CREW CENTRE OF EXPERTISE FOR WATERS

Policy Note

How might beavers influence the functioning of rivers and streams and water resource management in Scotland?

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Beavers could make an important contribution to improving the condition of Scotland's rivers, including helping to enhance water supply and water quality. This CREW Policy Note summarises the role beavers can play in water resource management, as well as in creating habitat, carbon sequestration and river restoration. It is based on evidence from 120 studies of beaver populations worldwide, as part of a large-scale review of their effects on the natural functioning of streams and rivers[1].

Background

Beavers are well known for their ability to transform ecosystems through dam building and other activities. By modifying the natural physical processes in streams and rivers, beavers have the potential to play a role in providing ecosystem services that link to key water resource management issues in Scotland, alongside wider benefits such as carbon sequestration and river restoration. The water management benefits include improvement of water quality, water supply, and the management of floods and droughts. However, evidence for the role of beaver activity in

Overview

- **Positive contributions:** Most of the evidence of beaver activity effects on the natural functioning of streams and rivers points to positive contributions to local ecosystem services. This includes contributions to water supply and purification, the moderation of flood and drought conditions directly downstream of beaver dams, and river restoration.

- **Adverse effects:** Beaver activity effects may include the loss of land because of wetland creation and increased flooding upstream of dams. Depending on site characteristics, fish passage may be interrupted. The breaching of beaver dams is part of the natural evolution of their ecosystems; breaches can have detrimental effects, such as exacerbating flood events and the releasing of sediment and contaminants that were being retained by a dam.

- **Potential opportunities:** The potential of beaver activity to contribute to a wide range of ecosystem services should be considered in riparian management appraisals.

- **Managing negative effects:** To inform an appraisal, and mitigate local adverse effects of beaver activity, discussion with landowners and wider societal groups is required. This should involve consideration of (i) wider ecological and socio-economic aspects of beaver translocation and expansion, and (ii) mechanisms that ensure that those who are negatively affected are appropriately involved in decision making and have access to appropriate management tools.

- **Larger scale uncertainties:** Most evidence has been recorded at the local scale, i.e., affecting streams draining an area of up to 1 km^2; policy and practice for ecosystem services could benefit from more evidence at larger scales.

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these various ecosystem services is typically diffuse or incomplete, especially for Scotland and Europe. In addition, beavers are increasingly spreading to prime agricultural land and other intensively used land in Scotland which has led to a range of conflicts.

This policy note provides an independent evidence review of the role of beavers in modifying natural physical processes in rivers and streams, and the potential benefits they may bring for the provision of ecosystem services. It will inform the dialogue on the benefits and limitations of beaver expansion, including where trade-offs are required. It also supports decision-making and policies related to Scotland's Beaver Strategy 2022-2045[2], in particular the thematic areas of 'management and mitigation' and 'research and innovation'. This policy note provides a benchmark for the strategy to build on, by establishing potential environmental gains while also indicating where action is needed to mitigate or avoid negative effects. Furthermore, the policy note informs strategy actions for future research to understand the full consequences of beavers within the Scottish landscape.

Developing a framework to capture evidence

Two mechanisms for capturing evidence were used: (1) an international literature review of quantifiable metrics of beaver activity effects, specifically of dam building; and (2) an expert evaluation and interpretation of the effects and remaining knowledge gaps. This review builds on NatureScot's 2015 'Beavers in Scotland' report and other recent international reviews, including [4,5].

This work specifically:

(i) collates measurable evidence for trends (i.e., increase, decrease, or no change) associated with the effects of beaver dam building on water quantity and quality and the geomorphological (river form and sediment) characteristics of Scottish rivers.

(ii) provides confidence levels for the evidence of these trends, determined as a function of the amount of robust evidence and the level of agreement between different evidence sources (see Box 1).

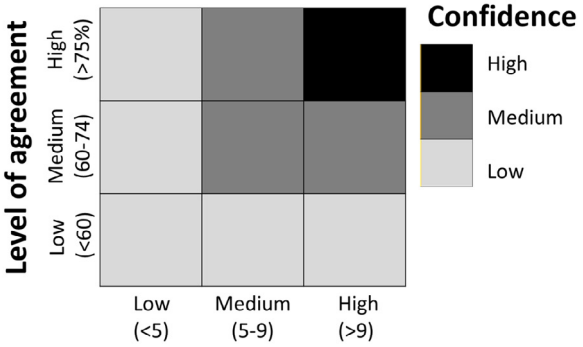
(iii) explores the limits of knowledge of beaver activity effects, e.g. on different types of environment, for the spatial and temporal scales for which evidence has been collected.

(iv) evaluates the results in the context of ecosystem services in Scotland.

The evidence base includes a total of 120 studies which report quantifiable evidence on the effect of beaver activity on one or more metrics related to geomorphology, water quantity and water quality. The review includes studies that were published before July 2021 .

Box 1: Developing evidence confidence indicators

Assessment of the levels of confidence in the evidence from literature and trends of change. The level of confidence is a function of the number of papers or reports presenting quantifiable evidence (x-axis) and the level of agreement (y-axis). Thresholds are provided in the axis's labels. Level of confidence method adapted from[3].

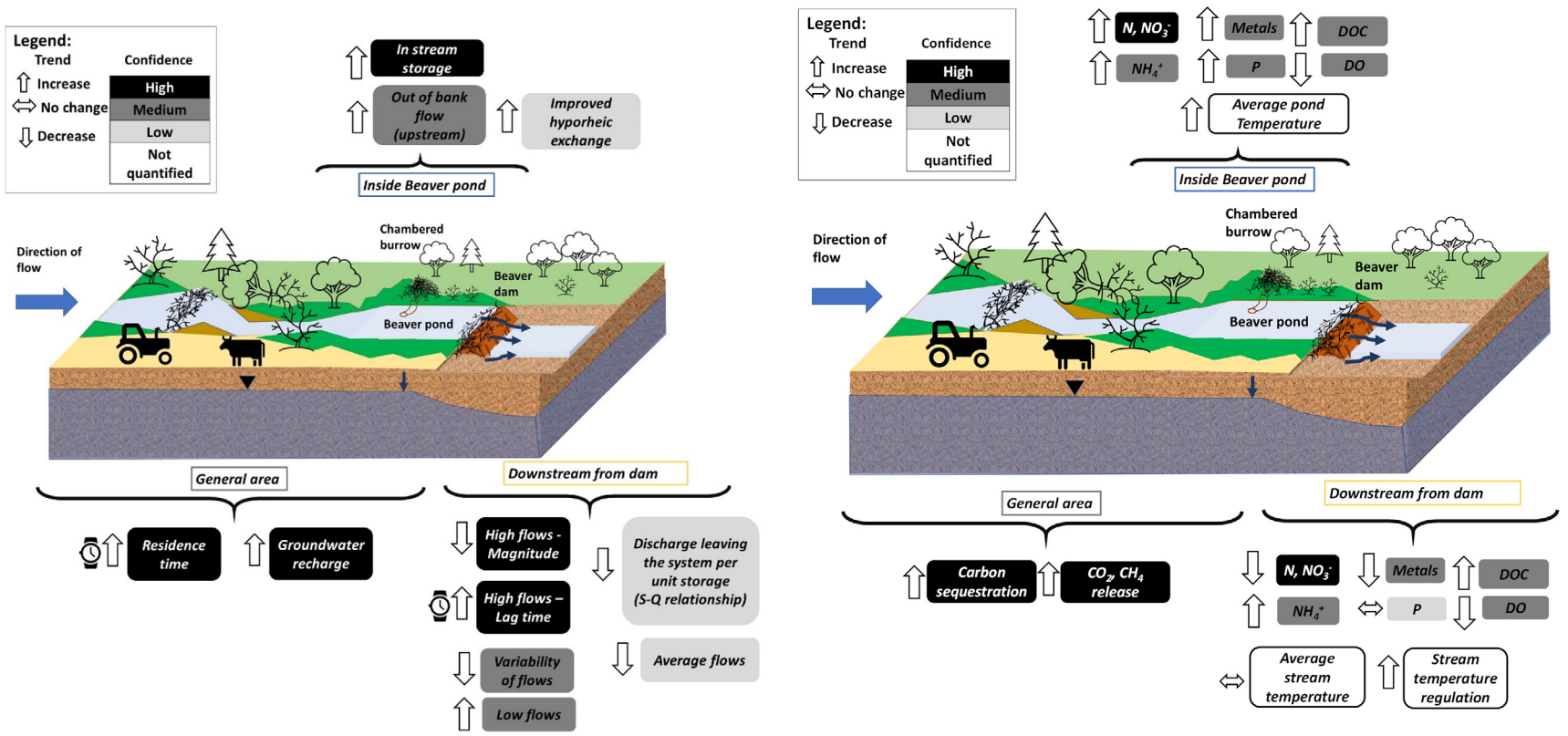


Beaver activity effects: what is known

Most of the evidence of beaver activity effects on natural physical functioning of streams and rivers points to positive contributions to local ecosystem services. There is strong evidence that beaver dam-building results in wetland creation and the trapping of suspended sediment, nutrients, and contaminants. In addition, high flows are typically lowered and delayed, while groundwater recharge and water storage are enhanced, and residence times increased. Beaver activity can therefore contribute to water supply and purification, the moderation of extreme events, nutrient cycling, river restoration and ecosystem resilience.

Enabling positive contributions to ecosystem services may also involve compromises and care must be taken to manage any adverse effects. Beaver activity effects may include the loss of land because of habitat creation and increased flooding behind dams. While flooding increases in the area behind beaver dams, beaver activity contributes to small-scale downstream decreases and delays in the flood peak. The relative effects will therefore depend on the location in relation to the beaver activity, as well as the surrounding land use. For example, flooding in built-up areas is likely to have larger socio-economic effects than flooding in forested areas. Furthermore, while the focus here is on the natural functioning of rivers and streams, it should be acknowledged that there are risks associated with the effects that beaver activity can have on the functioning of artificial drainage of agricultural land in low lying areas.

Box 2: Conceptual overview of confidence of trends (Box 1) in change in physical processes related to water quantity (left) and in water quality metrics (right) due to beaver activity.



Most of the evidence of beaver activity effects on the physical functioning of streams and rivers points to positive contributions to ecosystem services. The literature review revealed that there is a relatively high level of confidence that beaver activity results in wetland creation and the 'filtering' of suspended sediment, nutrients and contaminants. In addition, high flows are typically lowered and delayed, while recharge, water storage and residence times increase. Beaver activity can therefore contribute to water purification, water supply, the moderation of extreme events, nutrient cycling, and river restoration[6]).

Depending on site characteristics, other potential adverse effects include interruptions to fish passage, because of decreased hydrological connectivity within a river network. In addition, changes in water temperature can have implications for in-stream ecology and private and industry water users, but these are also strongly dependent on site characteristics.

Dam-breaching is part of the evolution of beaver systems. It can have detrimental effects including exacerbating flood events and the release of sediment and contaminants that were being retained by a dam. The significance of these effects will depend on the timing and extent of breaching.

Future perspectives

How does beaver activity affect rivers draining larger catchments? The most fundamental outstanding question relates to spatial scale. Most evidence has been recorded at the local scale, i.e., for streams that drain an area up to about 1 km^2; policy and practice for ecosystem services would benefit from evidence at larger scales. To consider beaver activities as part of wider nature-based catchment solutions, it is also important to know the aggregated effect of widespread beaver activity across multiple headwaters within larger catchments. Addressing these gaps requires integrated monitoring and modelling approaches over larger catchment scales (>10 km^2) and longer time scales. In an ideal situation, this would involve sites for which background hydrological and geomorphological data already exist.

What are the effects of beaver activity on the full range of stream discharge? There is less direct evidence of the effects of beaver activity on water storage and low flows than of the effects on high flows. Increased water storage because of beaver dams could provide ecosystem resilience during droughts by mitigating low flows, but data to confirm this are generally lacking. Future experimental data collection campaigns should therefore consider the full range of flow variability in streams.

What is the net effect of beaver activity on greenhouse gas emissions and carbon sequestration and so the carbon budget, and what controls the balance locally? Beaver activity effects include increased carbon cycling, thereby increasing carbon storage but also resulting in more greenhouse gas emissions; the offsets between these two effects are highly variable and less well known. Given that Scotland's climate legislation sets a target date for net zero emissions of all greenhouse gases by 2045, increasing our understanding of how beaver activity affects the carbon budget and what controls this locally could be another priority area for future research.

What are the site specific controls on the magnitude of beaver effects? Some effects depend strongly on local beaver activity and landscape characteristics. For example, how much potential there is for beaver activity to improve water quality depends on the background water quality prior to beaver presence. This means that information on the magnitude of effects of beaver activity is often not transferrable, even though the direction of change can be. The evidence base lacks long-term, large scale studies from Scotland and the UK, in non-forested environments. Such data are critical to gain a better understanding of the transferability of the magnitude of effects from one site to another.

Policy recommendations

- The potential for beaver activity to contribute to a wide range of ecosystem services should be considered in relevant riparian management appraisals. These services include water supply and purification, the moderation of flood and drought events, nutrient cycling, and river restoration. This aligns with SEPA's river basin management planning and with Scottish Government's Environment and Land Use Strategies, and programmes for climate change and mitigation, a green recovery and a fairer, greener Scotland.
- To inform an appraisal, and mitigate local adverse effects of beaver activity, discussion with landowners and wider societal groups is required. This should consider (i) the wider ecological and socio-economic aspects of beaver translocation and expansion, as well as (ii) mechanisms to ensure that those negatively affected are involved and appropriate 'payment for public goods' models are identified alongside other mitigation strategies. Together, these actions are included in Scotland's Beaver Strategy 2022-2045.
- More empirical research is required to address the fundamental knowledge gaps, particularly on the scaling and magnitude of beaver activity effects. This needs to be supported by long-term experimental monitoring in Scotland and modelling. Monitoring efforts should involve the interlinked characteristics of water quantity, water quality, and geomorphology alongside effects on ecology, landowners and wider society, so that a holistic evaluation can be made for ecosystem services.

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