملك عبدالعزيز: علوم البحار	2000-2018	Arabic
Afak Ilmia Journal مجلة آفاق علمية	2017-2020	Arabic
The Arab Journal for Arid Environments المجلة العربية للبيئات الجافة	2009-2018	Arabic
Baghdad Science Journal مجلة بغداد للعلوم	2004-2020	Arabic
Tishreen University Journal for Research and Scientific Studies: Biological Sciences Series مجلة جامعة تشرين للبحوث والدراسات العلمية _ سلسلة العلوم البيولوجية	2001-2020	Arabic
Journal of Plant Protection مجلة وقاية النبات العربية	1993-2019	Arabic
Journal of King Abdulaziz University: Economics and Administration مجلة جامعة الملك عبدالعزيز: الاقتصاد والإدارة	2015-2020	Arabic
Marsh Bulletin مجلة الاهوار	2010-2020	Arabic
Revue d'Écologie (La Terre et La Vie) Earth and Life	2006-2018	French
Bulletin de la Société Zoologique de France Bulletin of the French Zoology Society	1973-2015	French
Bulletin Français de la Pêche et de la Pisciculture French Bulletin of Fishing and Aquaculture	1986-2007	French
Courrier Scientifique du Parc Naturel Régional du Luberon et de la Réserve de Biosphère Luberon-Lure Scientific Letters from the Regional Natural Park of Luberon and the Biosphere Reserve Luberon-Lure	1997-2016	French
Le Naturaliste Canadien The Canadian Naturalist	2008-2018	French
VertigO	2009-2019	French

Biotechnologie, Agronomie, Société et Environnement Biotechnology, Agronomy, Society and Environment	2008-2020	French
Écoscience Ecoscience	1994-2019	French
Bois et Forêts des Tropiques Tropical Woodlands and Forests	2009-2020	French
Alauda	2000-2005	French
Ecologia Mediterranea Ecologia Mediterranea: International Journal of Mediterranean Ecology	2000-2019	French
Travaux Scientifiques du Parc National de Port-Cros Scientific Reports of the Port-Cros National Park	2000-2019	French
Travaux Scientifiques du Parc National de la Vanoise Scientific Reports of the Vanoise National Park	1986-2009	French
Naturae	2017-2020	French
Die Orchidee The Orchid	1949-2016	German
Mertensiella	1988-2017	German
Die Erde The Earth	1952-2004	German
Journal für Ornithologie (German: up to 2004) Journal of Ornithology (German: up to 2004)	1959-2003	German
Mitteilungen des Badischen Landesvereins für Naturkunde und Naturschutz Communications of the Baden Association for Natural History and Nature Conservation	1953-2015	German
Die Vogelwelt: Beiträge zur Vogelkunde Bird Life: Contributions to Ornithology	2005-2017	German
Zeitschrift für Jagdwissenschaft Journal of Hunting Science [Became European Journal of Wildlife Research (Springer) in 2004]	1955-2003	German
Freiberg Online Geoscience - FOG	1998-2017	German
Gesunde Pflanzen: Pflanzenschutz, Verbraucherschutz, Umweltschutz Healthy Plants: Crop Protection, Consumer Protection, Environment Protection	2002-2017	German
Vogelwarte: Zeitschrift für Vogelkunde Bird Observatory: Ornithology Journal	2005-2017	German
Die Bodenkultur: Journal of Land Management, Food and Environment Soil Culture: Journal for Land Management, Food and Environment	2016-2017	German
Waldökologie Online (until 2008) Forest Ecology Online	2004-2008(6)	German
RANA - Mitteilungen für Feldherpetologie und Ichthyofaunistik RANA - Communications for Field Herpetology and Ichthyofauna	Vol1(1983)-Vol17(2016) excluding special issues	German
Telma	1971-2019	German

Auenmagazin (Magazin des Auenzentrums Neuburg a. d. Donau) Floodplains Journal (Magazine of the Auenzentrums Neuburg a. d. Danube)	2010-2017	German
Biodiversität und Naturschutz in Ostösterreich Biodiversity and Conservation in Eastern Austria	2015-2018	German
The Bird Fauna Die Vogelwelt	2005-2017	German
Salamandra (German 1965-2004)	1965-2004	German
Insecta	1992-2014	German
Natur und Landschaft: Zeitschrift fur Naturschutz und Landschaftspflege Nature and Landscape: Journal for Nature Conservation and Landscape Management	1990-2017	German
Bulletin de la Société des Naturalistes Luxembourgeois Bulletin of the Luxemburgian Naturalist Society	1950-2017	German
Tuexenia	1981-2016	German
Forstarchiv Forestry Archive	2007-2017	German
Zeitschrift für Feldherpetologie Journal for Field Herpetology	1994-2017	German
Naturschutz und Landschaftsplanung Conservation and Landscape Planning	2003-2017	German
Arachnologische Mitteilungen Arachnological Letters	1991-2017	German
Fachzeitschrift für Waldökologie, Landschaftsforschung und Naturschutz (formerly Waldökologie Online) Journal for Forest Ecology, Landscape Research and Nature Conservation	2008-2016	German
Silva Fera: Wissenschaftliche Nachrichten aus dem Wildnisgebiet Dürrenstein Silva Fera: Scientific News from the Dürrenstein Wilderness Area	2012-2017	German
Inatura Forschung Online Inatura Research Online	1996-2007	German
ABU-Info (Arbeitsgemeinschaft Biologischer Umweltschutz im Kreis Soest e.V.) ABU-Info (Working Group for Biological Environmental Protection in Soest District	2006-2017	German
Libellula	1982-2016	German
Der Zoologische Garten: Zeitschrift für die Gesamte Tiergärtnerei (Neue Folge) The Zoological Garden: Journal for the Entire Zoo	2007-2017	German
Pulsatilla: Zeitschrift für Botanik und Naturschutz Pulsatilla: Journal of Botany and Nature Conservation	2000-2007	German
Hercynia	1963-2017	German
Der Ornithologische Beobachter Ornithological Observer	1950-2017	German

Allgemeine Forst- und Jagdzeitung Journal for Forestry and Forest Science	2000-2016	German
Nyctalus: Internationale Fledermaus-Fachzeitschrift Nyctalus: International Bat Journal	2005-2017	German
Ornithologischer Anzeiger Ornithological Journal	1951-2017	German
Archiv für Forstwesen und Landschaftsökologie Archive for Forestry and Landscape Ecology	2013	German
Botanik und Naturschutz in Hessen Botany and Nature Conservation in Hessen	1987-2018	German
ANLiegen Natur: Zeitschrift für Naturschutz und Angewandte Landschaftsökologie Concerning Nature: Journal for Nature Conservation and Applied Landscape Ecology	2006-2017	German
Természetvédelmi Közlemények Journal of Nature Conservation	2010-2019	Hungarian
Állattani Közlemények Journal of Zoology	2010-2019	Hungarian
Tájökológiai Lapok Journal of Landscape Ecology	2010-2019	Hungarian
Botanikai Közlemények Journal of Botany	2010-2020	Hungarian
Jurnal Primatologi Indonesia	2009	Indonesian
Avocetta	2000-2013	Italian
Rivista Italiana di Ornitologia Research in Ornithology	2010-2019	Italian
Picus	2004-2018	Italian
Forest@ - Rivista di Selvicoltura ed Ecologia Forestale Forest @ - Journal of Silviculture and Forest Ecology	2004-2020	Italian
Alula Alula	1992-2019	Italian
Biologia Ambientale Environmental Biology	1994-2018	Italian
Hystrix, the Italian Journal of Mammalogy (Italian 1986-1993)	1986-1993	Italian
Japanese Journal of Ornithology 日本鳥学会誌	1917-2015	Japanese
Mammalian Science 哺乳類科学	1961-2016	Japanese
Journal of the Japanese Forest Society (2005+) 日本森林学会誌	2005-2017	Japanese
The Journal of the Japanese Landscape Architectural Society 造園学雑誌	1925-1927	Japanese
Landscape Ecology and Management 景観生態学	2005-2016	Japanese
Japanese Journal of Ecology 日本生態学会誌	1954-2017	Japanese

Wildlife Conservation Japan 野生生物保護	1995-2013	Japanese
Doubutsugaku zasshi 動物学雑誌	1888-1983	Japanese
Bulletin of the Herpetological Society of Japan 爬虫両棲類学会報	1999-2008	Japanese
Landscape Research Japan Online ランドスケープ研究(オンライン論文集)	2008-2017	Japanese
Journal of the Japanese Institute of Landscape Architects (1934-1994) 造園雑誌	1934-1994	Japanese
Wildlife and Human Society 野生生物と社会	2013-2017	Japanese
Ecology and Civil Engineering 応用生態工学	1998-2017	Japanese
Japanese Journal of Conservation Ecology 保全生態学研究	1996-2016	Japanese
Journal of the Mammalogical Society of Japan 哺乳動物学雑誌	1959-1986	Japanese
Journal of the Japanese Institute of Landscape Architecture (1994+) ランドスケープ研究	1994-2017	Japanese
Reintroduction 野生復帰	2011-2019	Japanese
Bulletin of the International Association for Landscape Ecology-Japan 国際景観生態学会日本支部会報	2002-2003	Japanese
Strix ストリクス	1982-2017	Japanese
Journal of the Japanese Forestry Society (1919-2004) 日本林学会誌	1985-2004	Japanese
Nippon Suisan Gakkaishi (Japanese edition) 日本水産学会誌 / Journal of the Japanese Society of Fisheries Science	2013-2023	Japanese
Korean Journal of Environmental Biology 환경생물	2002-2020	Korean
Korean Journal of Environment and Ecology 한국환경생태학회지	2001-2020	Korean
Journal of Wetlands Research 한국습지학회지	1999-2020	Korean
Korean Journal of Ornithology 한국조류학회지	1994-2020	Korean
Journal of Korean Society of Forest Science 한국산림과학회지(한국임학회지)	2002-2020	Korean
Iranian Journal of Natural Resources مجله منابع طبیعی ایران	2002-2009	Persian

Journal of Environmental Studies محیط شناسی	2009-2017	Persian
Journal of Natural Environment نشریه محیط زیست طبیعی	2010-2017	Persian
Environmental Researches پژوهش های محیط زیست	2010-2017	Persian
Experimental Animal Biology زیست شناسی جانوری تجربی	2012-2017	Persian
Journal of Animal Researches پژوهش های جانوری	2013-2017	Persian
Journal of Environmental Sciences علوم محیعلوم محیطیطی	2004-2017	Persian
Iranian Journal of Applied Ecology بوم شناسی کاربردی	2012-2017	Persian
Journal of Animal Environment فصلنامه محیط زیست جانوری	2014-2017	Persian
Parki Narodowe i Rezerwaty Przyrody National Parks and Nature Reserves	2009-2015	Polish
Chrońmy Przyrodę Ojczystą Let's Protect Our Indigenous Nature	2004-2019	Polish
Ornis Polonica	2010-2020	Polish
Nature Conservation (English language Vol58 2001+; formerly in Polish as Ochrona Przyrody 1920-2000)	2001-2008	Polish
Studia Naturae Studia Naturae / Nature Studies	1987-2013	Polish
Notatki Ornitologiczne Ornithological Notes	1989-2009	Polish
Przegląd Przyrodniczy Nature Review	2010-2019	Polish
Naturalia	2012-2016	Polish
Nietoperze Bats	2000-2011	Polish
Kulon Stone Curlew	1996-2018	Polish
Biodiversidade Brasileira Brazilian Biodiversity	2011-2016	Portuguese
Revista de Gestão Costeira Integrada Journal of Integrated Coastal Zone Management	2007-2019	Portuguese
Arquipelago - Life and Marine Sciences	1980-2020	Portuguese
Ambiência	2005-2019	Portuguese
Evolução e Conservação da Biodiversidade Evolution and Conservation of Biodiversity	2010-2011	Portuguese
Megadiversidade Megadiversity	2005-2009	Portuguese
Revista Brasileira de Gestão Ambiental e Sustentabilidade The Brazilian Journal of Environmental Management and Sustainability	2014-2017	Portuguese
Acta Amazônica Amazon Record/Journal	1971-2019	Portuguese

Chiroptera Neotropical Neotropical Chiroptera	1995-2015	Portuguese
MG Biota	2008-2016	Portuguese
Revista Nordestina de Biologia Northeastern Journal of Biology	1978-2016	Portuguese
Bioikos	1987-2016	Portuguese
Portugaliae Acta Biologica	2000-2003	Portuguese
FLORAM - Revista Floresta e Ambiente Brazilian Journal of Forestry and Environment	1994-2020	Portuguese
Biotemas	1988-2018	Portuguese
Iheringia: Série Zoologia Iheringia: Zoology Series	2000-2018	Portuguese
Revista CEPSUL - Biodiversidade e Conservação Marinha CEPSUL Magazine - Marine Biodiversity and Conservation	2010-2017	Portuguese
Natureza & Conservação Brazilian Journal of Nature Conservation	2003-2009	Portuguese
Neotropical Biology and Conservation	2006-2017	Portuguese
Ciência & Ambiente Science and Environment	1990-2015	Portuguese
Revista de Biologia Neotropical Journal of Neotropical Biology	2004-2018	Portuguese
Revista de Ciências Agrárias (SCAP) Journal of Agricultural Sciences (SCAP)	2007-2019	Portuguese
Biodiversidade (UFMT)	2007-2019	Portuguese
Floresta	1969-2017	Portuguese
Revista Brasileira de Ecologia Brazilian Journal of Ecology	1997-2009	Portuguese
Biota Neotropica Neotropical Biodiversity	2001-2011	Portuguese
Boletim do Museu de Biologia Mello Leitão Bulletin of the Mello Leitão Biology Museum	2013-2018	Portuguese
Biota Amazônica Amazonian Biota	2011-2018	Portuguese
Boletim da Sociedade Brasileira de Mastozoologia Bulletin of the Brazilian Society of Mastozoology (mammalogy)	1985-2017	Portuguese
Zoologicheskiĭ Zhurnal (Russian Journal of Zoology) Зоологический журнал	1939-2020(8)	Russian
Contemporary Problems of Ecology Сибирский экологический журнал	1994-2020	Russian
Bulletin of Moscow Society of Naturalists: Biological Series Бюллетень МОИП, серия биологическая	1935-2020	Russian
Steppe Bulletin Степной бюллетень	1998-2020	Russian
Russian Journal of Ornithology Русский орнитологический журнал	1993-2020	Russian

Journal of Ichthyology Вопросы ихтиологии	1961-2020	Russian
Herald of Game Management Вестник охотоведения	2007-2020(2)	Russian
Ekologiya (Russian Journal of Ecology) Экология	2000-2020(4)	Russian
Current Studies in Herpetology Современная герпетология	2000-2019	Russian
Biology Bulletin Известия РАН, серия биологическая	1957-2020	Russian
Povolzhsky Journal of Ecology Поволжский экологический журнал	2002-2020	Russian
Nature Conservation Research Заповедная наука	2016-2020(No.3)	Russian
Advances in Marine Science 海洋科学进展	1983-2017	Simplified Chinese
Journal of Fisheries of China 水产学报	1965-2017	Simplified Chinese
Asian Journal of Ecotoxicology 生态毒理学报	2006-2017	Simplified Chinese
China Environmental Science 中国环境科学	1981-2017	Simplified Chinese
Plant Diversity and Resources 植物分类与资源学报杂志	1975-2017	Simplified Chinese
Journal of Arid Land Resources and Environment 干旱区资源与环境	1987-2017	Simplified Chinese
Journal of Mountain Science/Research 山地学报	1983-2017	Simplified Chinese
Resources and Environment in the Yangtze Basin 长江流域资源与环境	1992-2017	Simplified Chinese
Pratacultural Science 草业科学	1984-2017	Simplified Chinese
Acta Ecologica Sinica 生态学报	1981-2016	Simplified Chinese
Bulletin of Soil and Water Conservation 水土保持通报	1981-2017	Simplified Chinese
Chinese Journal of Eco-Agriculture 中国生态农业学报	1993-2017	Simplified Chinese
Chinese Journal of Ecology 生态学杂志	1982-2016	Simplified Chinese
Journal of Plant Resources and Environment 植物资源与环境学报	1992-2016	Simplified Chinese
Chinese Bulletin of Botany 植物学报	2006-2016	Simplified Chinese

Chinese Bulletin of Life Science 生命科学	1988-2017	Simplified Chinese
Sichuan Journal of Zoology 四川动物	1996-2016	Simplified Chinese
Marine Sciences 海洋科学	1977-2017	Simplified Chinese
Acta Theriologica Sinica 兽类学报	1981-2018	Simplified Chinese
Zoological Systematics 动物分类学报	1964-2017	Simplified Chinese
Marine Environmental Science 海洋环境科学	1982-2017	Simplified Chinese
Chinese Journal of Applied and Environmental Biology 应用与环境生物学报	1995-2017	Simplified Chinese
Environmental Science 环境科学	1976-2017	Simplified Chinese
Acta Phytophylacica Sinica 植物保护学报	1962-2017	Simplified Chinese
Bulletin of Botanical Research 植物研究	1959-2017	Simplified Chinese
Journal of Desert Research 中国沙漠	1981-2017	Simplified Chinese
Acta Hydrobiologica Sinica 水生生物学报	1997-2017	Simplified Chinese
Acta Agrestia Sinica 草地学报	1989-2017	Simplified Chinese
Soils 土壤	1958-2017	Simplified Chinese
Journal of Soil and Water Conservation 水土保持学报	1987-2017	Simplified Chinese
Plant Protection 植物保护	1963-2016	Simplified Chinese
Chinese Journal of Biological Control 中国生物防治学报	1985-2017	Simplified Chinese
Journal of Agro-Environment Science 农业环境科学学报	1981-2017	Simplified Chinese
Journal of China Agricultural University 中国农业大学学报	1955-2017	Simplified Chinese
Shanghai Environmental Science 上海环境科学	1982-2017	Simplified Chinese
Biodiversity Science 生物多样性	1993-2016	Simplified Chinese

Chinese Journal of Plant Ecology (formerly Acta Phytoecologica Sinica, Acta Phytoecologica et Geobotanica Sinica, Journal of Plant Ecology) 植物生态学报	1963-2016	Simplified Chinese
Resources Science 资源科学	1977-2016	Simplified Chinese
Ecological Science 生态科学	1982-2016	Simplified Chinese
Journal of Natural Resources 自然资源学报	1986-2016	Simplified Chinese
Current Zoology (formerly Acta Zoologica Sinica 1935-2008) 动物学报	1935-2008	Simplified Chinese
Chinese Journal of Wildlife 野生动物学报	1979-2016	Simplified Chinese
Journal of Biology 生物学杂志	1983-2016	Simplified Chinese
Urban Environment & Urban Ecology 城市环境与城市生态	1988-2016	Simplified Chinese
World Forestry Research 世界林业研究	1988-2017	Simplified Chinese
Scientia Silvae Sinicae 林业科学	1955-2017	Simplified Chinese
Acta Botanica Boreali-Occidentalia Sinica 西北植物学报	2012-2016	Simplified Chinese
Wetland Science 湿地科学	2003-2017	Simplified Chinese
Journal of Lake Sciences 湖泊科学	1989-2017	Simplified Chinese
Acta Pedologica Sinica 土壤学报	1948-2017	Simplified Chinese
Chinese Journal of Applied Ecology 应用生态学报	1990-2016	Simplified Chinese
Acta Prataculturae Sinica 草业学报	2008-2017	Simplified Chinese
Chinese Journal of Grasslands (formerly Grassland of China) 中国草地学报	1979-2016	Simplified Chinese
Chinese Journal of Microecology 中国微生态学杂志	1989-2017	Simplified Chinese
Journal of Ecology and Rural Environment (formerly Rural Eco-Environment) 生态与农村环境学报	1985-2017	Simplified Chinese

Chinese Journal of Zoology 动物学杂志	1957-2016	Simplified Chinese
Journal of Tropical and Subtropical Botany 热带亚热带植物学报	1992-2016	Simplified Chinese
Life Science Research 生命科学研究	1997-2016	Simplified Chinese
Zoological Research 动物学研究	1980-2016	Simplified Chinese
Journal of Hydroecology (formerly Reservoir Fisheries) 水生态学杂志	1981-2017	Simplified Chinese
Ecology and Environmental Sciences (formerly Ecology and Environment) 生态环境学报	1992-2016	Simplified Chinese
Cedamaz	2014-2018	Spanish
BioScriba	2008-2017	Spanish
Ecosistemas: Revista Científica de Ecología y Medio Ambiente Ecosystems: Scientific Journal of Ecology and Environment	2001-2018	Spanish
Notulas Faunisticas	2008-2018	Spanish
Animal Biodiversity and Conservation	2001-2019	Spanish
Folia Amazónica	1988-2018	Spanish
Caldasia	1940-2019	Spanish
El Hornero: Revista de Ornitología Neotropical	2003-2017	Spanish
Revista Española de Herpetologia Spanish Journal of Herpethology	2003-2007	Spanish
Revista de Biología Tropical International Journal of Tropical Biology and Conservation	1976-2018	Spanish
Colombia Forestal	2000-2018	Spanish
Revista Chilena de Historia Natural Chilean Journal of Natural History	1897-2018	Spanish
Therya	2010-2019	Spanish
Ecología Austral Austral Ecology	2001-2018	Spanish
Ardeola	1954- 2019	Spanish
Hidrobiológica Hydrobiology	1991-2018	Spanish
Revista Mexicana de Mastozoología Mexican Journal of Mastozoology	1995-2017	Spanish
Madera y Bosques Wood and Forests	1995-2018	Spanish
Revista Chilena de Ornitología (formerly Boletín Chileno de Ornitología) Chilean Journal of Ornithology	2016-2018	Spanish
Galemys	1997-2017	Spanish

Novitates Caribaea	1999-2019	Spanish
Mediterránea: Serie de Estudios Biológicos Mediterranean: Biological Studies Series	1982-2015	Spanish
Revista Nicaragüense de Biodiversidad Nicaraguan Journal of Biodiversity	2015-2019	Spanish
Revista Mexicana de Biodiversidad Mexican Journal of Biodiversity	2005-2018	Spanish
Semiárida	2013-2018	Spanish
Boletín de la Real Sociedad Española de Historia Natural: Sección Biológica Bulletin of the Royal Spanish Society of Natural History: Biological Section	2003-2017	Spanish
Bosques Latitud Cero Forests Latitude Zero	2014-2018	Spanish
Anales de Biología	1984-2019	Spanish
Revista Peruana de Biología Peruvian Journal of Biology	1974-2019	Spanish
Edentata Edentata	1994-2018	Spanish
Boletín Científico Centro de Museos Bulletin of the Museum Scientific Center	1996-2019	Spanish
Revista Catalana d'Ornitologia Catalan Journal of Ornithology	2002-2018	Spanish
A Carriza: Sociedad Gallega de Ornitologia	2001-2009	Spanish
Gestión Ambiental	1999-2017	Spanish
Mastozoología Neotropical Neotropical Mammalogy	1994-2017	Spanish
Journal of Bat Research and Conservation (formerly known as Barbastella)	2017-2019	Spanish
Boletín de la Sociedad Argentina de Botánica Bulletin of the Argentinean Society of Botany	2013-2018	Spanish
Acta Zoológica Mexicana Mexican Zoological Record/Journal	1984-2019	Spanish
Biodiversity and Natural History (formerly Boletín de Biodiversidad de Chile) Biodiversity and Natural History (formerly Boletín de Biodiversidad de Chile)	2015-2017	Spanish
Ocelotlán	2003-2012	Spanish
Zoologica Baetica	1990-2015	Spanish
Mammalogy Notes	2014-2017	Spanish
Centros: Revista Cientifica Universitaria Centros: Scientific Journal of the University	2012-2018	Spanish
Huitzil: Revista Mexicana de Ornitología Huitzil: Journal of Mexican Ornithology	2000-2018	Spanish
Bioma (El Salvador)	2012-2016	Spanish
Barbastella	2000-2016	Spanish
Quebracho: Revista de Ciencias Forestales Quebracho: Journal of Forest Sciences	2008-2018	Spanish

Etología Ethology	1989-2003	Spanish
Historia Natural Natural History	2011-2018	Spanish
Arxius de Miscel·lània Zoològica Arxius de Miscel·lània Zoològica	2003-2019	Spanish
Agrociencia Uruguay Agroscience Uruguay	1997-2017	Spanish
Boletín de la Asociación Herpetológica Española Bulletin of the Spanish Herpetological Association	2004-2018	Spanish
Ecología Aplicada Applied Ecology	2002-2018	Spanish
Cuadernos de Herpetología Herpetology notes	2010-2018	Spanish
Orinoquia	2003-2018	Spanish
Butlletí del Grup Català d'Anellament Bulletin of the Catalan Ring Group	1981-2001	Spanish
Boletín Chileno de Ornitología Chilean Ornithology Bulletin	1994-2015	Spanish
Revista Internacional de Contaminación Ambiental International Journal of Pollution	1985-2018	Spanish
Revista Mexicana de Ciencias Forestales Mexican Journal of Forestry Sciences	2010-2018	Spanish
Boletín de Biodiversidad de Chile Bulletin of Biodiversity of Chile	2009-2014	Spanish
Studia Oecológica	1981-1995	Spanish
Grupo Jaragua	1997-2011	Spanish
Ecosistemas y Recursos Agropecuarios Ecosystems and Agropecuary Resources	1994-2018	Spanish
Notes and Newsletter of Wildlifers (Taiwan) 野生動物保育彙報及通訊	2005-2012	Traditional Chinese
Journal of Ecology and Environmental Sciences (Taiwan) 環境與生態學報	2008-2012	Traditional Chinese
Fungal Science (Taiwan)	1995-2019	Traditional Chinese
Chinese Bioscience (Taiwan) 生物科學	2003-2014	Traditional Chinese
Journal of National Park (Taiwan) 國家公園學報	1989-2019	Traditional Chinese
Taipei Zoo Bulletin 動物園學報	1989-2013	Traditional Chinese
Journal of Agriculture and Forestry (Taiwan) 農林學報	2000-2018	Traditional Chinese
Journal of the Experimental Forest of National Taiwan University 臺灣大學生物資源暨農學院實驗林研究報告	1987-2019	Traditional Chinese
Taiwan Journal of Forest Science 臺灣林業科學	1986-2020	Traditional Chinese

Journal of the National Taiwan Museum 國立臺灣博物館學刊	2005-2019	Traditional Chinese
Raptor Research of Taiwan 台灣猛禽研究	2003-2016	Traditional Chinese
Bio Formosa (Taiwan) 生物學報	1966-2014	Traditional Chinese
Quarterly Journal of Chinese Forestry (Taiwan) 中華林學季刊	2004-2019	Traditional Chinese
Taiwan Journal of Biodiversity 台灣生物多樣性研究	1999-2019	Traditional Chinese
Zeugma Biyolojik Bilimler Dergisi Zeugma Biological Science	2020	Turkish
Kommagene Biyoloji Dergisi Commagene Journal of Biology	2017-2019	Turkish
Akdeniz Üniversitesi Ziraat Fakültesi Dergisi Mediterranean Agricultural Sciences	2009-2019	Turkish
Deniz Bilimleri ve Muhendisligi Dergisi Aquatic Sciences and Engineering	2007-2020	Turkish
Bağbahçe Bilim Dergisi Journal of Bagbahce Science	2019	Turkish
Türk Coğrafya Dergisi Turkish Geographical Review	2000-2019	Turkish
Uluslararasi Doga Bilimleri be Biyoteknoloji Dergisi International Journal of Life Sciences and Biotechnology	2018-2019	Turkish
Kastamonu Üniversitesi Orman Fakültesi Dergisi Journal of Kastamonu University Faculty of Forestry	2001-2019	Turkish
Ege Üniversitesi Ziraat Fakültesi Dergisi Journal of Ege University Faculty of Agriculture	2014-2019	Turkish
Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi Artvin Coruh University Journal of Forestry Faculty	2000-2020	Turkish
Doğu Coğrafya Dergisi Journal of Eastern Geography	2010-2019	Turkish
Atatürk Üniversitesi Ziraat Fakültesi Dergisi Atatürk University Journal of Agricultural Faculty	2008-2020	Turkish
Dumlupınar Üniversitesi Fen Bilimleri Enstitüsü Dergisi Journal of Dumlupınar University Institute of Science	2000-2019	Turkish
Orman Bilimleri Dergisi Turkish Journal of Forest Science	2017-2019	Turkish
Akademik Ziraat Dergisi Journal of Academic Agriculture	2012-2019	Turkish
Trakya University Journal of Natural Sciences Trakya University Journal of Natural Sciences	2000-2019	Turkish
İstanbul Üniversitesi Orman Fakültesi Dergisi (1951-2017; continues in English as Forestist from 2018) Journal of the Faculty of Forestry Istanbul University (continues in English as Forestsist from 2018)	2009-2019	Turkish
Uluslararası Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi	2019	Turkish

Journal of International East Anatolia Science Engineering and Design		
Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi Journal of Dicle University Natural Sciences Enstitute	2019	Turkish
Doğanın Sesi Journal of Nature's Voice	2018-2019	Turkish
Anadolu Orman Araştırmaları Dergisi Anatolia Journal of Forest Research	2015-2019	Turkish
Toprak Bilimi ve Bitki Besleme Dergisi Journal of Soil Science and Plant Nutrition	2012-2019	Turkish
Bartın Orman Fakültesi Dergisi Journal of Bartin Faculty of Forestry	2000-2019	Turkish
Türk Tarım - Gıda Bilim ve Teknoloji Dergisi Turkish Journal of Agriculture - Food Science and Technology	2014-2019	Turkish
Su Ürünleri Dergisi Journal of Fisheries	2000-2019	Turkish
Türkiye Ormancılık Dergisi Journal of Turkey Forestry	2000-2019	Turkish
Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi Journal of Iğdır University Institute of Science	2019-2020	Turkish
Visnyk of Lviv University: Biological Series Вісник Львівського університету: Серія біологічна	2005-2019	Ukrainian
Nature Conservation (2013-2016) [formerly Nature Reserves in Ukraine (1995-2012)] Заповідна справа (2013-2016) [Заповідна справа в Україні (1995-2012)]	2013-2016	Ukrainian
Problems of Bioindication and Ecology Питання біоіндикації та екології	2008-2019	Ukrainian
Nature Reserves in Ukraine (1995-2012) [changed to Nature Conservation (2013-2016)] Заповідна справа в Україні (1995-2012) [Заповідна справа (2013-2016)]	1995-2012	Ukrainian

Appendix 3: Conservation reports searched

All conservation reports searched for the discipline-wide Conservation Evidence database (29 reports)

Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS)	45 numbered documents	Resolutions - Conservation actions (45 documents, numbered but not in order). Official reports not searched (http://www.accobams.org/documents-resolutions/official-reports/)
Amphibian and Reptile Conservation (ARC)	2021	Dated reports 2012-2021 at https://www.arc-trust.org/technical-reports
Amphibian Survival Alliance	1994-2012	"Froglog (Bulletin of the Amphibian Survival Alliance" magazine: Vol 9 - Vol 104
Back from the Brink: Shifting Sands	x5 documents dated 2021	All docs (x5 dated 2021) at this URL https://naturebftb.co.uk/the-projects/shifting-sands/
British Trust for Ornithology	1981-2016	BTO Research Reports: 1-687
Convention on the Conservation of Migratory Species of Wild Animals (CMS)*	1998-2018	All documents 1998-2018 inclusive, including Techincal Series reports TS no. 1-38 (some numbers missing: 6,28-30,36,37)
Environment Agency	1996-2023	Environment Agency - Environment Research Reports - Dated UK reports under the heading 'Research' and topic 'Environment', and Organisation 'Environment Agency' at: https://www.gov.uk/search/research-and-statistics
International Council for the Exploration of the Sea (ICES)	2011-2018	ICES Working Group on Bycatch of Protected Species (WGBYC) Expert Reports: 2011-2018 inclusive (www.ices.dk/publications/our-publications/Pages/Expert-Group-Reports.aspx)
International Council for the Exploration of the Sea (ICES)	2003-2018	ICES Working Group on Marine Mammal Ecology (WGMME) Expert Reports: 2003-2018 inclusive (www.ices.dk/publications/our-publications/Pages/Expert-Group-Reports.aspx)
International Society for Mangrove Ecosystems	1993–2014	Occasional Papers, and Technical Reports dated 1993–2014 searched at http://www.mangrove.or.jp/english/subpage/publications.html
IUCN-SSC Anguillid Eel Specialist Group	2016-2021	IUCN-SSC Anguillid Eel Specialist Group Reports - Dated reports at:

		https://www.iucn.org/ourunion/commissions/group/iucn-ssc-anguillid-eel-specialist-group
IUCN-SSC Cetacean Specialist Group	1989-2018	Cetacean Specialist Group Reports. Dated reports at https://iucn-csg.org/downloads/
IUCN-SSC Conservation Translocation Specialist Group	2008-2021	Conservation Translocation Specialist Group reports at https://iucn-ctsg.org/resources/ctsg-books/
IUCN-SSC Crocodile Specialist Group	2006-2018	Crocodile Specialist Group Articles. Dated articles at http://www.iucncsg.org/pages/Publications.html
IUCN-SSC Crocodile Specialist Group	2005-2017	Crocodile Specialist Group Reports. Dated reports at http://www.iucncsg.org/pages/Publications.html
IUCN-SSC Freshwater Fish Specialist Group	Annual reports: 2014-2008 Newsletters: 2008-2023	Freshwater Fish Specialist Group reports at https://www.iucn.org/our-union/commissions/group/iucn-ssc-freshwater-fish-specialist-group
IUCN-SSC Freshwater Plant Specialist Group	2016-2018	Freshwater Plant Specialist Group Reports at https://www.iucn.org/commissions/ssc-groups/plants-fungi/plants/plants-a-g/freshwater-plant
IUCN-SSC Invasive Species Specialist Group	1995-2013	Aliens: The Invasive Species Bulletin (IUCN) Vol 1 - Vol 33
IUCN-SSC Marine Mammal Protected Area Specialist Group	2017-2018	Marine Mammal Protected Area Specialist Group Reports. Dated documents at https://www.marinemammalhabitat.org/downloads/
Joint Nature Conservation Committee (JNCC)	1991-2018	Report no.s 1-627
MedWet	1994-2017	All publications dated 1994–2017 at https://medwet.org/publications/
National Oceanic and Atmospheric Administration (NOAA)	1962-2018	Fisheries Science & Data Resource Reports. Science & Data>Research and Survey Resources (dated) for species categories: whales, dolphins and porpoises, seals and sea lions i.e. not all reports at this link checked (https://www.fisheries.noaa.gov/resources/all-science?title=&species%5B54%5D=54&species%5B1000000066%5D=1000000066&species%5B53%5D=53&field_species_vocab_target_id=&sort_by=created)

Natural England	1991-2018	Reports dated 1991-2018 listed at http://publications.naturalengland.org.uk/category/7002 & http://publications.naturalengland.org.uk/category/10002 at Sep 2019. Records about... Habitat and species group sub-categories; Records about... Species; Terrestrial habitats; Farming & land management; Coastal, Freshwater, Marine
NatureScot	2016-2018	Reports 1-945 (2004-2018)
North Atlantic Marine Mammal Commission	1998-2018	NAMMCO outputs (Scientific publication series Vol1(1998)–10(2018) at https://nammco.no/library/
Ramsar	1998-2017	Documents dated 1998-2017 at https://www.ramsar.org/search
Scientific Committee on Antarctic Research (SCAR)	2004-2018	4 dated reports (2014-2018) and list of 7 selected publications (https://www.scar.org/science/eg-bamm/)
Sea Mammal Research Unit (SMRU)	2012-2018	Marine Mammal Scientific Support to Scottish Government reports at http://www.smru.st-andrews.ac.uk/research-policy/reports-to-scottish-government/
Sea Mammal Research Unit (SMRU)	1990-2018	SMRU reports for funders at http://www.smru.st-andrews.ac.uk/reports/
Wetlands International	1980-2017	Publications, Case Studies dated 1980–2017 (including "Flamingo: Bulletin of the IUCN-SSC/Wetlands International Flamingo Specialist Group" magazine) at https://www.wetlands.org/resources/
Whale and Dolphin Conservation (WDC)	2001-2018	Dated reports 2001 - 2018 at https://uk.whales.org/policy/wdc-publications-and-reports/

www.conservationevidence.com • www.clr.conservation.cam.ac.uk • www.fenlandsoil.org