Cyfoeth Naturiol Cymru
Natural Resources Wales

A review of evidence on the interactions of beavers with the natural and human environment in Wales

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Report No: 735

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Mae'r adroddiad hwn yn adolygu'r dystiolaeth sydd ar gael ar sut y mae afancod yn rhyngweithio â'r amgylchedd naturiol a'r amgylchedd dynol a sut y gallai hyn fod yn berthnasol yng nghyd-destun Cymru.

Mae afancod yn un o'r rhywogaethau o ffawna Ewropeaidd sydd wedi'i hailgyflwyno fwyaf eang, ac mae llawer iawn o wybodaeth ar gael am y dulliau ailgyflwyno, eu cynnydd a'u heffeithiau (Halley *et al.* 2009).

Bu arbenigwyr technegol CNC o amrywiaeth o ddisgyblaethau yn adolygu'r adroddiadau tystiolaeth a gyhoeddwyd yn Lloegr (Howe 2020) a'r Alban (Gaywood 2015) i ystyried effaith debygol afancod ar amgylchedd Cymru. Cofnododd y rhain hefyd dystiolaeth ychwanegol a gyhoeddwyd yn fwy diweddar ac unrhyw fylchau yn y dystiolaeth.

Ar sail y dystiolaeth a adolygwyd daethpwyd i'r casgliad bod ailgyflwyno afancod Ewrasiaidd i Gymru yn ymarferol yn ecolegol ac y gallai fod budd net i ecosystemau Cymru. Fodd bynnag, gallai afancod hefyd gael rhai effeithiau negyddol lleol ac mae meysydd o ansicrwydd gan nad yw rhai astudiaethau ar afancod yn berthnasol yn uniongyrchol i afancod yn nhirweddau Cymru.

Executive summary

This report reviews the available evidence on the interactions of beavers with the natural and human environment and how it might apply in the Welsh context.

Beavers are one of the most extensively reintroduced species of European fauna, and there is a substantial amount of information available on the methods, progress, and effects of reintroductions (Halley *et al.* 2009).

NRW technical experts from a range of disciplines reviewed the published English (Howe 2020) and Scottish (Gaywood 2015) evidence reports to consider the likely impact of beavers in the Welsh environment. They also identified additional evidence that has been published more recently and any evidence gaps.

Based on the evidence reviewed it is concluded that the reintroduction of Eurasian beavers into Wales is ecologically feasible and that there could be a net benefit to Welsh ecosystems. However, beavers could also have some localised negative impacts and there are areas of uncertainty as some studies on beavers are not directly relevant to beavers in Welsh landscapes.

1. Introduction

1.1. Beaver behaviour

The Eurasian Beaver (hereon referred to as beaver) is a semi-aquatic rodent that lives in rivers, streams, lakes and wetlands (Jones *et al*. 2012). Beavers are often referred to as ecosystem engineers and are able to restore wetland ecosystems and produce a mosaic of diverse riparian habitats (Howe 2020).

Beavers live in burrows or lodges that provide protection from predators; they require a depth of water of at least a metre outside their lodges so they can swim into the lodge. Dams are built to create water deep enough for them to swim in, therefore if the water is already of sufficient depth, they have little need for dams (Brazier *et al*. 2021). They prefer to swim, rather than walk and like to transport branches through water. To facilitate this, they will commonly dig shallow channels, often referred to as canals, which extend laterally from beaver ponds (Brazier *et al*. 2021). Beavers construct dams using a combination of small diameter tree stems, branches, sticks and mud, but other materials can sometimes be used if trees are absent (Jones *et al*. 2012).

Beaver dams are temporary structures and are generally quite leaky. By building new dams in different places, beavers bring a changeable mixture of habitats into the landscape, with streams, pools and bare mud (Stringer *et al*. 2015). Dams vary significantly in their size, structure and longevity depending on physical factors such as hydrology, topography and building materials (Graham *et al*. 2020) but also ecological factors (Howe 2020).

Beavers are herbivorous and can feed on a wide variety of woody and herbaceous vegetation but have favoured foods when available. As a consequence of their diverse diet, they are often described as foraging generalists (Jackowiak *et al*. 2020). Beavers fell trees to access bark, upon which they can feed, and also use as building materials. Tree species particularly favoured by beavers for food are aspen, willow and birch (Jones *et al*. 2012). Broadleaved deciduous tree bark is mostly eaten during the winter months when other food is less available. Beavers do not hibernate, but they do reduce their activity over winter.

Beavers rarely move more than 10 metres from water so will usually only coppice or fell trees that are within this distance from a river. On the River Otter in Devon, it was found that the majority of trees felled by beavers were no more than 3cm in diameter and willow was by far the most favoured tree species (Brazier *et al*. 2020), which grows back very quickly when cut (Jones *et al.* 2009).

1.2. History of beavers in Wales

The Eurasian beaver is native to Britain and was once widespread across Europe and northern Asia. The last record of beaver presence in Wales is from the River Teifi in 1188 AD and it is likely that beavers were extinct in Wales by the 15th century (Jones *et al*. 2012). Their extinction was due to unsustainable levels of hunting for their valuable pelts, and to a lesser extent for castoreum and meat (Gaywood 2015). Habitat loss may have played a part in some instances but is thought to have been relatively minor and localised (Gaywood 2015).

1.3. Current status of beavers in Great Britain

Beavers have been successfully reintroduced and protected in many countries across Europe, including Scotland and England (Gov.uk 2020), although the landscapes that beavers are now returning to have been significantly altered by anthropogenic land use (Graham 2023).

1.3.1 Scotland

Beavers are currently present in two main areas of Scotland – Tayside in the northeast and Knapdale on the west coast. The first confirmed records of beavers in the Tay catchment were in 2006 and were the result of escapes or illegal releases (Howe 2020). The Scottish Beaver Trial at Knapdale commenced in 2009 with a small number of animals released as part of a planned reintroduction. A survey of the Tayside population in 2012 estimated that there were around 39 family groups (Campbell *et al*. 2012). A further survey was carried out in 2018 which recorded an increase to approximately 114 family groups and a significant increase in range, with animals now being found outside of the catchment (Campbell-Palmer *et al.* 2018). The beaver populations in Tayside and Argyll are currently being supplemented to facilitate population expansion (NatureScot 2023). The third wild beaver release in Scotland took place at the RSPB Scotland reserve on Loch Lomond in January 2023 and work is progressing to support the consideration of further translocations to new catchments (NatureScot 2022).

In 2019 beavers were given European Protected Species (EPS) status in Scotland under the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended). As such they receive legal protection, where any actions affecting them can only be carried out under licence from NatureScot. This also places a requirement on NatureScot to monitor populations and to ensure that any licensed actions will not be detrimental to the maintenance or restoration of favourable conservation status of beaver populations.

Prior to full protection being afforded to beavers as EPS, unregulated culling of beavers was undertaken in some areas. The extent of this culling is not known but is thought to be largely confined to the Tayside population (Gaywood 2015).

In November 2021 the Scottish Government announced that it would actively support the expansion of the Eurasian beaver population into new areas of Scotland to establish the species in areas outside their current range (Scottish Government 2021). A Beaver Strategy for 2022-2045 has been published to steer wider efforts to identify and actively expand the population to new catchments, alongside appropriate management and

mitigation (IUCN/CPSG 2022). The development of the strategy involved more than 50 stakeholder organisations and was led by the International Union for Conservation of Nature (IUCN) Conservation Planning Specialist Group (CPSG).

The NatureScot Beaver Management Framework (NatureScot 2019) includes their approach to species licensing and to mitigation. Where impacts are serious and there is no alternative some interventions such as removing established dams, can take place under licence. Beaver mitigation seeks to minimise beaver impacts where necessary, thereby promoting co-existence with beavers.

1.3.2 England

A five-year licence was issued by Natural England (NE) in 2015 for the River Otter Beaver Trial (ROBT). This licence legitimised the presence of beavers that had been living wild on the River Otter in Devon, enabling an authorised trial of a beaver reintroduction. The ROBT was led by Devon Wildlife Trust and, working with Exeter University, the beavers were studied between 2015-2020 (Brazier *et al.* 2020). In 2020 a decision was made by Defra Minister, following the conclusion and assessment of trial results, to permit those free-living beavers to remain and continue to expand their range naturally (Gov.uk 2020). Other groups of beavers exist in the wild in England, as a result of escapes/unauthorised releases.

Beavers were made an EPS in England in October 2022 and a licensing regime is now in place (Gov.uk 2022).

1.3.3 Wales

A feasibility study undertaken by Jones *et al.* (2012) concluded that restoring beavers in Wales was ecologically feasible. Evidence collected from habitat surveys (Halley *et al.* 2009) confirmed there is abundant habitat present in Wales suitable for sustaining viable populations of beavers in the wild.

In 2015 the Board of Natural Resources Wales agreed a broad position statement which recognised the benefits that beavers can bring, whilst also recognising the potential risks and stakeholder concerns.

NRW and NE commissioned a cross-border survey of the River Wye in 2019. The results suggested that there may be a small number of free-roaming beavers on the Welsh part of the Wye, although field signs found in Wales were more than a year old at that time (Campbell-Palmer *et al*. 2019).

NRW also commissioned a field survey of beaver activity on the Dyfi catchment in late 2020. The survey involved looking for beaver field signs in areas of suitable habitat and information from sightings was used to inform the survey area. A total of 53km of freshwater bank was surveyed. The survey found signs of beaver activity in four main areas. The results suggest beavers have been present in small numbers over several years at low density in discrete areas over parts of the lower Dyfi (Campbell-Palmer *et al*. 2022).

In 2021 NRW issued a licence to Montgomeryshire Wildlife Trust to release up to six Eurasian Beavers into an enclosure at Cors Dyfi Nature Reserve. There are currently 4 beaver enclosures in Wales (Figure 1). In addition, there have been a number of reports of beaver sightings in other locations in Wales.

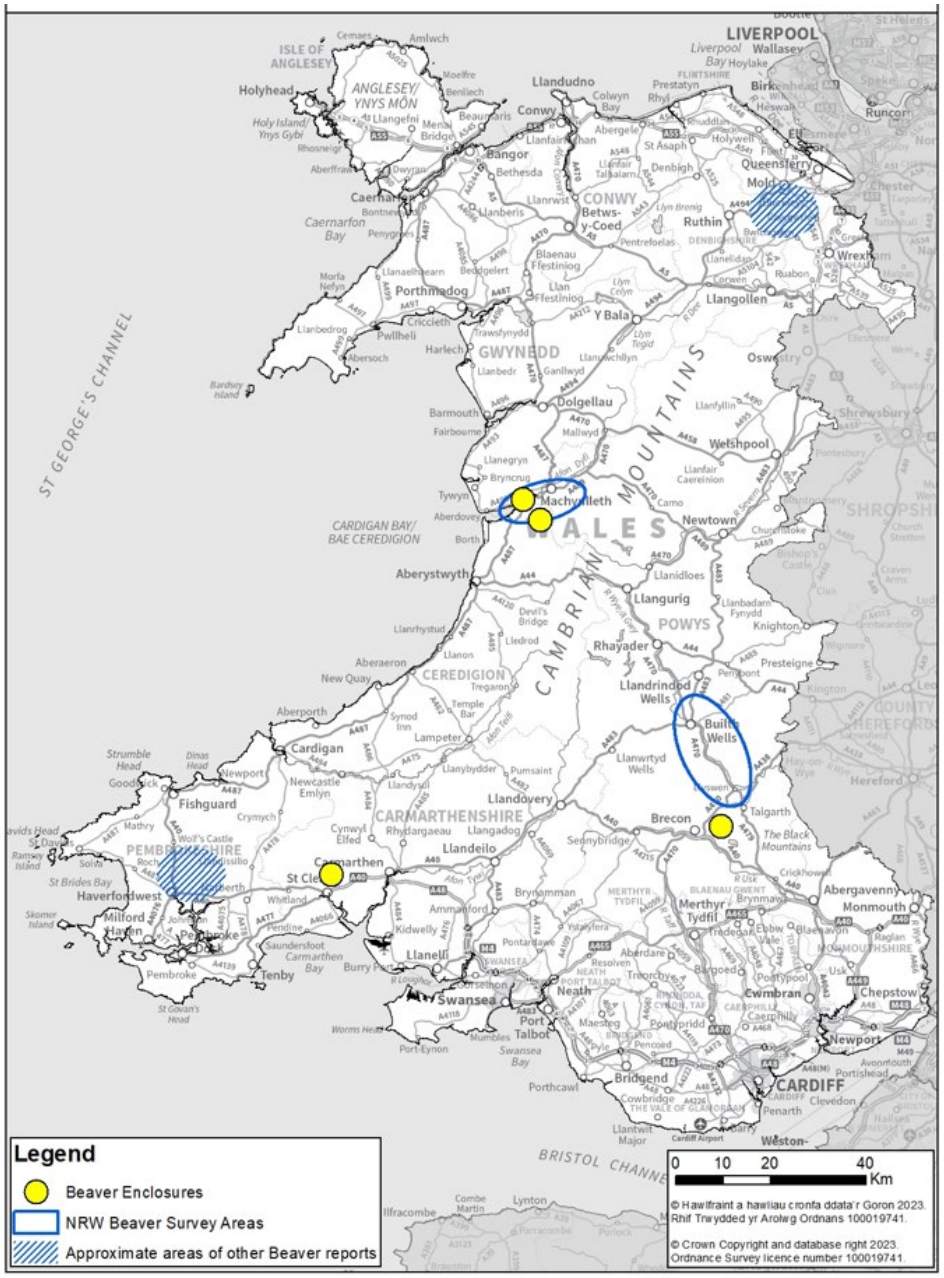

Figure 1 Location of beaver enclosures and areas where beavers have been reported in the wild, including two areas with NRW commissioned surveys

1.4. Legal position

Eurasian beaver was added to Schedule 9 of the Wildlife and Countryside Act (1981) in England and Wales in 2015. This means that it is an offence to release a beaver or to allow one to escape into the wild, without a licence. A release of beavers into an enclosure or into the wild in Wales requires a licence issued by NRW.

Any release of beavers without a licence, or the breach of conditions of a licence that has been issued, would also be unlawful. In Wales, the Police are the enforcement authority and responsible for investigating any alleged incidents. NRW would provide advice and guidance to the police in this situation.

When considering licence applications or project proposals for the reintroduction of a species or a conservation translocation NRW undertakes an assessment of the project to ensure that it is in line with the IUCN Guidelines for Reintroductions and Other Conservation Translocations. Advice on the information to be provided to support a licence application is available on the NRW website: Natural Resources Wales / Beaver licensing.

Beavers receive legal protection in Scotland and England as European Protected Species.

2. Evidence review

This review considers evidence on the interactions of beavers with the natural and human environment and how it might apply in the Welsh context. NRW technical specialists (see Annex 2) reviewed relevant sections of the Natural England report *A review of the evidence on the interactions of beavers with the natural and human environment in relation to England* - NEER017 (naturalengland.org.uk) (Howe 2020). The Natural England review focuses on new evidence available since an earlier feasibility assessment published by Natural England (Gurnell *et al.* 2009) and the extensive review carried out by Scottish Natural Heritage, now NatureScot *Beavers in Scotland - A Report to the Scottish Government* (nls.uk) (Gaywood 2015). NRW technical specialists also considered how the evidence might apply in Wales, identified any new evidence available since the 2020 report and identified any evidence gaps.

The evidence presented in Howe 2020 and Gaywood 2015 is not fully represented in this review. **Readers are advised to consult these reviews for more detail regarding the topics discussed in this report**.

This report is divided into three broad headings that considers the interactions with habitats, species and people. All sections follow the structure below:

- Overview - summary of the topic area
- Natural England 2020 Review - conclusions from the review
- NRW assessment - review of the English and Scottish reports
- Further research available since 2020 – identification of any new significant research
- Welsh Context - how the England or Scotland conclusions relate to Wales
- Conclusion of the NRW review

2.1. Interactions with habitats

2.1.1. Running water habitats

Overview

Beaver activity has the potential to influence a watercourse through burrowing, foraging, damming and tree felling. This can bring about changes in the processes that occur in streams and rivers which can affect the hydrology, fluvial geomorphology and river habitat. The extent of the impact will vary across space and time; some of the processes resulting from beaver activity are rapid and some will take decades to develop.

Beavers can also influence the river system by restoring riparian and floodplain habitats, creating new areas of full and partial inundation, connecting isolated aquatic features, and diverting water into colonised areas.

Creation of beaver pools and wetlands is covered in this section, as these habitats are part of and connected to the river network.

Natural England Review conclusions

"Recent evidence published since the Scottish Review complements previous evidence demonstrating that beaver activity can enhance the natural functions of river systems, although the extent of influence is dependent on the natural characteristics of the watercourse and the nature and scale of existing habitat degradation. Key factors affecting the response of watercourses to beaver activity include stream power, gradient and the size of naturally vegetated riparian zones. There is potential for significant habitat restoration opportunities associated with the delivery of large woody material to the channel and beaver activity in riparian zones, helping to restore lost habitat dynamism and diversity.

The scale of ecological change will be highly site-specific and dynamic, but where beaver activity is high there will be an overall shift in the balance of lentic and lotic character and associated biological assemblages, in line with natural functioning of river ecosystems, as long as beaver population levels are subject to population controls that also mimic natural systems."

NRW assessment of English and Scottish Reviews

We broadly agree with the findings of the English review. Whilst there are further considerations required in Wales, it is likely that the ecological effects of beavers in Devon will be transferable to parts of Wales, especially in the south and west.

Hydrological monitoring undertaken on the River Otter catchment indicate that dam construction is raising riverbed levels, which in turn is expected to improve river channel morphology and therefore the ecological condition of rivers through increased habitat area, stable flows, and better connection with the floodplain. Morphological problems are also a significant cause of ecological problems in Welsh rivers (Natural Resources Wales 2021). Evidence from the ROBT shows that peak flows (flood flows) have apparently reduced and base flows (fair weather flows) increased, and there is an approximately fivefold increase in the area of rural floodplain land flooding suggesting catchment level flow benefits. However, it would be beneficial to have data from a longer time series in order to increase confidence and better quantify the scale of these benefits against the cost of impacts against farmers affected by upstream flooding.

In Scotland the trial site at Knapdale has an unusual landscape character (i.e., low nutrient, forested upland areas with lakes) that is applicable only to very limited areas of Wales. Fairly similar areas are parts of the Gwydir Forest and Dyfi Forest. The Tay, a much larger river, is more comparable to the Welsh landscape as it comprises a mainly rural landscape with a mixture of upland areas, lakes, and more intensively farmed areas.

Further research available since 2020

There is developing evidence that beavers may have ecohydrological benefits at a catchment scale by increasing both groundwater and surface water levels (Dittbrenner *et*

al. 2022 – American Beaver) and reducing flashiness (sudden increase in water levels due to heavy rainfall (Puttock *et al*. 2021 – Eurasian Beaver).

Studies undertaken in North America provide useful comparable information. For example, Jordan & Fairfax (2022) recommended using beaver-based restoration as a tool for climate mitigation in a North American context, whilst Dewey *et al*. (2022) show that beaver can provide hydrological and water quality benefits that compensate for climate extremes in the western USA. Nash *et al*. (2021) emphasise the uncertainties underlying beaver-related restoration and advocate an ecosystem process-pathways approach as a means of evaluating the success of beaver reintroduction designed to restore rivers – a philosophy that is in line with Sustainable Management of Natural Resources (SMNR) and the ecosystem approach. Ronnquist & Westbrook (2021) describe the hydrological consequences of different beaver dam types in the Canadian Rocky Mountains. Graham *et al*. (2022) provides further evidence that beaver dam sequences attenuate peak flows during hydrological events.

In Finland, European beaver activity greatly increases water beetle diversity and abundance (Nummi *et al.* 2021a) and numbers of both green and common sandpiper (Nummi *et al*. 2021b), due to the creation of increased and more diverse habitat area and increases in food source, supporting existing research that beaver have wider biodiversity benefits by diversifying the habitat structure of the river corridor. A Scottish study (Needham *et al*. 2021) showed an increase in brown trout abundance and size but not density, reflecting increased habitat area and quality.

Larsen *et al*. (2021) and Brazier *et al*. (2021) both provide important reviews and synthesis of the state of knowledge regarding beaver. These reviews are extensive and take into account hydrology, geomorphology, biogeochemistry (including the carbon, nitrogen and phosphorus cycles) and ecosystems. Of note Larsen *et al.* (2021) included suggestions that beaver dams can increase geomorphic heterogeneity, delay sediment transport and increase habitat complexity and biodiversity on reach scales and, Brazier *et al.* (2021) find that beaver ponds are effective at retaining phosphorus associated with high sediment loads. Murray *et al*. (2023) explores whether beaver dams are a natural method for reducing excess nitrogen (N) concentrations within streams, concluding the geomorphic composition of a beaver pond can inform whether beaver activity can provision water quality remediation.

Welsh Context

Beaver activity can help restore the natural functioning of river systems, although such potential is dependent on the nature and scale of existing habitat degradation. Welsh river systems have significant morphological problems, such as the legacy of many years of human interventions in an attempt to drain the landscape, intensification of livestock grazing areas and intervention to minimise flooding. These result in poor riverbed quality, a reduction in water quality and loss of riparian habitat that is a key component of the river ecosystem, preventing SMNR objectives in rivers. Although multiple projects have attempted to tackle this in the past, landowner consent and lack of resource are significant issues.

In general, the ecological impact of beaver reintroduction is large and complex. Depending on location, flows can be slowed, resulting in increased channel stability and a more

geomorphologically complex system overall. Both these potential changes are positive within the context of restoring a naturally functioning, dynamic fluvial system. Beavers increase both large and small woody debris in river systems (Gurnell *et al.* 2002) and improve fluvial geomorphology. However, while many of the effects of beavers will be beneficial, these same activities can conflict with different stakeholder interests. For example, water held behind dams may cause localized flooding of property (Rosell & Campbell-Palmer 2022).

Many rivers in Wales suffer from high nutrient and sediment load. River and stream channels that are heavily enriched are likely to suffer from high algal biomass production behind beaver dams, with associated impacts on the biota (Mainstone 2010). Whilst beaver ponds can trap nutrient-rich silt in the short term, warming of these ponds during low flow periods could then result in algal blooms within them and / or deoxygenation of the bed sediments, releasing phosphorus into the water column.

A watercourse may also be carrying excessive amounts of fine sediment from upstream erosion, which can lead to very deep, fine sediments in beaver ponds that are uncharacteristic of the natural river and only suitable for a limited number of species (Brazier *et al.* 2021). Rivers and streams that have more natural nutrient and sediment systems will benefit from beaver activity increasing heterogeneity of habitats associated with high quality environmental conditions (Howe 2020).

Conclusion

There is ample evidence of the effects of beavers on many aspects of river systems in the published literature, including other literature reviews. However as highlighted by Brazier *et al.* (2021) further research on the impacts of beaver on geomorphic processes (the erosion, transport and deposition of sediments) is required at a larger spatial scale; presently most research focuses on site or reach scale.

Rivers are active and variable environments where an understanding of the underlying processes is required to predict likely responses to change such as beaver activity. Beaver activity has a strong impact on these processes.

In wooded river sections, beavers can be expected to diversify instream and riparian habitat, create ponds, trap silt, increase base flows and reduce flood peaks. However, there is strong evidence that we need to increase woodland cover along our river systems which would benefit all river habitat.

Beavers can provide an important means of managing habitat, increasing complexity and improving ecosystem resilience and services. These benefits may be evident at a catchment as well as a reach scale. However, beavers are not a substitute for tackling water quality issues.

2.1.2. Standing water habitats and associated wetlands

Overview

The effects of beavers on standing water habitats and associated wetlands are mainly related to building dams and lodges and herbivory. Beavers have the capacity to both create new standing water and transform riparian landscapes into complex wetland habitats that may lead to impacts on existing habitats.

Natural England Review conclusions

"Recent evidence published since the Scottish Review is consistent with previous evidence demonstrating that beavers can help restore wetlands and promote biodiversity. Beaver-induced ponded and wetland habitats have the potential to enhance and restore natural processes in English catchments with a significant benefit to overall wetland function. There have been many changes to the water environment since beavers were widely present and while many of the effects of beaver will be beneficial, there will also be situations where landowner objectives will differ, and conflict may occur."

NRW assessment of English and Scottish Reviews

Whilst we broadly agree with the findings of the reviews, further scientific studies are required to assess the impacts of beavers on standing water and wetland habitats. Lakes that are under existing nutrient pressure would be a significant area of concern in Wales, as the potential for beaver reintroduction to increase algal blooms in lakes has not been assessed by either the Scottish or English reviews.

Further research available since 2020

Wetlands are declining worldwide, and there is a great need for their restoration and creation and Nummi & Holopainen (2020) provide evidence that shows having beavers as wetland managers is a feasible tool for creating and restoring wetlands for waterbirds and other biota.

Minke *et al.* (2020) report beaver activity can restore a peatland's carbon sink and reduce Greenhouse Gas emissions, and advocates beavers are of great benefit in peatland restoration and a valuable support for the slowly progressing deliberate rewetting activities in Belarus and beyond.

Andersen *et al.* (2023) demonstrates that wetlands with beaver activity harbour significantly higher moth diversity, as well as increase vegetation greenness and heterogeneity.

Murray *et al.* (2023) highlights beaver ponds are increasingly promoted as a strategy for physical stream restoration, and more recently recognized as natural solutions for excess nonpoint source pollutants.

Welsh Context

A particular concern is the likely impact of beaver grazing on submerged plant communities on shallow lakes under mild to moderate nutrient stress, potentially tipping some ecosystems from a desirable macrophyte-dominated, clear water system to an undesirable turbid state with more frequent and severe algal blooms. Aquatic plants, especially submerged species, are crucial for ecosystem resilience in these environments. Examples of these include several lakes on Anglesey, Llangorse Lake, and Kenfig Pool.

In terms of marginal communities, beaver activities are likely to be beneficial by opening up overly dense reedbed and marginal woodland. Raising of water levels may also result in eutrophication and a reduction in dissolved oxygen. As beaver modifications promote the expansion of lentic (or still) water areas and anaerobic conditions, there is the potential for significant net transfers of carbon stored as woody biomass carbon to herbaceous and grass biomass, as well as increased sediment carbon storage (Larsen *et al.* 2021).

A number of Welsh lakes have been colonised by invasive aquatic plant species such as non-native pondweeds (eg Curly Waterweed *Lagarosiphon major,* New Zealand Pygmyweed *Crassula helmsii, and Elodea* waterweed spp). The impact of beaver grazing on these, if any, is unclear. In addition, the creation of slow moving or still water habitat may lead to the potential spread of INNS such as killer shrimp (*Dikerogammarus villosus*) and zebra mussel (*Dreissena polymorpha*) and could benefit competitive native fish species such as roach or bream.

The impact of beavers on peatland ecosystems is given limited coverage in the reviews. The principal concern for peatlands relates to our much-diminished lowland peatland resource which now exists in a highly constrained and agriculturally managed landscape. The essentially uncontrolled and unplanned nature of beaver activity has the potential to cause damage in contexts where restoring hydrological function may require significant technical and carefully planned restoration activity. There is also the issue that managing and restoring peatlands within agricultural landscapes already presents many challenges (chiefly in relation to the restoration of grazing, but also the management of drainage and nutrient regimes). Beavers have the potential to make peatland restoration even more challenging, with a risk of beaver introduction becoming the dominant issue to the exclusion of everything else. The specific potential impact of beavers on *Cladium mariscus* - a signature species of the Annex 1 community H7230 calcareous fen - is also a very significant concern for sites supporting that habitat (primarily the Corsydd Mon and Corsydd Llyn SACs); such sites should be excluded from any potential trial.

There are, however, two clear potential roles for beavers across the Welsh peatland and more generally wetland landscape, namely (i) in the 're-naturalising' of lowland wetland landscapes so heavily modified to the point that little semi-natural habitat cover remains - this could include hypermodified lowland peatlands but perhaps more so floodplains on less dominantly organic substrates, and (ii) in upland and upland fringe contexts on peat and peaty soils damaged by forestry and agriculture, particularly contexts which would support marshy grassland or soligenous mire as opposed to blanket bog. For these contexts there is scope for considering beavers as a beneficial agent. Resources are not sufficient to restore all this resource to rewetted non-wooded and grazed wetland and instead it is likely that restoration in the future will focus upon rewetting surfaces without first removing the tree cover and in the hope that deciduous species will slowly outcompete

any non-native conifers. Beavers could play a significant role in promoting heterogeneity and aiding rewetting in these places.

Conclusion

All of the standing water evidence relevant to beavers in Wales comes from Scotland. The available evidence is from existing lakes with low nutrient levels. In these habitats, the effect of beaver is comparatively small, although there could be some shifts in vegetation composition. In very small lakes, beavers may dam to increase water depth and habitat area. We do not have significant concerns regarding the ecological impact of beaver in low nutrient lakes.

Beavers could make an important contribution to the improving the condition of peatland in Wales, although this area remains a little understudied.

Further research is required on the plant and animal communities that colonise beaver ponds, and whether these correspond with existing habitat types or constitute an entirely new type of habitat. Additionally, further information is required on the impact of beaver on existing habitats, especially shallow lakes with an existing nutrient problem. These environments are already under stress, and introducing a herbivorous species is likely to shift the balance of the system towards algal blooms.

2.1.3. Woodlands

Overview

Beavers affect woodland primarily through the felling of trees and damming watercourses. Felling may affect tree species composition and age structure of a woodland, which will diversify in even-aged forests, and is likely to create more open habitats. This may influence woodlands towards an overall younger age structure in high impact areas (i.e. close to watercourses and lodges). Damming may inundate and kill trees, leading to increased volumes of deadwood, and change the abundance of different habitats, in particular increasing areas of standing water habitat and wetter woodland types.

Natural England Review conclusions

"Evidence from research published since the Scottish Review is in accord with previous evidence demonstrating that beavers can affect tree species composition and age structure of wet woodlands and woodlands along riparian corridors with subsequent positive impacts for biodiversity.

Beaver activity within riparian woodlands is likely to lead to greater structural complexity and, consequently, greater diversity of conditions within woodlands, particularly in terms of wetness. As a result, there would also be greater diversity in hydro-chemistry, light availability and openness. Overall, beavers can create more heterogeneous and diverse riparian woodlands both across the landscape and through time."

NRW assessment of English and Scottish Reviews

Although we broadly agree with the findings of both the English and Scottish reviews there are a few further considerations needed in a Welsh context. For example, the creation of 'younger' woodland is at odds with statutory sites monitoring where most woodland in Wales fails condition assessment due to lack of older trees, though the potential production of more deadwood may bring the deadwood criteria into a more favourable condition.

There is also the potential for areas of fragmented riparian woodland to become more patchy and possibly lost due to beaver coppicing, and subsequently deer or sheep grazing of new growth.

Beaver preference for Ash will potentially reduce the trees' ability to cope with Ash dieback infection as coppiced trees are more susceptible to the disease (Fuller, 2016). Therefore, beaver activity could result in accelerated dieback of Ash in non-resistant trees and a greater fragmentation of riparian ash dominated woodland communities, including SSSIs, that are often found adjacent to streams and soakaways within more oak-dominated woodland.

Further research available since 2020

Since the English review was undertaken there has been limited further scientific studies that that significantly changes the conclusions of Gaywood (2015) and Howe (2020). The study of Graham (2023) suggests rates of canopy growth and height decline were greater in regions where beavers were actively foraging, indicating that beaver foraging may increase canopy height variability which could have varying implications for riparian/aquatic species and woodland management.

Welsh Context

Both the potential loss of fragmented woodland and greater impacts of grazing from deer or sheep on beaver coppiced regrowth needs consideration. In a Welsh context it is also important to give further consideration to the following:

- The potential reduction in the occurrence and development of mature and veteran trees alongside streams and watercourses.
- Any increased fragmentation of fragmented woodland to the point it can no longer be classified as woodland (<20% canopy cover, UKFS/NFI).
- The potential added impact on Ash by decreasing longevity of beaver coppiced trees due to increased infection rates by Ash die-back.
- The potential spread of INNS such as Himalayan balsam, Japanese knotweed and rhododendron due to opening up of canopies and disturbance along river/stream corridors.

Conclusion

There is strong evidence that beavers can affect the tree species composition and age structure of woodlands with subsequent positive impacts for biodiversity.

There is no direct evidence in Wales on the effects of beavers on woodlands, but evidence from published studies indicate that beavers will likely have positive impacts on woodland biodiversity in under-managed riparian woodland across the country, provided above considerations are managed. There will be potential impacts however in temperate rainforest areas with opening up of canopies and reduction in humidity, with corresponding declines in lower plants that characterise these extremely restricted woodland types.

2.2. Interactions with species

2.2.1. Freshwater fish assemblages

Overview

Beavers, as habitat engineers, have the ability to dramatically alter the water environment in ways that have the potential to impact fish in both positive and negative ways. The consequences of habitat changes will vary depending on a multitude of factors including the fish species in question, its life-stage, river/lake typology, beaver dam characteristics and longevity, and other environmental conditions such as flow and temperature. Impacts are also likely to be dynamic and will vary both spatially and temporally.

Natural England Review conclusions

"Evidence from research published since the production of the Scottish Review continues to present a complex and often contradictory picture on the impacts of beavers on fish populations. This reflects the high number of variables involved in assessing the potential impact of changes resulting from beaver activity such as the reference point against which change is evaluated (existing or natural reference conditions), spatial and temporal population variation, species diversity and the long timescales necessary to observe ecological responses, particularly at the population level.

Where the impacts of beaver on aquatic habitats are considered at a suitably broad temporal and spatial (catchment) scale, the increase in habitat diversity and dynamism brought about by beavers is likely to result in more diverse fish populations with greater ability to sustain themselves, particularly in the face of climate change. Ensuring there is adequate space for restoring more natural river and lake ecosystem function will help to ensure that benefits to fish assemblages are maximised."

NRW assessment of English and Scottish Reviews

In general, we found the English and Scottish reviews are detailed and comprehensive and set out the issues well.

Further research available since 2020

Since the English review Needham *et al.* (2021) investigated the response of a population of brown trout (*Salmo trutta*) to reintroduced Eurasian Beaver habitat modifications in

northern Scotland, concluding beavers had profound effects on the local brown trout population that promoted higher abundances of larger size classes.

In 2020 Cowx undertook a review of evidence of the interactions between beavers and fish and fisheries. This review was published on the Angling Trust website and was not subject to the normal peer review process for scientific publications. The review concluded that "there is a clear need for more robust studies on the barrier effects and otherwise of beaver dams on fish migration and recruitment processes". Reviews of Cowx (2020) were subsequently produced by Malison (2021) and Brazier (2021). They each concluded that the review of potential interactions between beavers and fish and fisheries was flawed and unbalanced, by focusing primarily on the potential negative impacts of beaver dams and not considering the literature that identified positive impacts.

The first IUCN Red List assessment of extinction risk for fish in Great Britain and in Wales has identified seven freshwater fish species as being threatened with extinction at the regional level, with Atlantic salmon being categorised as endangered (Nunn *et al*. 2023). Whilst not research relating to the impact of beavers on freshwater fish, it emphasises the need for greater understanding of the potential benefits and impacts on catchments where salmon populations are present.

Welsh Context

The main issues in Wales arise from differences in the native fish fauna compared to England, and in particular a higher proportion of migratory fish species which are more vulnerable to the impact of dams. The significant impacts on Atlantic salmon and sea trout identified in this section will be important in Wales, see section 2.3.4 Freshwater Fisheries for further information. Both species are already declining, and beaver activity has the potential to increase the rate of decline. Beavers are potentially likely to increase the extent of habitat suitable for invasive non-native fish such as topmouth gudgeon, and predatory native species such as pike.

Conclusion

Evidence from research published since the Scottish and English reviews continues to present a complex picture on the impacts of beavers on fish populations. The overall balance of impact (potential positive and negative) of beavers on fish will be dependent on a multitude of factors. Species considered most likely to benefit from beaver activity include brown trout and eel, but further information is needed with regards to Atlantic salmon, sea trout and bullhead which may be negatively affected.

2.2.2. Bryophytes

Overview

Bryophytes comprise the non-vascular plants: mosses, liverworts and hornworts. They play a vital role in carbon and nutrient cycling, regulate water availability, promote soil formation, and stabilise soils against wind and water erosion. They contribute to a

substantial proportion of the global plant biomass in a range of ecosystems. Many bryophytes prefer moist environments, hence are likely to be affected by beaver activity affecting trees on which they grow in wet and riparian habitats.

Natural England Review conclusions

"Evidence from research published since the Scottish Review is limited.

Increases in habitat heterogeneity and deadwood brought about by beavers are likely to benefit English bryophyte species, but case by case analyses may be required for bryophytes which are very rare or have restricted distribution."

NRW assessment of English and Scottish Reviews

Wales is more akin to Scotland in terms of its Global importance for oceanic bryophytes than is England. Therefore, the conclusions of the Scottish review are more applicable to Wales, because of our greater extent of oceanic woodland, than those of the English review.

There are no apparent gaps in evidence from either of the previous reviews and we broadly agree the conclusions are applicable in Wales.

Further research available since 2020

Since the English review there has been very limited further relevant research published would that significantly changes these conclusions.

Welsh Context

There is some potential for damage to epiphytic bryophytes alongside rivers, for example the mosses Many-fruited Cryphaea (*Dendrocryphaea lamyana)* and Flood Moss (*Myrinia pulvinata)* which are usually found on just a small number of trees per river. Results from Knapdale, detailed in the Scottish Review, found that within Atlantic hazel habitat beaver activity may eventually result in the permanent or temporary localised loss of a globally restricted lichen habitat. The impact was restricted to a maximum of about 60 metres from a loch and within woodland on gentler, less bouldery slopes. Within this zone, 24% of stems had been felled, affecting just over half of the stools. Whilst these figures relate to lichens they serve as an example of the potential impacts to bryophytes growing on riverside trees.

The Scottish review states: "The Scottish landscape has changed significantly since the national extinction of beavers several hundred years ago. In this time, habitats have been subject to disturbance through often drastic changes in land use (e.g. conversion to conifer plantations). Hence, many areas, such as Knapdale, have suffered severe habitat reduction, and ancient woodland lichen, bryophyte and fungus populations could be described as remnants, only now beginning to recover. Beavers have the potential to reintroduce a further source of habitat disturbance, albeit one that occurred as a natural component of the landscape in the past. Whether habitats, particularly those that support ancient woodland species, have the resilience to withstand additional disturbance should be a key consideration when interpreting the information available on the effects of beavers." This is even more true of the much-altered landscape of Wales, and many

species that would once have been widespread across Wales are now surviving only in a handful of SSSIs. When their populations were widespread they would have been resilient to some loss from beaver tree felling, or the flooding of the streamside boulders on which they grew, but pollution and habitat change leave many species with nowhere to go if their one niche is lost to beaver activity.

Conclusion

Beavers have the potential to cause damage to bryophyte-rich riparian woodlands, especially in the oceanic 'rainforests' of north and west Wales, particularly if they dam smaller rocky streams and inundate rocks with oceanic liverworts growing on them. They also have the potential to fell important host trees for a small number of very rare mosses alongside lowland rivers. Potential impacts are highly localised, but if beavers become genuinely wild in Wales then damage cannot be ruled out. Potential benefits to bryophytes are very compared to potential (if localised) damage.

In the right place, beavers can enhance habitats and produce niches for diverse species, but in the wrong place they are a potential threat to the survival of some of our rarest plants. Careful consideration is needed to assess how predicted beaver habitat overlaps with habitats for Wales's vulnerable and rare species of bryophyte.

2.2.3. Fungi and lichens

Overview

Riparian woodland and trees can be an important habitat for lichens and fungi in Wales, supporting species and assemblages significant at national and European scales. Old riverside trees provide a refugium in unmanaged woodland and are more buffered against the impacts of climate change. However, occupation rates of specialist lichens, many of which are threatened or rare species, are naturally low so there is uncertainty regarding whether beaver will negatively impact their populations.

Natural England Review conclusions

"Since the Scottish Review there has been limited further relevant research related to fungi and lichens. The impacts on lichen species across England are likely to vary and will not be known for many years. While there is no direct evidence in England, published literature from other countries, and expert opinion, suggest that generalists, ephemeral and deadwood species will benefit, whilst specialist epiphytic lichens, especially those associated with old trees, will gradually decline in beaver occupied areas. However, the significance of such changes at a landscape scale are uncertain.

Fungi are dominated by rare species at local levels and are considered highly sensitive to woodland structural change. Both mycorrhizal and deadwood fungal species richness have been shown to increase with tree and woodland age and tree species diversity. In addition, ectomycorrhizal fungal diversity is positively related to canopy cover, whilst saprotrophic fungi of fine woody debris benefit from canopy gaps. Beavers have the potential to

influence all of these at local scales. Whether species extirpations at such scales are compensated by increased habitat heterogeneity at a landscape scale is uncertain.

Further research is required to understand the influence of beavers on relevant species and assemblages of fungus and lichen in England."

NRW assessment of English and Scottish Reviews

The conclusions are broadly applicable, although oak mycorrhizal and beech saprotrophic fungi are less significant in Wales than in England. Aspen and Hazel woodland are relatively rare in Wales, although Hazel supports very significant lichen assemblages in parts of Meirionnydd, Ceredigion, Carmarthenshire and Pembrokeshire. Shading of riverine lichens is an issue in Wales, highlighted in reports on river stippled lichen (*Endocarpon adscendens)* by the Usk, so there are potential benefits in limited areas.

Potential mitigation options risk damaging lichen communities, for example protecting trees with paint/mesh is likely to directly damage lichens, whilst fencing off riparian woodlands is likely to allow damaging growth of brambles and ivy.

Further research available since 2020

Since the English review there has been very limited further relevant research published would that significantly changes these conclusions.

A National Strategy workshop for beavers in Scotland held in February 2022, recommended that the British Lichen Society data be utilised to identify initial constraints and help highlight the most sensitive and most threatened areas (British Lichen Society 2022). Survey data from Welsh lichen sites, notably in riparian woodlands in the Dyfi Forest of NW Powys is available.

Welsh Context

Overall, the England review considers beavers and lichens issues well. However, the conclusions risk underplaying the issues by suggesting its significance is "uncertain". The problems in some areas of Wales are the same as those in parts of England: internationally important lichen communities are often found on riverside trees, and the populations of many of those lichens are now so small that the loss of one or two host trees could significantly impact a population. These Welsh lichen populations have been forced back to a few refugia by pressures such as air pollution and the historic felling of veteran trees, and their populations are now far less resilient. The felling of riverside trees by beavers in key lichen areas in Wales could significantly threaten internationally important lichen populations.

The review correctly highlights that some lichens (and other species) will benefit from beavers, but the species which will benefit are those of younger habitats and those are by definition less threatened than species of older habitats - widespread establishment of beavers will potentially create relatively common habitats at the expense of relatively rare ones.

The review covers non-lichenised fungi well, but there are not such significant potential problems for non-lichenised fungi in Wales than there are for lichens.

Conclusion

Numerous rare and threatened lichens grow on trees that could be felled by beavers, and as such beaver reintroduction poses a significant threat to Welsh lichens in some locations. Some benefits might occur along shaded rocky rivers, but these are limited in extent. Potential mitigation options to prevent negative impacts in sensitive areas can in themselves be damaging to lichens. Even though rare lichens are concentrated in certain parts of Wales, such as Powys, Meirionnydd, Ceredigion and Pembrokeshire, the successful reintroduction of beavers could lead to these areas being impacted as well as the less lichen-rich parts of Wales.

Fungi are considered highly sensitive to woodland structural change so further research will be required to understand the influence of beavers on key species and assemblages of fungus and lichen in Wales.

2.2.4. Vascular plants

Overview

Beavers exploit both terrestrial and aquatic vascular plant species for food and gather mainly terrestrial woody species for the construction of their dams and lodges. Their 'engineering' activities result in enhanced habitat heterogeneity which generally increases vascular plant species diversity at the landscape scale.

Natural England Review conclusions

"Research published since the Scottish Review is limited but complements existing studies demonstrating that increased habitat heterogeneity and dynamism is likely to benefit vascular plants at the landscape scale.

Further work is required to investigate the impacts on locally occurring rare or threatened species, particularly those whose habitats are likely to be directly impacted or whose morphologies are known to be favoured for food, making them particularly vulnerable to exploitation by beavers."

NRW assessment of English and Scottish Reviews

We broadly agree with the conclusions of the previous reviews that the activities of beavers are likely to be positive. However, there is little available evidence regarding impacts on threatened vascular plants, and although increased habitat heterogeneity is a positive of beaver presence and habitat engineering, it is dependent on that landscape not being constrained or 'squeezed' by manmade infrastructure.

Further research available since 2020

Since the English review there has been limited further relevant research. Orazi *et al.* (2022), studied the effects of beavers on the terrestrial biodiversity of eight taxonomic groups by comparing beaver ponds with river and forest habitats in a mountain forest

ecosystem in Central Europe. Analysis showed no difference in the number of species, abundance, or community composition of terrestrial vascular plants between the beaver ponds and river plots.

Welsh Context

The conclusions from the England review are applicable to Wales, particularly given the extent of intensive land use causing fragmentation of plant populations and this being a cause of increased threat.

Regarding Killarney Fern, one of Wales's rarest plants, the sporophyte generation has a very restricted distribution and these are unlikely to be impacted by beaver activity. The gametophyte generation is more widespread and it is feasible that populations of this could become inundated through beaver activity.

Conclusion

No evidence is available for the preferential or differential effects of beaver activity and exploitation levels for almost all of the threatened Welsh vascular flora species. Strong evidence suggests that increased habitat heterogeneity and dynamism is likely to benefit vascular plants at the landscape scale. However, further work is required to investigate the impacts on locally occurring rare or threatened species, particularly those whose habitats are likely to be directly impacted or whose morphologies are known to be favoured for food, rendering them particularly vulnerable to exploitation.

2.2.5. Invertebrates

Overview

Invertebrates represent a large proportion of the animal diversity within riparian and wetland habitats. The impact on invertebrates by beavers is likely to be from two main sources: direct impacts on modification of specific niches and a more generalised habitat shift as a result of beaver activity over time. Invertebrates perform various ecological functions, consequently their abundance and distribution are likely to affect other vertebrate species.

Natural England Review conclusions

"Evidence from research published since the Scottish Review presents a sometimes contradictory picture on the effects of beavers on invertebrates. Whilst the high variation in microhabitat diversity caused by beavers is expected to benefit riparian invertebrate species overall, the development and presence of beaver dams, which alter physical and chemical characteristics of streams, will create change in the balance of functional characteristics and hence species composition of macroinvertebrate assemblages.

Impacts from beaver activities on remaining populations of freshwater pearl mussels and white-clawed crayfish in England are expected to be complex, with both positive and negative impacts at differing times. Due to the very restricted distribution and vulnerable

nature of populations in England, appropriate management and action would be required if beavers colonise rivers where freshwater pearl mussels occur.

Overall, the activities of beavers are likely to have differing effects on different invertebrate groups at different times and locations. Such changes are expected in the process of restoring natural function to freshwater and associated ecosystems, restoring lost diversity, dynamism and ecological resilience in the face of climate change. Local assessments should be undertaken to identify potential risks to those species of conservation concern and/or restricted distribution."

NRW assessment of English and Scottish Reviews

Although, we broadly agree that the conclusions can be expected to apply to Wales, the very different environmental context for some studies introduces uncertainty regarding the transferability. Notable problems are likely to be existing or newly translocated freshwater pearl mussel sites and white-clawed crayfish sites, and localities where lentic invasive invertebrates are established.

Further research available since 2020

There is increasing research on how beavers affect riverine aquatic macroinvertebrates, such as Washko *et al*. 2022; Nummi *et al*. 2021b; Bylak & Kukuła 2022 and Hood *et al*. 2021; these publications all support the existing body of evidence.

Andersen *et al.* (2023) demonstrates that the reintroduction of beavers has a profound effect on the riparian zone as indicated by the increased moth richness and diversity as well as increased greenness and habitat heterogeneity found at beaver sites. Thus, when reintroducing beavers the effects are not limited to the aquatic environment but spans into the riparian zone.

A review undertaken by Larsen *et al*. (2021) suggest that beavers can increase not only the diversity of invertebrate species in the habituated stream section, but also potentially throughout entire stream reaches through the pervasive increase in large woody debris increasing the abundance of macroinvertebrate taxa specialised in wood herbivory. However, these larger spatial scale effects of increased large woody debris on macroinvertebrate assemblages depend strongly on the local hydro-geomorphologic conditions and requires further study in order better understand the influence of beaver impacts on macroinvertebrates in the aquatic food chain across a gradient of stream order sizes.

Welsh Context

In a Welsh context there are significant concerns regarding the potential vulnerability of freshwater pearl mussel to beaver activity. Although a large and healthy pearl mussel population can be expected to be resilient to change, freshwater pearl mussels in Wales are Critically Endangered and restricted to a few locations. Beaver activities in these locations could result in serious impacts to freshwater pearl mussel populations. The potential issues are discussed in the English review which identifies impacts from three potential sources:

- Hydraulic (flows) and structural changes to watercourses from beaver impoundments.
- A more generalised habitat shift and increased habitat heterogeneity through beaver activity (e.g. tree felling, increased woody debris, alteration of riparian woodland).
- Indirect effect on salmonid fish host through impeding migration and access to spawning areas.

By shifting macroinvertebrate communities away from lotic species towards lentic species, beavers may also cause a reduction in some river quality indices. However, beavers should also increase the extent and water quality of existing river habitat. The net effect of this is unclear. For example, freshwater invertebrates associated with fast flow e.g. *Simulium morsitans* (only UK locality is on Afon Teifi at Cors Caron) or riffles e.g. *Macronychus quadrituberculatus*, *Riolus nitens* and *Stenelmis canaliculata* could be impacted. Freshwater species with highly restricted distributions should also be taken into account e.g. *Hydroporus rufifrons* (Afon Teifi), *Isogenus nubecula* (River Dee), *Potamanthus luteus* (River Dee & Wye), *Setodes punctatus* (River Wye) and *Ylodes simulans* (River Dee).

There is little reference to terrestrial invertebrates in the English review other than the Scottish review findings for those associated with aspen woodlands. The Welsh fauna associated with aspen is impoverished compared to Scotland and any impact will be very localised. Impacts upon saproxylic invertebrates will also be localised. There could be losses of Exposed Riverine Sediments to raised water levels which has the potential to impact rare species and assemblages of a fauna already under stress from habitat loss and succession. These are likely to be localised but should be assessed as part of any beaver release programme.

Conclusion

In general beavers can be expected to benefit freshwater invertebrates by diversifying habitat, increasing habitat area, stabilising flow and reducing pollution below dams. However, there are key concerns around freshwater species that mainly relate to scarce or endangered species that require running water and where beaver activity may damage or destroy their habitat. Also, with respect to invasive non-native species that may have the potential to exploit beaver habitat.

2.2.6. Amphibians and reptiles

Overview

Beavers are likely to have a positive overall effect on reptile and amphibian distribution, diversity and numbers by modifying both aquatic and terrestrial habitats, although this influence is expected to be higher for amphibians. The impact on amphibians will mainly come from two sources: the creation of beaver ponds, and foraging canals which will provide habitat and function as movement corridors for emigrating young.

Reptiles will benefit from tree felling providing increased opportunities for thermoregulation. Grass Snake (*Natrix helvetica*) is most likely to benefit from beaver activity, as it feeds largely on fish and amphibians. The species could also benefit from beaver lodge structures in which to lay eggs.

Natural England Review conclusions

"*Evidence since the Scottish Review on the effects of beavers on amphibians demonstrates a positive effect. Research on reptiles is more limited, but where studies have been undertaken, they support the existing body of evidence that beavers can improve reptile biodiversity.*

The effects of beavers on amphibian species in England is generally positive due to the creation of new ponds and wetland areas which provide habitat for breeding, foraging and dispersal. The grass snake is also expected to benefit from the habitat created. Adders prefer drier soils so local distribution of this species may be negatively affected."

NRW assessment of English and Scottish Reviews

The English review identifies and balances positives with and possible negatives. There appears to be no difference in conclusions applicable to England over that in Wales.

Further research available since 2020

There is no additional recent evidence to consider in this chapter. It is well referenced, well written and balanced.

Conclusion

Potential negative issues are identified for amphibians from the possible spread of predatory fish and for reptiles from the inundation of winter hibernacula and the loss of dry terrestrial habitat. However, overall beaver habitat creation will benefit amphibian and reptile populations in Wales.

2.2.7. Birds

Overview

It is well documented that the activities of beavers are of benefit to a range of avian species by creating wetland systems and increasing the available habitat for feeding and breeding. Wetland areas created by beavers can significantly increase bird biodiversity and are quick to take effect, with numbers much higher in comparison to surrounding areas. It has also been shown that beavers act as a whole-community facilitator for waterbirds and that favouring beavers is a worthwhile tool in restoring wetlands to promote waterbird communities.

Natural England Review conclusions

"*Since the Scottish Review there has been limited further relevant research related to birds. Where studies have been undertaken, they support the existing body of evidence that demonstrates the generally positive benefits of beavers for birds through the creation*

of wetland areas and increased habitat heterogeneity resulting in additional ecological niches for birds to exploit.

There is no evidence that bird biodiversity is likely to be negatively affected by the activities of beavers."

NRW assessment of English and Scottish Reviews

We broadly agree with the overall conclusions that generally beaver reintroductions could have a positive impact and result in greater bird diversity and abundance.

Further research available since 2020

Since the English review was undertaken there has been limited further relevant research related to birds. Where studies have been carried out, such as Orazi *et al.* (2022) and Fedyń *et al.* (2023), they support the existing body of evidence that there is a greater bird species richness and abundance on water bodies modified by beavers.

Welsh Context

Willow tit and lesser spotted woodpecker populations in Wales are likely a beneficiary species with an increase in deadwood and greater structural diversity. It is unclear whether the presence of beavers would facilitate the colonisation of more species of breeding water bird Wales, such as great white egret, spoonbill and purple heron. In areas where deer browsing already presents a land management issue for woodland regeneration, beavers could present an additional pressure.

Conclusion

Beavers create heterogenous and structurally rich/ complex habitats that are favoured by many bird species. There is no evidence that bird populations in Wales are likely to be negatively affected by the activities of beavers, beyond the local impacts as described. However, there may be a need to consider deer management to increase the potential benefits for tree pipit.

2.2.8. Mammals

Overview

The activities of beavers may affect mammal species through changes in habitat, abundance and distribution of food sources, increased structural complexity of habitat and direct provision of resting and breeding places. Mammal species of particular note are the water-dependent mammal species: European otter (*Lutra lutra*), water vole (*Arvicola amphibious*), water shrew (*Neomys fodiens*) and Daubenton's bat (*Myotis daubentonii*). Non-native American mink (*Neovison vison*), which is a significant predator on water voles, could also benefit.

Interspecific behavioural interactions may also occur, such as predator/prey relationships between beavers and predators such as foxes (*Vulpes vulpes*), otter and potentially American mink which may take young beaver kits. Indirectly, there will be impacts on these mammalian predators through changes to their other prey sources due to beaver induced changes to the habitat.

Natural England Review conclusions

"*Since the Scottish Review there has been limited further relevant research related to mammals. Where studies have been undertaken they support the existing body of evidence. This demonstrates the positive benefits of beavers for native mammal species through increased habitat complexity and food sources. Beavers may, however, also provide opportunities for increased distribution and abundance of the non-native American mink through improved habitat and prey provision. The significance of this for the native water vole is uncertain and requires further investigation. The impact of American mink generally on water voles may be exacerbated by habitat loss and fragmentation. As mature beaver habitat has been shown to be highly suitable for water voles they should benefit from increased habitat. Whether this improves their resilience to mink predation is uncertain."*

NRW assessment of English and Scottish Reviews

Although we broadly agree with the conclusions of the English review, there is minimal discussion of bat species which roost, forage and commute along in riparian corridors.

Further research available since 2020

Since the English review was undertaken a number of further relevant research papers relating to mammals have been published. Where studies have been carried out, such as Pejstrup *et al.* 2023, Orazi *et al.* 2022, Fedyń *et al.* 2022, Fedyń *et al.* 2023, Sundell *et al.* 2021, Wikar & Ciechanowski 2023 and Wikar *et al.* 2023, the findings support conclusions from the existing body of evidence. This demonstrates the positive benefits of beavers for native mammal species through increased habitat complexity and food sources.

Most recently Puttock *et al.* (2023) presented data showing the expansion of water vole into wetland areas shaped by beaver activity and propose that complex beaver wetlands may benefit water vole populations by creating new habitat and providing refuge from predation, warranting further investigation as a nature recovery option. Water voles are most vulnerable to predation in simplified, linear channels; studies have demonstrated that where complex wetland habitats remain, water vole have higher resilience. Therefore, beavers are creating new wetlands which may provide water voles with resilience to predation pressures.

Welsh Context

There is limited discussion of potential impacts to bat species. Studies have found a general increase in bat activity within beaver habitats; beavers create complex wetland habitat and standing dead trees which may offer additional foraging and some additional roosting habitat for species such as pipistrelle bats and Daubenton's. This must however be balanced with some loss of live trees already capable of supporting roosting bats, along with the opening up of previously dark riparian corridors. This latter point may reduce connectivity for bats through beaver territories by both reducing connecting tree lines and

by removing the sheltering effect of riparian trees i.e. increase light levels and wind exposure, although this does depend on the tree species and whether beavers 'coppice' rather than remove trees in the long term. From a Welsh perspective, one of the greatest impacts of this could be to lesser horseshoe bats, however this may be balanced with creation of more complex, structured habitats. Equally, the impact of commercial forestry operations and other anthropogenic tree felling works on lesser horseshoes will require additional considerations when in proximity to beaver territories, as retaining riparian tree corridors is often required in mitigation and is factored into Habitats Regulations Assessments. Related impacts will depend on the specific location, and the level of coppice regrowth, however while it deserves due consideration, overall impacts on bats are unlikely to be significant while overall positive impacts may well be seen.

The harvest mouse is not mentioned within the English review but it is considered there could be a positive impact as the habitats created by beavers may be suitable for the species.

Finally, evidence suggests mature beaver habitat has been proved to be highly suitable for water voles and that they should benefit from created habitats.

Conclusion

Taking all the evidence into account and considering the possible impacts on landscape connectivity for horseshoe bats, it is concluded that overall beavers are likely to positively influence native mammal fauna in Wales.

2.3. Interactions with people

2.3.1. Public attitude and perceptions

Overview

Social science research approaches and methods (qualitative, quantitative and mixed) can be used to better understand individual and community attitudes and experience of benefits and disbenefits of beaver reintroduction. Social science can also be used to explore the underlying values and behaviours of those involved, and the social, cultural, political and historical contexts under which these are formed and enacted. It can also help to identify best practice approaches to stakeholder engagement. All of which can be employed to develop better approaches to reintroduction and management options.

Natural England Review conclusions

"*Evidence since the Scottish review on social science related to beaver reintroduction is limited, but growing, and suggests that stakeholders and the public are generally supportive of beaver reintroductions. There are some notable exceptions to the generally favourable view, typically amongst those negatively affected. Evidence suggests that this is linked to the fact that the impact of beaver reintroduction is not distributed evenly and*

the costs are disproportionately borne by a small number of individuals while the benefits accrue to society.

There is potential for conflict related to beaver reintroduction in certain contexts and amongst certain groups, including landowners and farmers in specific geographies, anglers and commercial fisheries and specific communities living close to reintroductions.

Conflicts can be heightened when linked to perceived legitimacy of releases, mis-trust between parties and in management processes, power imbalances (including feelings of not being listened to), differences in value sets and identities, and where scientific information is partial, uncertain, or perceived differently. There is evidence that dialogue improves trust and can help reduce conflict, and that engagement can support attitudinal change (though further research is needed to understand how this is sustained).

There is a widely held view that getting the management of beaver impacts right is important and concerns about the lack of agreed measures to address any emergent problems quickly (hence support for culling by some stakeholders).

Better integration between the social and natural sciences is needed to understand the social context of beaver reintroduction and to inform effective management. Social research methods should be incorporated into longer term monitoring and evaluation to understand 'what works' in reducing conflict and supporting co-habitation of people and beavers, both relating to reintroduction and longer term management as beavers start to expand their range."

NRW assessment of English and Scottish Reviews

Although we broadly agree with the conclusions, more research is needed to understand beaver reintroduction in the Welsh context, in particular with a focus on understanding the relationship between beaver re-introduction and cultural ecosystem services.

Further research available since 2020

There has been a growing amount of research published since the English review was undertaken. Larsen *et al*. (2021) noted that beavers have an 'amazing capacity' to engineer streams across a wide spectrum of environmental gradients, which also shapes a range of positive and negative perceptions concerning their influence. And even though the positive benefits are numerous, conflicts can arise from an overlap of preferred habitats by both humans and beavers, misunderstandings of how beavers modify their habitats, and a lack of planning or use of adaptive management on restoration projects (Pollock *et al*. 2023). Auster *et al*. (2022a) considered public attitudes towards the role of beavers in Natural Flood Management. They identified that there are polarised viewpoints on the role of beavers in flood management with real diversity in the values held among communities downstream of beavers in England. Auster *et al*. (2022b), learning from the experiences of the River Otter Beaver Trial steering group, suggest the adoption of the term 'renewed coexistence' for a reintroduced species which was present in the landscape historically, but which will likely be a 'new' presence for people living in the locality post-release. They suggest that renewed coexistence is more likely to be achieved and sustained with effective project governance and early stakeholder engagement.

Gandy and Watts (2021) explore the psychological benefits of beaver reintroductions, their literature review concluding that if reintroduction efforts are well-planned with a viable management strategy in place, clear communication and support provided to all involved stakeholders, and positive, socially connective community-led initiatives applied, potential issues that may arise are far from insurmountable. Oliveira *et al.* (2023) considers public attitudes in Kent, the findings suggesting the need to strengthen cooperation between nature conservationists and local communities and incorporate public views on beaver management decision-making process, in order to prevent potential future conflicts from establishing. Campbell-Palmer *et al.* (2022) discuss how unofficial beaver releases have presented challenges in terms of sourcing and genetics, health status and disease risks, the risk of introducing the non-native North American beaver species and the lack of engagement with communities and resulting conflict. It is concluded that agreed approaches require development using multi-stakeholder approaches to recognise and promote benefits whilst sensitively managing beavers' impacts on people's livelihoods.

Auster *et al*. (2023) reviewed the role of Beaver Management Groups (BMG) to capture lessons from existing groups in England. They identified that BMGs are not a fixed structure but are a dynamic process that must have the capacity to adapt to changing circumstances. They concluded that this evolution is influenced by resource availability and national policy direction and that sufficient flexibility is needed to facilitate a sustainable coexistence.

Exeter University undertook a public attitudes survey in spring 2023 on behalf of North Wales Wildlife Trust (NWWT). The research aims to better understand public attitudes towards beaver reintroduction in Wales which will inform NWWT's licence application to NRW for a wild release of beavers in the Dyfi catchment. The report has not yet been published.

Welsh Context

The context in Wales is different (less populated and less man-shaped landscape), so more research is needed to understand beaver reintroduction in this context. The summary of the English report describes unsupportive attitudes from anglers and landowners/farmers. Both groups have significant interest in environmental decisions taken in Wales and so more engagement with these specific groups would be needed to ensure proper consideration of views.

From the research that has been undertaken, it seems that the following points should be taken into consideration for the Welsh context:

- Most people seemed favourable or without opinion towards the re-introduction of beavers in Scotland or England.
- Those who were strongly opposed were more likely to be the ones potentially bearing the most cost (landowners/farmers) and anglers (who saw beaver re-introduction as an additional barrier for the reproduction of Atlantic Salmon), and ad-hoc communities.

Conclusion

The following socio-cultural considerations were highlighted by previous studies and should be considered in a Welsh context for any reintroduction programme:

- The current human uses of the land and rivers systems.
- Population density of beavers (and humans).
- Trust and confidence in management processes (and institutions/ professionals).
- Trust and dialogue between stakeholders.
- Awareness of beavers and management processes.
- Provenance and legality of beaver population.
- Decision making processes and governance.
- Efficacy of management response to any problems or issues arising.

2.3.2. Economic benefits and costs

Overview

Reintroducing beavers can generate a range of benefits for society and the economy. For example, beaver activity can reduce the risk of flooding, allow people to enjoy wildlife experiences, create volunteering opportunities and provide ecosystem services for humans.

This section summarises the available evidence on the impacts of beaver reintroductions that have been valued in existing studies, i.e. monetary costs and benefits.

Natural England Review conclusions

"Reintroducing beavers can generate a range of both positive and negative aspects for society, the environment and the economy. Limited evidence exists on the monetary benefits and costs of wild and reintroduced beavers across a wide range of contexts and this evidence is insufficient *to assess the benefits and costs of a full reintroduction of beavers into England. There are three reasons for this; i) evidence on costs and benefits is location-specific and reintroducing beavers to different locations may not result in the same type and/or magnitude of benefits and costs, ii) how benefits and costs evolve with time and beaver population densities needs to be understood better and iii) appropriate management and* mitigation *strategies need to be identified as part of a reintroduction to maximise the benefits and minimise the costs of beaver activity.*

Recommendations for future cost benefit work to allow this analysis are provided and should be considered as a priority for future research."

NRW assessment of English and Scottish Reviews

We agree with the English report view that more evidence is needed to obtain an understanding of the monetary impact of beaver reintroductions. Among other things, an understanding is needed of how benefits and costs evolve with time and beaver population densities and what management and mitigation strategies should be part of a reintroduction to maximise the benefits and minimise the costs of beaver activity.

Further research available since 2020

In Portugal Veríssimo & Roseta-Palma (2023) analysed the monetary values associated with avoided river-restoration costs and concluded that beavers will save millions of euros in interventions. Brazier *et al.* (2021) suggests that effective management strategies should consider the beneficiaries and cost-bearers in a holistic manner, bridging the distinctions within a closed-loop management system.

Welsh Context

Reintroducing beavers can generate a range of benefits for society and the economy. As ecosystem engineers their activities can increase the supply of ecosystem services such as water purification, moderation of extreme events, habitat and biodiversity provision, nutrient cycling, greenhouse gas sequestration (Thompson *et al*. 2021). The ROBT found that there were economic benefits that had resulted from an increase in visitors to see beavers and that the economic benefit was greatest where businesses actively sought to maximise the opportunity (Auster *at el.* 2020). However, they noted there may need to be consideration of other potential local issues and challenges which may contribute towards (whether directly or indirectly) in the uptake of the new wildlife tourism opportunity (Auster *et al.* 2020), as well as the need to protect animal welfare. Also, evidence on costs and benefits is location-specific and reintroducing beavers to a different location, such as rural Wales will not result in the same type and/or magnitude of benefits and costs as on the River Otter. Robust cost benefit analysis is needed in the Welsh context to consider the potential benefits which could include: increased business turnover; opportunities for recreation and volunteering; educational benefits; alleviation of flood and drought risk.

Evidence since the English review on social science related to beaver reintroduction is growing and suggests that stakeholders and the public are generally supportive of beaver reintroductions. However, there are exceptions especially from those that stand to be negatively affected, due to the fact that the impact of beaver reintroductions is not distributed evenly and the costs are disproportionately borne by a small number of individuals while the benefits accrue to society (Howe, 2020).

Conclusion

More work is needed in a Welsh context to understand how the benefits and costs would develop with time and what management and mitigation strategies should be part of a reintroduction to maximise the benefits and minimise the costs of beaver activity. Where appropriate, benefits and costs are explored in more detail in following sub-sections with respect to different management themes.

2.3.3. Water management issues

Overview

The creation of natural dams through beaver activity, with their associated wetting and flooding of adjacent land, can help restore natural hydrological and related sediment

processes and improve water quality through water attenuation and sediment storage. This creates decreased peak flows and extension of lag times by increasing storage capacity, channel complexity and surface roughness.

Natural dams can contribute to drought resilience by maintaining base flow, storing water during dry periods and raising ground water tables. In addition, natural dams capture fine sediment so helping to in-fill artificially deepened channels and improve water quality downstream by filtering out pollutants.

Natural England Review conclusions

"*Strong evidence from England and Europe since the Scottish Review strengthens our understanding that beavers can have a wide range of positive effects on water-related ecosystem services associated with restoring natural hydrological, sedimentological and geomorphological processes. This includes helping to restore: i) catchment water storage, improving the resilience of water supplies; ii) generating natural attenuation of flood flows in rivers, reducing downstream flood risk; and iii) natural processing of nutrients and fine sediments, benefiting downstream water quality. The scope for benefits varies with the scale of influence of beaver activity in different environmental conditions.*

Whilst beavers can play a positive role in restoring the natural processes upon which water management depends, it is important not to over-estimate this role in ways that might undermine strategies for addressing impacts on natural processes at source. Impacts on natural processes (abstraction and water diversion, diffuse and point source pollution, drainage, physical modifications to rivers, streams and lakes) are many and varied and need to be tackled through concerted and strategic restoration plans, providing beavers with a foundation upon which to add their beneficial contribution.

Improved understanding of the influence of beavers on water objectives at the catchment scale is needed, together with continued development of tools that help to increase benefits and identify when management is needed to address conflict."

NRW assessment of English and Scottish Reviews

We broadly agree with the overall conclusions that generally beaver reintroductions could have a positive impact on water quality, water resources and flood risk management. Beaver activity could also have a significant positive impact on water resources by stabilising and increasing base flows, and on flood risk by reducing the height of flood peaks. However, many Welsh rivers and streams are highly modified with high nutrient and sediment loads; beaver activity in these locations may have the potential to exacerbate these issues. Evidence suggests that rivers and streams that have more natural nutrient and sediment regimes are much more likely to benefit from beavers, adding heterogeneity of habitats associated with high quality environmental conditions.

Beaver activity is not a substitute for tackling impacts on catchments (such as pollution, over-abstraction, and artificially exacerbated flood risk) at source, but can enhance water-related ecosystem services, especially where suitable measures have already been taken to restore natural ecosystem function to the headwater areas of catchments.

Further research available since 2020

There have been new literature reviews on the ecosystem services provided by beavers related to water management issues. Brazier *et al.* (2021) provides a review on how beavers impact: ecosystem structure and geomorphology, hydrology and water resources, water quality, freshwater ecology, and humans and society. It concludes by examining future considerations that may need to be resolved as beavers further expand in the northern hemisphere with an emphasis upon the ecosystem services that they can provide and the associated management that will be necessary to maximize the benefits and minimize conflicts.

Another review, undertaken by Larsen *et al.* (2021) examines the current state of knowledge on how beavers influence the structure and function of river corridors. This report is consistent with very strong evidence elsewhere that the activity of beavers can modify the supply of water and sediment and increase the supply of wood to watercourses.

Overall, the findings were that beaver dams can:

- increase surface and subsurface water storage.
- modify the reach scale partitioning of water budgets.
- allow site specific flood attenuation.
- alter low flow hydrology, increase evaporation.
- increase water and nutrient residence times.
- increase geomorphic heterogeneity.
- delay sediment transport, increase carbon.
- nutrient and sediment storage.
- expand the extent of anaerobic conditions and interfaces.
- increase the downstream export of dissolved organic carbon and ammonium.
- decrease the downstream export of nitrate.
- increase lotic to lentic habitat transitions and aquatic primary production.
- induce ‘reverse’ succession in riparian vegetation assemblages.
- increase habitat complexity and biodiversity on reach scales.

It is important to note that considerable knowledge gaps and outstanding questions remain.

Welsh Context

Many Welsh catchments are flashy (i.e. prone to sudden or rapid flooding and extreme low flows). Catchment land management over time has increased these issues due to increased installation of drainage ditches, bank reinforcement, destruction of wetlands and removal of trees. At the same time, climate change is causing drier summers and wetter winters. All of these issues result in larger fluctuations in water levels and increased likelihood of pollution events.

Beaver activity can help to mitigate these impacts by stabilising flows and increasing drought and fire resilience (Fairfax & Whittle 2020). They can also have a positive impact on the geomorphology by allowing the channel to re-naturalise. The magnitude of this effect at a catchment level is not clear, but it has the potential to be significant. However, there are some notable exceptions to the generally favourable view, typically amongst those negatively affected.

There are situations however when water stored behind beaver dams, could have a negative impact, for instance risks associated with dam failure (Howe & Crutchley 2020). Beaver ponds can also trap and store potential pollutants, such as large quantities of phosphorus, due to unsustainable management of the catchment land. In these situations where water is being held by a beaver dam and phosphorus is retained it could result in algal blooms, this has been known to occur in areas such Llangorse Lake. Therefore, any proposals for beaver reintroduction should consider any potential exacerbation of impacts on already degraded ecosystems and should seek to target systems that have reasonable levels of natural function.

Conclusion

There is evidence to suggest that in the right locations beaver reintroduction programmes can act as nature-based solutions reducing concentrations of suspended sediment, nitrogen and phosphate, restoring rivers to a more natural state (Puttock *et al*. 2017; Brazier *et al*. 2021). In general beavers are also expected to have beneficial effects on flood risk by reducing peak flows. Beavers are becoming a highly rated as a tool for river restoration, which has useful implications for water management especially where impacts of climate change need to be considered (Larsen *et al*. 2021). However, more long-term work (including mapping to look at suitable locations) is needed to understand the success beaver populations can provide to these ecosystem services along with any potential negative impacts such as documented examples of beaver burrows damaging flood defences. There are also catchments with existing pollution sources which could be exacerbated by the creation of beaver dams.

Beaver presence will generally be positive for water management objectives but is not a substitute for catchment-based water management actions to deal with impacts on water and the water environment at source. There will also be broader socio-economic issues arising on riparian and floodplain land, associated with localised flooding, impacts on assets and infrastructure, land drainage and site-specific (often time-limited) restrictions on fish passage. Catchment-scale ecological and water benefits do not offset site-level impacts on land and water use for the individuals affected. Therefore, continued understanding of catchment-scale effects of beavers is needed in Wales.

2.3.4. Freshwater fisheries

Overview

The potential interactions between beavers and fish (see section 2.2.1 Freshwater Fish Assemblages above) represent the principal interactions between beavers and fisheries, both recreational and commercial. In this context, ‘fisheries’ are considered to represent the exploitation of the ‘fish’ resource, i.e. the activity of fishing. Although there are some fisheries for salmon and sea trout, current byelaws aimed at protecting stocks mean all salmon are protected and sea trout take is restricted. Most of the freshwater and migratory fisheries likely to be affected are recreational and are known to deliver a variety of socio-economic and health and wellbeing benefits.

This human socio-economic element distinguishes the interactions between beavers and fisheries from the interactions between beavers and fish, though many aspects are intrinsically linked.

Natural England Review conclusions

"*The limited understanding of impacts of beaver activity on some commercially [SIC] significant fish populations and lack of published data considering the potential implications for fisheries make it difficult to fully determine the effects, positive and negative, of beavers on fisheries. Angling and the attitudes of anglers to beavers adds another dimension to an already complex mix of factors relevant to beaver-fishery interactions.*

Improved understanding of the balance of benefits and risks to migratory fish populations is needed to evaluate the implications for fisheries for these species. Interactions between beavers and migratory salmonids are of concern given the status of sea trout and salmon stocks in England. Shads, smelt, river and sea lamprey should also be considered as there is potential for loss of connectivity between feeding and spawning grounds resulting from the construction of beaver dams.

The potential effects of beavers on the types of small stillwater fisheries common across England are not widely considered in the available literature, though are likely to be dependent on their proximity to watercourses."

Scotland and England Reviews

Although the conclusions are broadly applicable, the potential impacts and conflicts in Wales are arguably greater. The riverine freshwater fisheries of Wales are heavily dominated by migratory salmon and sea trout fisheries, both are subject to rapid decline, principally due to poor marine survival (presumably due to climate induced changes in marine ecology, as well as possible bycatch), poor freshwater quality arising from changing flow and temperature regimes as well as habitat fragmentation and degradation, pollution and predation. Any additional pressure to the most vulnerable fisheries is likely to exacerbate these affects.

The context in Scotland is broadly similar in that the river systems species composition and associated fisheries are dominated by salmonids. In contrast to Wales however, Scottish river systems tend to be larger, more pristine, less intensively manged for land use and with lower population densities, hence there is likely to be greater scope for them to withstand additional pressures and for beavers to have a potentially more 'natural' impact on rivers. Being at more pristine, higher latitude, and closer proximity to salmon marine feeding areas, Scottish rivers tend to have more robust salmon stocks than in Wales, and so may also be better able to withstand additional pressures.

Further research available since 2020

We are not aware of any new evidence on the impacts of beavers on freshwater fisheries *per se*, beyond that noted in section 2.2.1 Freshwater fish assemblages above. However there does need to be a recognition of the continuing rapid decline in salmon (and sea trout) in Wales, and the classification of salmon as Endangered in Wales (whilst classed Vulnerable in England and Scotland) (Nunn *et al*. 2023). In addition, there are a number of

upland lake trout fisheries, which although not unique to Wales, are probably more prevalent and economically significant than in England.

Welsh Context

The principal factors affecting both species, but especially salmon, appear to be reduced survival at sea, most likely due to climate driven changes in ocean currents, nutrients and prey availability. Climate change is also a significant factor affecting in-river survival as changes in river flows and temperatures directly influence key life stages of both species. Habitat degradation, barriers to migration, pollution, predation are also important factors, all of which may be exacerbated by the effects of climate change. Recently the Fish-eating Bird Advisory group for Wales identified that increased predation risk at downstream migration pinch points was a factor limiting salmon recovery. It should also be noted that NRW's Plan of Action for the recovery of salmon and sea trout stocks (Natural Resources Wales 2020) already seeks to address many of these factors, including an ongoing programme to remove barriers to migration and to restore degraded spawning habitat. However, current NRW fisheries surveys are constrained and targeted at discrete sites within a catchment and are unlikely to identify new barriers.

Based on the evidence presented in the English review, it appears likely that beavers may, at least in some circumstances, have an adverse effect on salmon and sea trout populations. Dam construction may impede upstream and downstream migration and will also alter river habitat suitability for spawning and juvenile recruitment. These impacts are likely to be most pronounced on smaller tributaries, especially where the amount of habitat available to beavers is constrained by adjacent land use.

We need better understanding of the potential economic impacts on fisheries above and beyond the possible implications for fish stocks. Fishing clubs and private fisheries may be impacted if anglers perceive the presence of beavers adversely affect their fishing, and there may be additional costs associated with management measures. There also needs to be some consideration of the possible socio-economic impact in Wales, especially given that fisheries are often part of the tourism economy.

Conclusion

Recent evidence shows that salmon and, to a lesser degree, sea trout face the risk of localised extinction on many of our rivers. The economically and socially important rural fisheries they support are under threat. Wide scale, catchment based, habitat interventions to improve the climate resilience of our rivers are essential if we are to mitigate these risks. The evidence available indicates clearly that beaver introductions present an additional risk to some fish stocks and hence to some fisheries.

There may however be benefits that arise for some fisheries, for example where beaver introductions are part of wider habitat restoration plan. However, it seems unlikely that beaver introduction alone will deliver these benefits for fish and fisheries. Wider scale habitat improvements, such as riparian buffer strip creation and tree planting, may provide scope for mutual benefits.

Further studies are needed to determine the potential positive and negative effects with respect to the vulnerable salmon or sea trout rivers in Wales that are designated as SACs for migratory fish.

Further information is also required on the potential impacts of beaver activity on fish migration (by creating barriers to upstream and downstream passage) and habitat changes, i.e. the quantity or quality of spawning habitat and the possible interaction with predation risk. The future impacts of climate change also need to be considered.

We need to understand the effectiveness of control measures being applied elsewhere, especially in the UK.

In summary the critical evidence gaps that need addressing to understand the impacts in the Welsh context include:

- The impacts on downstream migration of salmon and sea trout smolts.
- The impacts on salmonid juvenile and spawning habitat on streams.
- The interactions with likely climate change scenarios.
- Interaction between habitat changes and predation risk.

2.3.5. Forestry

Overview

Beavers are likely to interact with commercial forestry through tree-felling, flooding and impacts on forest infrastructure. Small-scale farm woodlands are also potentially likely to be subject to high impacts if a water course is present and if they are of a species which beavers prefer. Forestry operations that may be impacted, depending on the level of protection given to beavers in the future, include felling operations along river corridors; restocking or new planting in riparian zones; and infrastructure (road, ride and culvert) creation and maintenance.

Natural England Review conclusions

"Since the Scottish Review there has been limited further relevant research related to forestry. For the most part, the forestry sector will see minimal impacts from beavers and is well placed to accommodate their impacts provided woodland managers follow the UK Forestry Standard. This requires buffer zones along watercourses, as well as dedicated areas for the protection and enhancement of biodiversity."

NRW assessment of English and Scottish Reviews

We broadly agree with the conclusions of the English and Scottish reviews, however the impact of the preferential feeding habits of beavers are not addressed. Preference for ash, willow and aspen might result in a reduction in the ability of these species to reach maturity. Coppiced specimens will provide structural diversity but provision of timber from these species could be locally reduced. Additionally, the impact of deer browsing on the regrowth of broadleaf species following beaver activity is likely to mean that many of the

perceived benefits to woodlands of beaver presence are not achieved if deer management is not implemented.

Further research available since 2020

Further evidence published since the English and Scottish evidence reviews were completed include Mikulka *et al.* (2022a) which illustrates specific examples where damage to commercial species has been reduced by the presence of less commercial species such as willow and suggests potential parameters for buffer zones, based on those known to affect browsing by beavers, i.e., water distance, tree species composition and tree diameter. Mikulka *et al.* (2022c) suggests that by using knowledge of foraging behaviour, economically profitable species can be protected by encouraging the non-commercial species most preferred by beaver (predominantly willow) near the shoreline. In addition, the natural tree composition around rivers or lakes will be promoted. Furthermore, Juhász *et al.* (2023) proposes that beaver activity is mainly limited to the water bank, which indicates that the band situated 10–20 m from the water should be considered not primarily as an area of forest management objectives, but rather as a green corridor, a means of preserving part of aquatic and riparian biodiversity.

Welsh Context

Inundation is a risk to mature trees and is likely to alter the character of woodlands. This may be beneficial for biodiversity and increasing surface roughness creating wet woodlands that help with flooding downstream but may reduce their productive capacity. Measures referenced to protect individual trees appear simple but bring with them an additional cost implication for the landowner and may not be practical in the Welsh context.

Both the Scottish and English reports refer to minimal impacts on the forest industry due to high use of conifer species which beavers do not prefer. In Wales the management and use of timber products from all types of woodlands is promoted.

The need to make forests/woodlands more resilient means diversifying the range of tree species used and there is a drive for more native woodland, this will result in a higher proportion of woodlands being palatable to beavers. The focus of beaver activity is within the riparian zone of woodlands and here there will be benefits to biodiversity and resilience as long as other pressures do not prevent regeneration of trees in these areas, notably deer.

The preference for Ash in the current climate with ash dieback has risks. Ash dieback tolerant trees need to be retained in the environment and allowed to reach reproductive state if tolerant trees are to provide the genetic resource for future ash trees in the environment.

Impacts on forest infrastructure such as roads need to be managed carefully. The English review states: "*The impacts on forest infrastructure may be an area of conflict. Forestry operations, and in particular timber extraction, rely on a robust network of forest infrastructure such as forest roads, bridges and culverts. This is potentially a key source of conflict as beavers view pinch points along rivers, such as culverts, as preferred places for dam building. Levelling devices and culvert designs to ensure impacts can be prevented or mitigated are well understood and may need implementation*." This is relevant in a Welsh

context and guidance on techniques to prevent or mitigate impacts will need to be provided to practitioners to minimise the potential impacts. There will be costs related to retrofitting or adapting existing culverts and bridges.

Conclusion

It is expected any impact on Welsh forestry from the presence of beavers will be minimal. However, the impact of the preferential feeding habits of beavers are not addressed. Preference for ash, willow and aspen might result in a reduction of these species reaching maturity. Additionally, the impact of deer browsing on the regrowth of broadleaf species following beaver activity is likely to mean that many of the perceived benefits to woodlands of beaver presence are not achieved if deer management is not implemented.

2.3.6. Agricultural land

Overview

Agriculture is a vital part of the Welsh economy with almost 90% of land is utilised for agricultural production, and farmers hence the largest group of land managers. Only a very small proportion of this land is ever likely to be affected by the presence of beavers, but it is important to consider the implications of beaver reintroduction for agriculture in the Welsh context.

Beaver reintroduction programmes and other studies have identified multiple influences that beaver activity can have on agriculture. The significance of these influences depends upon variables such as proximity to water and vegetation available, as well as local topography, soil structure, hydrology and the vulnerability of the agricultural activity itself.

Natural England Review conclusions

"Beaver activity can have a range of impacts on agriculture, both positive and negative. Research has shown that the costs from negative impacts will be higher on intensively farmed, high value, arable land. The likelihood of any impact, however, will depend on factors such the local topography, soil structure and texture, hydrology, the type of agriculture and proximity to watercourses. Therefore, the regions of England dominated by lowland arable agricultural land on floodplains are likely to be where the potential for conflict is greatest.

At the catchment scale, the potential for positive impacts to agricultural land by beaver activity is most likely through flood attenuation, slowing the flow, and baseflow maintenance. However, those benefitting from beaver activity may not be the same as those who bear the cost, and such an imbalance has the potential to cause further conflict. A range of variables must therefore be considered collectively for any reintroduction project. Analysis using mapping software could pinpoint key areas where conflict is most likely to occur."

NRW assessment of English and Scottish Reviews

We broadly agree with the conclusions of the reviews including that the recipients of positive impacts are not necessarily the same as those who experience the negative impacts. The 2020 English review confirms the conclusion of the 2015 Scottish review, which is that beavers can have a negative impact on the production and productivity of intensively farmed low-lying agricultural land. This is supported by strong evidence elsewhere in Europe and North America, although the impacts will vary according to land use and topography. However, the topographical variations that might have an effect here in Wales.

Further research available since 2020

There are some recent studies available since the English review was completed, such as Lodberg-Holm *et al.* (2022) which highlighted that the probability of beaver foraging was reduced with wider forested buffer zones and that wheat was the most foraged species, followed by oats, barley and rye. Mikulka *et al.* (2020) in a 2-year study found that while beaver population density in the agricultural landscape remains low, damage to agricultural production is relatively insignificant; however, field crops clearly represent an important part of the beavers' diet in such areas, helping them survive in such open landscapes. Mikulka *et al.* (2022b) found that beavers in sparsely forested agricultural landscapes have adapted by utilising the diverse supply of herbaceous vegetation, though its continued presence in the landscape is still primarily dependent on sufficient stocks of woody plants, which beavers need to survive winter.

Graham (2023) discusses that the landscapes to which beavers are now returning have been significantly altered by anthropogenic land use. This land use change has had hugely detrimental impacts for natural riverine and riparian processes, with respect to their structure and function. We now rely on agriculture and infrastructure; the expansion of beaver populations can consequently result in conflict where their impacts intersect anthropogenic activity.

Welsh Context

Beaver distribution is associated with running or standing water, so potential impacts on agriculture will occur in the vicinity of streams, rivers, drainage ditches, wetlands, lakes or ponds. Once beavers occupy an area, they actively modify their surroundings to suit their needs, so they are able to use a wide range of wet environments, whether artificial or more natural. Activities likely to impact on agriculture include burrowing, canal construction, dam-building, culvert blocking, direct foraging of crops, and gnawing and felling trees. It has been assessed that 40% of Wales's woodlands are unmanaged and the majority of this occurs in farms. Beaver damage to trees on farmland is unlikely to be of significant economic value in relation to the timber they produce, but there will be increased costs of inspection, particularly as there have been cases of trees being felled over roads in Scotland. The Welsh Government has a target of creating 43k hectares of new woodland by 2030, and as much of this will be in linear strips (as this is easiest to fence and manage) it is possible this will be alongside roads. Inspections will therefore be necessary up to 20 metres from watercourses, but also potentially up to 150 metres as beavers have very occasionally been found to range this far. The 2015 Scottish review highlights that the greatest concern arises where beaver activities affect areas of more intensive agricultural

activity. In terms of agricultural land quality, most of Wales is Less Favoured Areas (LFA) but some areas are Best and Most Versatile (BMV) - particularly in Pembrokeshire, Flintshire and Anglesey - and these areas might have the most potential conflict once populations spread.

The reference in the 2015 Scottish review to agricultural crops being eaten in close proximity to watercourses is likely to resonate with many Welsh farmers, particularly as a wide variety of agricultural crops can be affected: sugar beet, maize, cereals, oilseed rape, peas, potatoes, asparagus and carrots. The areas grown of some of these crops is small in Wales and crops/forage grown close to water courses will be of greater potential significance to the agricultural businesses affected. The review states that the scale of crop loss is usually confined to an arc of about 10m from the waterbody and that fencing may be the most effective way to tackle the problem. The burrowing into flood defence banks where these protect land is likely to be of most concern to Welsh farmers. The 2015 Scottish review notes that such damage has been recorded on five sites in Tayside and the damage, although localised, can be quite costly.

Spatial analysis in Wales with respect to agriculture to determine impact of beavers on agriculture and on the soil resource is missing from review as well as the impact on regulating services.

Key differences in agriculture between England and Wales below will significantly affect interpretation of the reports of impact on agriculture in a Welsh context:

- Wales has limited BMV land (Agricultural Land Classification, ALC grades 1-3a) in comparison to England with lower quality land (3b) in Wales being of significance to many agricultural businesses, no consideration is given in the reports to 3b.
- BMV in Wales follows the river systems unlike in England therefore potentially having a greater impact on businesses affected.
- Areas impacted are likely to be of greater significant to the individual agriculture businesses impacted due to smaller field sizes in Wales than in England. This will mean more farmers are affected and a greater proportion of each individual farmer's land could be impacted (Welsh Government 2019).

Conclusion

There is a consistent message coming from both reviews that beavers may have positive benefits on agricultural land through flood attenuation. However, this would be at a catchment scale, so not necessarily directly beneficial to individual farmers who may be impacted by their presence.

Without a detailed analysis at a spatial scale, we cannot draw the same conclusions as those drawn in relation to England. The impact on the soil resource is not included in the reviews. The impacts in terms of environment, social and economic will be catchment specific and spatial in nature.

2.3.7. Infrastructure and land use

Overview

Infrastructure and land use have the potential to be affected by beaver activity where they are in close proximity, or closely connected, to still or running waters. Beavers readily use natural, semi-natural and artificial water bodies and can tolerate living in close association with humans, including within urban areas and intensively managed landscapes.

Natural England Review conclusions

"*Various infrastructure types and networks have a high likelihood of being affected by beaver activity where they lie on floodplains. Whether this is positive or negative and the scale and significance of these resulting effects will vary according to local circumstances and over space and time.*

The presence of beavers may benefit some infrastructure network and assets, such as wetland designations, drinking water storage assets and flood mitigation. A clear plan is recommended, based on appropriate criteria, to zone vulnerable infrastructure and identify responsibilities for managing beaver activity.

Any assessment of beaver activity, or interventions considered necessary should be carried out in the context of wider existing legal and policy frameworks. This includes policy and legislation that seeks to enhance natural processes and make space for water. These considerations are likely to reduce the risk and likelihood of beaver activity having a negative effect on infrastructure networks and assets."

NRW assessment of English and Scottish Reviews

NRW broadly agree with the conclusions and likely impacts in Wales from both the 2015 Scottish review and the 2020 English review. The lessons from the beaver populations in the Tay catchment are possibly more relevant to Wales with its network of major rivers, but the experiences from Knapdale are also relevant as beavers can be expected to inhabit the many lakes in Wales - and where applicable their islands - in a similar way to Knapdale.

It is recognised that although there are many positive benefits from the reintroduction of beavers, such as reducing and slowing flood peaks, it is expected that there will be localised issues. The two study sites in Scotland (Knapdale and Tay catchment) are very different from each other but there are aspects of each that are likely to be directly applicable to Wales too.

Further research available since 2020

Although there is crossover with some of the literature relevant to agriculture, we are not aware of any additional relevant evidence or research published since the English review relating to infrastructure that significantly changes these conclusions.

Welsh Context

Localised impacts on local infrastructure from beaver activities would be expected, including - to mirror the list in the 2015 Scottish review - roads, tracks, culverts, weirs, sluices, fish passes, flood banks and other river structures, canals, water treatment plants, ornamental gardens, ponds and sites of historical value.

As noted above the Welsh Government has a target of creating 43k hectares of new woodland by 2030. Much of this will be in linear strips (as this is easiest to fence and manage) and much is likely to be alongside existing roads. Beavers are likely to be active up to 20 metres from watercourses, but very occasionally they can also be active up to 150 metres. There is potential for some trees to be felled or made unstable (from gnawing). Monitoring costs will increase as dangerous trees will need to be pre-emptively felled, and some nearby trees in areas where there is known beaver activity will need to be protected with for example wire mesh. The 2020 English review makes reference to the findings of the 2015 Scotland review, with bank erosion reported at four Tayside sites and five sites reporting burrows in flood banks. The Montgomery Canal in Powys suffered water loss from a breached bank a few years ago, and it might be expected there will be occasional occurrences of this nature with a reintroduced beaver population.

Conclusion

The research elsewhere in Europe suggests that even in highly human-dominated landscapes there should be space for beavers to thrive. Should beaver populations expand here in Wales, it is expected that - like the predictions for Scotland and England - they will prove to be beneficial for the environment in the right locations, where we have the right tools to manage them and the potential negative impacts. Management strategies will be needed and will incorporate effective communication to reduce any potential conflict caused by beaver activity requiring mitigating action and promote coexistence between humans and beavers.

2.3.8. Public and animal health

Overview

Species translocations can facilitate the movement of parasites and risk animals encountering parasites that they normally would not be exposed to. Risks from disease associated with wildlife translocations arise because individual animals moved are a biological package, consisting of the host and all the associated viruses, bacteria, fungi and other parasites that an animal or plant may naturally harbour (Davidson & Nettles 1992). Subsequently, reintroduced beavers may act as a mechanism for the introduction of new or previously eradicated parasites or may establish new transmission routes for the infection of humans, domesticated livestock and existing wildlife. Subsequently, disease risk analysis and the evaluation of mitigation measures is a key requirement if the risks from disease to humans, livestock and wildlife from the translocation are to be understood and controlled.

Beavers, like all wild mammals, are naturally associated with a range of parasites. Some of these parasites are specific to beavers while others can potentially infect other species and humans. Strong evidence from Europe and Great Britain is available to understand the risks posed to public and animal health from beaver translocations and reintroductions (Girling *et al*. 2019; Donald *et al*. 2020). These disease risk analyses have identified potential hazards that need to be taken into account for any reintroduction program.

Natural England Review conclusions

'Detailed research has been undertaken since the Scottish Review to understand the risks posed to human and animal health from beaver translocations and reintroductions. Disease risk analyses for beavers have identified potential hazards that need to be considered for any reintroduction programme. The most important for people is the tapeworm Echinococcus multilocularis. This and other risks can be effectively managed, so overall, if beaver reintroductions take appropriate measures, beavers are not considered to pose any increased risk to public health beyond that posed by existing native wildlife populations.

The risk of introducing significant parasites or infectious agents of humans, domestic animals or other wildlife is low if beavers used in reintroduction projects are taken from wild-living populations in Great Britain. If reintroduction projects plan to (i) source beavers from zoological or private collections, (ii) house them temporarily in zoological-type or private collections (unless housed in bio-secure facilities designed for beaver translocations), (iii) if it is proposed to release beavers held in enclosures into the wild, or (iv) release beavers from wild populations sourced outside of Great Britain, then further disease risk analysis is required. Pending this additional analysis it is recommended that beavers sourced from enclosures are only moved to other enclosures within Great Britain.

Any beavers of unknown origin in Great Britain could carry non-native diseases and parasites, though it should be noted that no cases of significant disease/parasite transmission have been recorded in Great Britain. Detailed post-mortem examinations are therefore recommended of any beavers found dead in enclosures or free-living in the wild. Efforts should also be made to use retrospective sample archives to build our understanding of potential hazards.'

NRW assessment of English and Scottish Reviews

NRW does not have public or animal health technical expertise; we have therefore only extracted information from the English review in order to provide an overview of the issue.

3. Beavers in the context of the Welsh legislative and policy framework

The reintroduction of beavers provides opportunities for creating more varied habitats in landscapes to tackle biodiversity decline and build resilient ecosystems so that nature can adapt to a changing climate. As ecosystem engineers, beavers can play an important role in increasing the supply of a range of ecosystem services (Willby *et al*. 2018; Braizer *et al.* 2021; Larsen *et al.* 2021). These include 'provisioning ecosystem services' such as increased ground water storage, 'regulation and maintenance ecosystem services' such as water flow regulation and flood prevention, and 'cultural ecosystem services' that relate to people's recreational, educational and other interactions with the environment. There is therefore the potential for beavers to contribute to the second goal of the Well-being of Future Generations (Wales) Act (2015) to have a resilient Wales that supports social, economic and ecological resilience through maintaining and enhancing a biodiverse natural environment and healthy functioning ecosystems.

Beaver re-introduction can thus provide nature-based solutions to address societal challenges through the protection, sustainable management and restoration of both natural and modified ecosystems, benefiting both biodiversity and human well-being, which aligns with the Natural Resources Policy in Wales.

The reintroduction of beavers could also contribute to the objectives of other existing policies such as River Basin Management Plans and the National Strategy for Flood and Coastal Erosion Risk Management in Wales.

The Environment (Wales) Act 2016 puts in place a legislative framework to promote the Sustainable Management of Natural Resources (SMNR). The reintroduction of beavers would contribute to delivery of the key principles of SMNR; to maintain and enhance the quality of natural resources to realise the benefits for the natural environment and people.

As part of an SMNR approach beavers are capable of enhancing and restoring ecosystems to ensure resilience, demonstrate adaptive management and in turn will deliver long-term multiple benefits. Taking a strategic landscape approach to managing the reintroduction of beavers will recognise the SMNR benefits in an integrated way and at an appropriate scale. However, it is recognised that this may result in some land use and / land management change, which could impact upon special qualities of the designated landscape in order to deliver an equal or better outcome in terms of public benefit. Therefore, it will be important to consider the needs of landowners, users, health and safety and nature and heritage conservation, as per a balanced SMNR approach.

4. Summary conclusion

Beaver dams provide a host of multiple benefits for biodiversity and humans. The formation of new complex wetland behind a dam provides new habitat for a diverse range of flora and fauna. This consequently provides breeding, foraging and shelter opportunities for a range of birds, mammals, amphibians and invertebrates. Reintroducing beavers will help restore natural ecosystem function, thereby contributing to enhancing resilient ecological networks that are vital for nature recovery and the supply of ecosystem services. For instance, the controlled retention and gradual release provided by the leaky structures of beaver damming enhances the drought resilience of river systems, increasing base flows in dry periods and decreasing the risk of flooding downstream during periods of high flows.

Based on the evidence presented in this report the reintroduction of beavers into Wales is ecologically feasible. The evidence leads us to believe there is enough suitable habitat in Wales to support the reintroduction of this species at various locations. There are however areas of uncertainty as many studies on beavers are not directly relevant to beavers in Welsh landscapes. Beavers will inevitably cause changes to river systems these changes will be quite complex and vary in different river systems. The creation of new habitat will generally benefit biodiversity. However, this may sometimes pose a risk to important, existing habitats for biodiversity and some of our most threatened species. It may also provide opportunities for non-native species, including invasives.

Whilst the general effects of beaver reintroduction will be beneficial, there will also be situations where there will be impacts and conflicts with existing land and river users that will need to be managed. Therefore, If the decision is made to reintroduce beavers in Wales, an appropriate management strategy will be required to ensure co-existence, by maximising the benefits that beavers can bring and minimising risks or negative impacts to land use, infrastructure, other environmental features or livelihoods, notably with respect to our most threatened and rare habitats and species.

It is also important to reiterate that reintroducing beavers cannot remove the pressures Welsh catchments are subjected to and could even exacerbate ecological impacts in degraded habitats where impacts from pollution, river channelisation, etc. have not been addressed. Therefore, the best outcomes for beaver reintroduction need to be delivered in combination with other landscape or habitats restoration approaches. Also ensuring river and lake systems have space to react to the habitat modifications brought about by beaver activity will be crucial in maximising ecological benefits and reduce risks to existing biodiversity.

5. Recommendations for further research

There are some key areas where further investigation could make a particularly important contribution to our understanding of the potential interactions of beavers with the natural and human environment in Wales:

- Assessment of suitable beaver habitat in Wales, taking into account environmental vulnerabilities (priority species and habitats at risk).
- Development of criteria for beaver reintroduction sites within suitable habitats to maximise benefits for people and nature, minimise costs and mitigate conflicts (e.g., associated with localised impacts on landowners and users).
- Improving our understanding of the effects of beavers on fish populations and Welsh fisheries.
- Research to understand the influence of beavers on rare and threatened species.
- Continued research and monitoring on a prioritised and long-term basis on the interactions between beavers and Welsh species, habitats and socio-economic factors.
- Improved understanding of the impacts of beavers on land-use in Wales.
- Investigations on how public and stakeholder attitudes respond to the reintroduction of beavers and what factors are most effective at securing support and avoiding conflict.

See Annex 1 for further details.

6. References

Andersen, L.H., Ransborg, C., Pertoldi, C., Pagh, S. & Bahrndorff, S. 2023. Can reintroduction of beavers improve insect biodiversity? Journal of Environmental Management, Volume 337,117719,ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2023.117719

Auster, R.E., Barr, S.W. & Brazier, R.E. 2020. Wildlife tourism in reintroduction projects: Exploring social and economic benefits of beaver in local settings. Journal for Nature Conservation, Volume 58, 2020, 125920, ISSN 1617-1381, https://doi.org/10.1016/j.jnc.2020.125920.

Auster, R. E., Barr, S.W., & Brazier, R. E. 2022a. Beavers and flood alleviation: Human perspectives from downstream communities. Journal of Flood Risk Management, 15(2), e12789. https://doi.org/10.1111/jfr3.12789

Auster, R.E., Barr, S.W. & Brazier, R.E. 2022b. Renewed coexistence: learning from steering group stakeholders on a beaver reintroduction project in England. Eur J Wildl Res 68, 1 https://doi.org/10.1007/s10344-021-01555-6

Auster, R. E., Puttock, A.K. Barr, S.W. & Brazier, R. E. 2023. Learning to live with reintroduced species: beaver management groups are an adaptive process. Restoration Ecology, https://doi.org/10.1111/rec.13899

Brazier, R.E. 2021. Independent review of Review of evidence of interactions between beavers and fisheries in England and Wales. COWX Review Beavers Fish and Fisheries_peer_reviewed.pdf (exeter.ac.uk)

Brazier, R.E., Elliott, M., Andison, E., Auster, R.E., Bridgewater, S., Burgess, P., Chant, J., Graham, H., Knott, E., Puttock, A.K., Sansum, P. & Vowles, A. 2020. River Otter Beaver Trial: Science and Evidence Report.

Brazier, R.E., Puttock, A., Graham, H.A., Auster, R.E., Davies, K.H. & Brown, C.M.L. 2021. Beaver: Nature's ecosystem engineers. WIREs Water.;8:e1494. https://doi.org/10.1002/wat2.1494

British Lichen Society. 2022. Available from: BRITISH LICHEN SOCIETY Beavers in Scotland a National Strategy 7.2.22.pdf [accessed 19 December 2023]

Bylak, A. & Kukuła, K. 2022. Impact of fine-grained sediment on mountain stream macroinvertebrate communities: Forestry activities and beaver-induced sediment management. Science of The Total Environment, Volume 832, 2022, 155079, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2022.155079.

Campbell, R.D., Harrington, A., Ross, A. & Harrington, L. 2012. Distribution, population assessment and activities of beavers in Tayside. Scottish Natural Heritage Commissioned Report No. 540.

Campbell-Palmer, R., Bauer, A., Jones, S., Ross, B., & Gaywood, M. 2022. The Return of the Eurasian Beaver to Britain: The Implications of Unplanned Releases and the Human Dimension. In M. Gaywood, J. Ewen, P. Hollingsworth, & A. Moehrenschlager (Eds.),

Conservation Translocations (Ecology, Biodiversity and Conservation, pp. 449-455). Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108638142.025

Campbell-Palmer, R., Puttock, A., Graham, H., Wilson, K., Schwab, G., Gaywood, M.J. & Brazier, R.E. 2018. Survey of the Tayside area beaver population 2017-2018. Scottish Natural Heritage Commissioned Report No. 1013.

Campbell-Palmer, R., Puttock, A., Leow-Dyke, A., Needham, R. & Brazier, R.E. 2019. River Wye Beaver Survey Wales. NRW Evidence Report No. 604, NRW.

Campbell-Palmer, R., Puttock, A. & Brazier, R. 2022. Beaver field sign survey and population status assessment Dyfi catchment, Wales. NRW Evidence Report No: 614. 44pp.

Cowx, I.G. 2020. Review of evidence of interactions between beavers and fisheries in England and Wales. COWX-Review-Beavers-Fish-and-Fisheries-06Jan2021-2.pdf (anglingtrust.net)

Davidson, W.R. & Nettles, V.F. 1992. Relocation of wildlife: identifying and evaluating disease risks, Transactions of the North American Wildlife and Natural Resources Conference, pp. 466-473.

Dewey, C., Fox, P.M., Bouskill, N.J., Dwivedi, D., Nico, P. & Fendorf, S. 2022. Beaver dams overshadow climate extremes in controlling riparian hydrology and water quality. Nature Communications 13: 6509. https://www.nature.com/articles/s41467-022-34022-0

Dittbrenner, B.J., Schilling, J.W., Torgersen, C.E. & Lawler, J.J. 2022. Relocated beaver can increase water storage and decrease stream temperature in headwater streams. Ecosphere 13(7): e4168. https://doi.org/10.1002/ecs2.4168

Donald, H., Common, S. & Sainsbury, A.W. 2020. Disease Risk Analysis for the Conservation Translocation of the Eurasian Beaver (*Castor fiber*) to England. Natural England Commissioned Report NECR345. Peterborough.

Fairfax, E. & Whittle, A. 2020. Smokey the Beaver: beaver-dammed riparian corridors stay green during wildfire throughout the western USA. Ecological Applications 30(8):e02225. https://doi.org/10.1002/eap.2225

Fedyń, I., Przepióra, F., Sobociński, W., Wyka, J. & Ciach, M. 2022. Eurasian beaver – A semi-aquatic ecosystem engineer rearranges the assemblage of terrestrial mammals in winter. Science of the Total Environment 831 154919. http://dx.doi.org/10.1016/j.scitotenv.2022.154919

Fedyń, I., Przepióra, F., Sobociński, W., Wyka, J. & Ciach, M. 2023. Beyond beaver wetlands: The engineering activities of a semi-aquatic mammal mediate the species richness and abundance of terrestrial birds wintering in a temperate forest. Forest Ecology and Management, Volume 529,120698, ISSN 0378-1127, https://doi.org/10.1016/j.foreco.2022.120698

Fuller, R.J. 2016. Management responses to ash dieback (Hymenoscyphus fraxineus) in woodland: implications for woodland structure and resources for biodiversity. Research Report no. 685. British Trust for Ornithology ISBN: 978-1-908581-80-8 50pp

Gandy, S. & Watts, R. 2021. Potential psychological benefits of nature enrichment through the reintroduction of the Eurasian beaver (*Castor fiber*) to Britain: A narrative literature review European Journal of Ecopsychology 7: 41 - 74 https://ecopsychology-journal.eu/v7/EJE%20v7_Gandy_and_Watts.pdf

Gaywood, M. (Ed.). 2015. Beavers in Scotland – A report to Scottish Government. Scottish Natural Heritage, Inverness.https://digital.nls.uk/pubs/e-monographs/2015/BeaversinScotlandAreporttoScottishGovernment.pdf

Girling, S.J., Naylor, A., Fraser, M. & Campbell-Palmer, R. 2019. Reintroducing beavers *Castor fiber* to Britain: a disease risk analysis. Mammal Review 49, 300-323.

Gov.uk. 2020. Available from: Five-year beaver reintroduction trial successfully completed - GOV.UK (www.gov.uk) [accessed 19/12/ 2023]

Gov.uk. 2022. Available from: Beavers are now legally protected in England – the licensing regime explained - Natural England (blog.gov.uk) [accessed 19/12/2023]

Graham, H. 2023. Quantifying the impact and expansion of Eurasian beaver in Great Britain (University of Exeter PhD thesis). http://hdl.handle.net/10871/132143

Graham, H. A., Puttock, A. K., Elliott, M., Anderson, K., & Brazier, R. E. 2022. Exploring the dynamics of flow attenuation at a beaver dam sequence. Hydrological Processes,36(11), e14735. https://doi.org/10.1002/hyp.14735

Graham, H.A., Puttock, A., Macfarlane, W.W. Wheaton, J.M., Gilbert, J.T., Campbell-Palmer, R., Elliott, M., Gaywood, M., Anderson, K. & Brazier, R. 2020. Modelling Eurasian beaver foraging habitat and dam suitability, for predicting the location and number of dams throughout catchments in Great Britain. Eur J Wildl Res 66, 42. https://doi.org/10.1007/s10344-020-01379-w

Gurnell, A.M., Pie, H., Gay, F.J. & Swanson, S.V. 2002 Large wood and fluvial processes. Freshwater Biology 47, 601–619.

Gurnell, J., Gurnell, A.M., Demeritt, D., Lurz, P.W.W., Shirley, M.D.F, Rushton, S.P., Faulkes, C.G., Nobert, S. & Hare, E.J. 2009. The feasibility and acceptability of reintroducing the European beaver to England. Natural England Report NECR002. Available from: http://publications.naturalengland.org.uk/publication/45003

Halley, D.J., Jones, A.C.L., Chesworth, S., Hall, C., Gow, D., Jones-Parry, R., & Walsh, J. 2009. The reintroduction of the Eurasian beaver *Castor fiber* to Wales: an ecological feasibility study / Ail-gyflwyniad yr afanc Ewropeaidd *Castor fiber* i Gymru. Astudiaeth dichonoldeb ecolegol. - NINA Report 457. 66 pp.

Hood, G.A., McIntosh, A.C.S. & Hvenegaard, G.T. 2021. Ecological Compromise: Can Alternative Beaver Management Maintain Aquatic Macroinvertebrate Biodiversity? Wetlands 41, 112. https://doi.org/10.1007/s13157-021-01494-7

Howe, C.V. (Ed) 2020. A review of the evidence on the interactions of beavers with the natural and human environment in relation to England. Natural England Evidence Review NEER017. Peterborough: Natural England.

Howe, C. V. & Crutchley, S. E. 2020. The River Otter Beaver Trial: Natural England's assessment of the trial and advice on the future of the beaver population. A report to the Department for the Environment, Food and Rural Affairs. Peterborough: Natural England.

IUCN/SSC. 2013. Guidelines for Reintroductions and Other Conservation Translocations., IUCN Species Survival Commission, Gland, Switzerland.

IUCN/CPSG. 2022. Scotland's Beaver Strategy 2022-2045. IUCN SSC Conservation Planning Specialist Group, MN, USA

Jackowiak, M., Busher, P. & Krauze-Gryz, D. 2020. Eurasian Beaver (*Castor fib*er) Winter Foraging Preferences in Northern Poland-The Role of Woody Vegetation Composition and Anthropopression Level. Animals (Basel). Aug 8;10(8):1376.

Jones, A., Gilvear, D., Wilby, N. & Gaywood, M. 2009. Willow (Salix, spp) and aspen (Populus tremula) regrowth after felling by Eurasian beaver: implications for riparian woodland conservation in Scotland. Aquatic Conservation: Marine and Freshwater Ecosystems 19.

Jones, A.C.L., Halley, D.J., Gow, D., Branscombe, J. & Aykroyd. T. 2012. Welsh Beaver Assessment Initiative Report: An investigation into the feasibility of reintroducing European Beaver (*Castor fiber*) to Wales. Wildlife Trusts Wales, UK.

Jordan, C. E., & Fairfax, E. 2022. Beaver: The North American freshwater climate action plan. WIREs Water,9(4), e1592. https://doi.org/10.1002/wat2.1592

Juhász, E., Molnár, Z., BedeFazekas, Á. & Biró, M. 2023. General patterns of beavers' selective foraging: how to evaluate the effects of a re-emerging driver of vegetation change along Central European small watercourses. Biodiversity and Conservation https://doi.org/10.1007/s10531-023-02598-8

Larsen, A., Larsen, J. & Lane, S. 2021. Dam builders and their works: Beaver influences on the structure and function of river corridor hydrology, geomorphology, biogeochemistry and ecosystems. Earth-Science Reviews 218(5):103623 http://dx.doi.org/10.1016/j.earscirev.2021.103623

Lodberg-Holm, H.K., Garvik, E.S., Fountain, M.S., Reinhardt, S. & Rosell, F. 2022. Crop circles revealed spatio-temporal patterns of beaver foraging on cereal fields, Agriculture, Ecosystems & Environment, Volume 337. https://doi.org/10.1016/j.agee.2022.108066

Mainstone, C. P. 2010. An evidence base for setting nutrient targets to protect river habitat. Natural England Research Reports, Number 034. Natural England, Sheffield.

Malison R.L. 2021. Independent Review of: "Review of evidence of interactions between beavers and fish and fisheries in England and Wales by Professor Ian G. Cowx". Malison_CowxReview_Feb27.pdf (exeter.ac.uk)

Mikulka, O., Homolka, M., Drimaj, J. & Kamler, J. 2020. European beaver (*Castor fiber*) in open agricultural landscapes: crop grazing and the potential for economic damage. Eur J Wildl Res 66, 101. https://doi.org/10.1007/s10344-020-01442-6

Mikulka, O., Adamec, A., Kamler, J., Homolka, M., Drimaj, J., Plhal, R. & Petr, P. 2022a. Using deciduous softwoods to protect commercial forest stands against damage by Eurasian beaver (*Castor fiber L.*). Forest Ecology and Management 520 (15) 1200328 https://doi.org/10.1016/j.foreco.2022.120328

Mikulka, O., Homolka, M., Drimaj, J., & Kamler, J. 2022b. Feeding behaviour of Eurasian beavers (*Castor fiber*) along small streams in an agricultural landscape. Acta Univ Agric Silv Mendelianae Brun, 70, 71-82. http://dx.doi.org/10.11118/actaun.2022.007

Mikulka, O., Pyszko, P., Skoták, V., Kamler, J., Drimaj, J., Plhal, R. & Homolka, M. 2022c. The Influence of Forestry Management on the Selection of a Non-Vegetative Diet by the Eurasian Beaver (*Castor fiber* L.). *Animals*, *12*, 2949. https://doi.org/10.3390/ani12212949

Minke, M., & Freibauer, A., Yarmashuk, T., Burlo, A., Harbachova, H., Schneider, A., Tikhonov, V. & Augustin, J. (2021). Flooding of an abandoned fen by beaver led to highly variable greenhouse gas emissions. Mires and Peat. Volume 26 (2020). 1-24. 10.19189/MaP.2019.SNPG.StA.1808.

Murray, D., Neilson, B. T., & Brahney, J. 2023. Beaver pond geomorphology influences pond nitrogen retention and denitrification. Journal of Geophysical Research: Biogeosciences, 128, e2022JG007199. https://doi.org/10.1029/2022JG007199

Nash, C.S., Grant, G.E., Charnley, S., Dunham, J.B., Gosnell, H., Hausner, M.B., Pilliod, D.S. & Taylor, J.D. 2021. Great Expectations: Deconstructing the Process Pathways Underlying Beaver-Related Restoration. *BioScience*, 71, 249-267. https://academic.oup.com/bioscience/article/71/3/249/6104136?login=false

Natural Resources Wales. 2020. Salmon and Sea trout action plan for Wales. Available from: Natural Resources Wales / Salmon and sea trout plan of action for Wales 2020: areas for action (accessed on 19 December 2023).

Natural Resources Wales. 2021. State of Natural Resources Report (SoNaRR): Assessment of the achievement of sustainable management of natural resources. Freshwater. Natural Resources Wales. Available from: Natural Resources Wales / SoNaRR2020: Structure and contents [accessed on 19 December 2023].

NatureScot. 2019. Management Framework - Conservation status of Beavers in Scotland. nature.scot/doc/management-framework-conservation-status-beavers-scotland [accessed 19/12/2023]

NatureScot. 2022. Beaver Management report 2022. Available from: Beaver Management Report for 2022 | NatureScot [accessed 19/12/2023]

NatureScot. 2023. Available from: Beaver release approved at new Argyll and Tayside sites | NatureScot. [accessed 19/12/2023]

Needham, R.J., Gaywood, M., Tree, A., Sotherton, N., Roberts, D., Bean, C.W. & Kemp, P.S. 2021. The response of a brown trout (Salmo trutta) population to reintroduced Eurasian beaver (Castor fiber) habitat modification. Canadian Journal of Fisheries and Aquatic Sciences. 78: 1650–1660 http://dx.doi.org/10.1139/cjfas-2021-0023

Nummi, P. & Holopainen, S. 2020. Restoring wetland biodiversity using research: Whole-community facilitation by beaver as framework. Aquatic Conserv: MarFreshw Ecosyst; 30:1798–1802. https://doi.org/10.1002/aqc.3341

Nummi, P., Liao, W., van der Schoor, J. & Loehr, J. 2021a. Beaver creates early successional hotspots for water beetles. Biodivers Conserv 30, 2655–2670. https://doi.org/10.1007/s10531-021-02213-8. (Nummi, P., Liao, W., van der Schoor, J. & Loehr, J. 2021. Correction to: Beaver creates early successional hotspots for water beetles. Biodiversity & Conservation 30, 3313–3314 (2021). https://doi.org/10.1007/s10531-021-02230-7)

Nummi, P., Arzel, C. & Sauramo, V. 2021b. Populations in stable and variable habitats: Green and common sandpiper in a beaver-influenced landscape. Global Ecology and Conservation 28: e01678. https://www.sciencedirect.com/science/article/pii/S2351989421002286

Nunn, A.D., Ainsworth, R.F., Walton, S., Bean, C.W., Hatton-Ellis, T.W., Brown, A., Evans, R., Atterborne, A., Dave Ottewell, D. & Noble, R.A.A. 2023. Extinction risks and threats facing the freshwater fishes of Britain. Aquatic Conservation: Marine and Freshwater ecosystems. https://doi.org/10.1002/aqc.4014

Oliveira, S., Buckley. P & Consorte-McCrea, A. 2023. A glimpse of the long view: Human attitudes to an established population of Eurasian beaver (*castor fiber*) in the lowlands of south-east England. Front. Conserv. Sci. 3:925594. https://doi.org/10.3389/fcosc.2022.925594

Orazi, V., Hagge, J., Gossner, M.M., Müller, J. & Heurich, M. 2022. A Biodiversity Boost from the Eurasian Beaver (Castor fiber) in Germany's Oldest National Park. Front. Ecol. Evol. 10:873307. doi:10.3389/fevo.2022.873307

Pejstrup, M.S., Andersen, J.R. & Mayer, M. 2023. Beaver foraging patterns in a human-dominated landscape: Effects on woody vegetation and mammals. Forest Ecology and Management, 528 120645. https://doi.org/10.1016/j.foreco.2022.120645

Pollock, M.M., G.M. Lewallen, K. Woodruff, C.E. Jordan and J.M. Castro (Editors) 2023. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 2.02. United States Fish and Wildlife Service, Portland, Oregon. 189 pp.

Puttock, A., Graham, H.A., Ashe, J., Luscombe, D.J. & Brazier RE. 2021. Beaver dams attenuate flow: A multi-site study. Hydrological Processes. 35:e14017. https://doi.org/10.1002/hyp.1401718

Puttock, I. Graham, H.A., Cunliffe, A.M., Elliott, M., & Brazier, R.E. 2017. Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from

intensively-managed grasslands, Science of The Total Environment, Volume 576, Pages 430-443, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2016.10.122

Puttock, A., Newman, M., Graham, H., Elliott, M., Chant, J., Auster, R.E. & Brazier, R.E. 2023. Positive coexistence of water voles and beaver: water vole expansion in a beaver engineered wetland. Mammal Communications 9: 7-15, Blandford Forum

Ronnquist, A.L. & Westbrook, C.J. 2021. Beaver dams: how structure, flow state, and landscape setting regulate water storage and release. Science of the Total Environment 785: 147333. https://beavertrust.org/wp-content/uploads/2021/06/Ronnquist_et_al-2021-Science-of-The-Total-Environment.pdf

Rosell, F. & Campbell-Palmer, R. 2022. Beavers: ecology, behaviour, conservation, and management. Oxford University Press, Oxford, UK.

Scottish Government. 2021. Available from: Protecting Scotland's beaver population - gov.scot (www.gov.scot) [accessed 19/12/2023]

Stringer, A.P., Blake, D. & Gaywood, M.J. 2015. A review of beaver (*Castor* spp.) impacts on biodiversity, and potential impacts following a reintroduction to Scotland. Scottish Natural Heritage Commissioned Report No. 815.

Sundell, J., Liao, W. & Nummi, P. 2021. Small mammal assemblage in beaver-modified habitats. *Mamm Res* **66**, 181–186. https://doi.org/10.1007/s13364-020-00545-4

Thompson, S., Vehkaoja, M., Pellikka, J. & Nummi, P. 2021. Ecosystem services provided by beavers Castor spp. Mammal Review, 51, 1: 25-39. https://doi.org/10.1111/mam.12220

Veríssimo, D. & Roseta-Palma, C. 2023. Rewilding with the beaver in the iberian peninsula - Economic potential for river restoration, Nature-Based Solutions, Volume 3, 100055, ISSN 2772-4115, https://doi.org/10.1016/j.nbsj.2023.100055

Washko, S., Willby, N. & Law, A. 2022. How beavers affect riverine aquatic macroinvertebrates: a review. PeerJ 10:e13180 http://dx.doi.org/10.7717/peerj.13180

Welsh Government. 2019. Agriculture in Wales. Available from: Securing Wales' Future Summary (gov.wales)

Wikar, Z. & Ciechanowski, M. 2023. Beaver Dams and Fallen Trees as Ecological Corridors Allowing Movements of Mammals across Water Barriers—A Case Study with the Application of Novel Substrate for Tracking Tunnels. Animals 2023, 13, 1302. https://doi.org/10.3390/ani13081302

Wikar, Z., Ciechanowski, M. & Zwolicki, A. 2023. The positive response of small terrestrial and semi-aquatic mammals to beaver damming. Science of The Total Environment, Volume 906, 2024, 167568, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.167568.

Willby, N.J., Law, A., Levanoni, O., Foster, G. & Ecke, F. 2018. Rewilding wetlands: beaver as agents of within-habitat heterogeneity and the responses of contrasting biota. Phil. Trans. R. Soc. B 373: 20170444. http://dx.doi.org/10.1098/rstb.2017.0444

Annex 1. Key evidence gaps

The evidence review has identified further research may be needed on the following:

Interactions with habitats

Running water habitats - the impacts of beaver on geomorphic processes at a larger spatial scale; presently most research focuses on site or reach scale.

Standing water habitats and associated wetlands - the impact of beaver activity on shallow lakes with an existing nutrient problem

Interactions with species

Freshwater fish assemblages - the likely impacts on Atlantic salmon and sea trout.

Fungi and lichens - the influence of beavers on key species and assemblages of fungi and lichens in Wales which are considered highly sensitive to woodland structural change.

Invertebrates - potential impacts on some critically threatened species, such as freshwater pearl mussel and white-clawed crayfish, also the potential risk of INNS spreading.

Mammals - potential impacts on species of bats which roost, forage and commute along in riparian corridors.

Interactions with people

Public attitude and perceptions - the Welsh context to ensure trust and confidence in management processes.

Economic benefits and costs - a fuller appraisal of the economic costs and benefits in the Welsh context. To consider the range of benefits for society and the economy of reintroducing beavers.

Water management - potential catchment-scale effects from beavers is needed in Wales.

Freshwater Fisheries - the critical evidence gaps that need addressing to understand the impacts in the Welsh context include:

- The impacts on downstream migration of salmon and sea trout smolts.
- The impacts on salmonid juvenile and spawning habitat on streams.
- The interactions with likely climate change scenarios.
- Interaction between habitat changes and predation risk.

Agricultural land - detailed analysis at a spatial scale is needed to draw conclusions for Wales. Also, research is needed on the use of riverine buffer strips to provide a natural corridor for natural processes take hold and reduce beaver-human conflict.

Infrastructure and land use - the potential impacts on infrastructure and land use in the Welsh context.

Annex 2. NRW reviewers

Interactions with habitats

- **Running water**: Dr Tristan Hatton-Ellis - Lead Specialist Advisor: Freshwater Habitats and Species
- **Standing water habitats and associated wetlands**: Dr Tristan Hatton-Ellis - Lead Specialist Advisor: Freshwater Habitats and Species, Dr Peter Jones - Senior Specialist Advisor, Peatland
- **Woodlands** - David Reed - Specialist Advisor, Terrestrial Habitats

Interactions with Species

- **Freshwater fish assemblages**: Dr Tristan Hatton-Ellis - Lead Specialist Advisor: Freshwater Habitats and Species
- **Bryophytes:** Sam Bosanquet - Specialist Advisor: Terrestrial Habitats and Species
- **Fungi & lichens:** Sam Bosanquet - Specialist Advisor: Terrestrial Habitats and Species
- **Vascular plants:** Julian Woodman - Specialist Advisor: Terrestrial Ecosystems and Species
- **Invertebrates:** Dr Mike Howe - Lead Specialist Advisor: Terrestrial Habitats and Species, Dr Tristan Hatton-Ellis - Lead Specialist Advisor: Freshwater Habitats and Species
- **Amphibians and reptiles:** Sam Dyer - Specialist Advisor: Terrestrial Habitats and Species
- **Birds:** Patrick Lindley – Lead Specialist Advisor, Terrestrial Ornithology, Richard Facey - Specialist Advisor, Terrestrial Ornithology
- **Mammals:** Dr Liz Halliwell - Team Leader Terrestrial Ecosystems and Species. Sam Dyer - Specialist Advisor: Terrestrial Habitats and Species

Interactions with people

- **Public attitude & perceptions** David Bleines - Specialist Advisor: Evaluation
- **Economic benefits & costs** John Gossage – Economist

- **Water management:** Jill Howells - Specialist Advisor: Sustainable Water, Jenny Dickinson - Lead Specialist Advisor Flood Risk Analysis Group
- **Freshwater fisheries**: Ben Wilson - Principal Advisor Fisheries
- **Forestry:** Chris Tucker - Specialist Advisor: Technical Forestry (Resilience)
- **Agricultural land** Dr Sarah Hetherington - Lead Specialist Advisor: Agriculture
- **Infrastructure & general land use**: John Browne - Senior Specialist Advisor Land
- **Public and animal health:** Not assessed.