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Restoring wetland biodiversity using research: Whole-community facilitation by beaver as framework

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Abstract

1. Wetlands are declining worldwide, and there is a great need for their restoration and creation. One natural agent of wetland engineering is beavers, *Castor* spp., which have returned or are returning to many parts of their former range.
2. We initially studied the facilitative effect of the beaver *Castor canadensis* on a waterbird community consisting of three waders and four ducks in boreal wetlands in southern Finland. Both waterbird species diversity and abundance increased when beavers impounded a pond. Common teal *Anas crecca* and green sandpiper *Tringa ochropus* were the species showing the most positive numerical response, but the other five species also increased upon flooding.
3. This article evaluates how the results of the study have been used in management, both in theory and practice. The whole-community facilitation concept has been taken up in numerous articles considering the restorative effects of beavers. It has also been used as ecological background when planning and executing man-made wetland projects in Finland within both the public and the private sectors.
4. Our study and its publication in *Aquatic Conservation: Marine and Freshwater Ecosystems* have set a foundation for further evidence-based management of waterbird communities. As the results show, having beavers as wetland managers is a feasible tool for creating and restoring wetlands for waterbirds and other biota. Moreover, wetland restoration projects are becoming more popular endeavours, owing to an understanding of the diverse benefits of wetlands. Flooding by beavers is used as a model for managers when creating man-made wetlands; for example, in urban areas where it is difficult to maintain beavers.

KEYWORDS

Castor canadensis, duck, man-made wetlands, waterbird, wetland management

1 | INTRODUCTION

Wetlands are declining worldwide (Kingsford, Basset, & Jackson, 2016; Hu, Niu, Chen, Li, & Zhang, 2017). This habitat loss has been especially pronounced in Europe, with 60–90% of wetlands lost during the twentieth century (Čížková et al., 2013). The fast rate of wetland decimation is alarming, particularly because wetlands support biodiversity that is disproportionately high for their area (Dudgeon et al., 2006). Wetlands are ranked as the most valuable ecosystems in the biosphere, providing more than a quarter of our

estimated ecosystem services, although globally they cover only 1.1% of the surface of the biosphere (Costanza et al., 2014; Kingsford et al., 2016).

In northern Europe (e.g. in Finland) the total wetland loss has not been as severe as in many other parts of Europe, but a disproportionately high number of shallow, productive wetlands have been drained for agricultural use (Kuusisto, Bäck, Vuoristo, Mannio, & Lappalainen, 1998). The demise of beavers by the end of the nineteenth century acted in the same unfavourable direction (Nummi, Vehkaoja, Pumpanen, & Ojala, 2018), also affecting the forested areas. Other shallow, flooded areas are facing a more recent threat: global warming. Climate change is predicted to reduce the extent of snowmelt-dependent spring flooding in northern Europe (Veijalainen, Lotsari, Alho, Vehviläinen, & Käyhkö, 2010), which has already been shown in the Alaskan boreal (Corcoran, Lovvorn, & Heglund, 2009). These human impacts potentially affect wetland organisms strongly (Colburn, 2004).

In an original study published in *Aquatic Conservation: Marine and Freshwater Ecosystems* (*AQC*) (Nummi & Holopainen, 2014), we investigated how the beaver affects wetland birds. The present article evaluates how the results of the study and its publication in *AQC* have been used in management, both in theory and practice. The aim of the study was to demonstrate the broad facilitating effect of beavers on the guild of insect-eating waterbirds. In the boreal study area in southern Finland, this guild consisted of seven species – four ducks and three waders: common teal (*Anas crecca* L.), mallard (*Anas platyrhynchos* L.), wigeon (*Mareca penelope* L.), common goldeneye (*Bucephala clangula* L.), green sandpiper (*Tringa ochropus* L.), common sandpiper (*Actitis hypoleuca* L.) and common snipe (*Gallinago gallinago* L.). In the Evo area, the birds in 51 lakes were surveyed from 1988 to 2009, four times per season from early May to early August, except in 2009, when there were only three surveys from May to July. The beavers in the area are introduced North American beavers (*Castor canadensis* Kuhl.) (Parker, Nummi, Hartman, & Rosell, 2012). According to recent findings, the North American beaver has similar dam-building activities (Danilov & Fyodorov, 2015) to the original European beaver (*C. fiber* L.). During the 22 study years, beavers occupied new previously non-engineered ponds. The beaver activity formed an experimental setting, where 'before flood' and 'during flood' situations could be compared and a 'before–after control–impact' assessment conducted (Nummi & Holopainen, 2014).

Beavers are known for their engineering skills with which they mould the riparian ecosystems, thereby affecting their hydrology, geomorphology and biogeochemistry (Johnston, 2017; Nummi et al., 2018; Persico & Meyer, 2013; Polvi & Wohl, 2012). Beavers also facilitate various groups of organisms, such as butterflies (Bartel, Haddad, & Wright, 2010), frogs (Vehkaoja & Nummi, 2015), birds (Aznar & Desrochers, 2008) and mammals (Nummi, Liao, Huet, Scarpulla, & Sundell, 2019). One group of animals also potentially affected is ducks, especially broods. Commonly, boreal ponds do not offer enough food for broods (Sjöberg, Pöysä, Elmberg, & Nummi, 2000) and also lack suitable habitat structure (Nummi & Hahtola, 2008). In the boreal setting, duck broods have been found to congregate in beaver flowages (bodies of water formed by overflowing or damming; Nummi & Pöysä, 1995). Moreover, in the common teal (*Anas crecca* L.), the yearly production of recruits is largely dictated by the number of beaver flowages in the landscape (Holopainen, Nummi, & Pöysä, 2014).

With the global decline of wetlands it is crucial to acknowledge the ecological value of the return of beavers to many parts of their former range (Halley, Rosell, & Saveljev, 2012; Whitfield, Baulch, Chun, & Westbrook, 2015), and to investigate the effects of this comeback. Many management and restoration studies have identified whole-community facilitation of waterbirds (Nummi & Holopainen, 2014) as an integral part of habitat conservation (Table 1). The way beavers engineer and 'manage' the biota can be used as a model; for example, for duck habitat creation and restoration (Nummi, 1989).

2 | SUMMARY OF THE *AQC* PUBLICATION

Our study showed that the mean number of waterbird species per pond was significantly higher during beaver flooding than before beaver occurrence (average 1.48 vs. 0.43 species per pond per year), as was their abundance (0.80 vs. 0.14 observations per survey). All seven

TABLE 1 Examples of publications in which the management aspects of the original *AQC* article (Nummi & Holopainen, 2014) has been discussed

Context	Reference
Beavers increase wetland connectivity	Hood & Larson, 2015
Management of urban biodiversity	Wahlroos et al., 2015
Habitat engineering (agricultural stream restoration)	Law, Mclean, & Willby, 2016
Beavers impact biodiversity, and the ecological basis for their reintroduction to Scotland, UK	Stringer & Gaywood, 2016
Beavers as tools for ecosystem restoration	Law, Gaywood, Jones, Ramsay, & Willby, 2017
Rewilding of wetlands	Willby, Law, Levanoni, Foster, & Ecke, 2018
Biodiversity ecosystem services for urban areas	Bailey, Dittbrenner, & Yocom, 2019
Beavers as solution to freshwater biodiversity crisis	Law, Levanoni, Foster, Ecke, & Willby, 2019
Beaver food web restoration	McCreesh et al., 2019
Beavers in riparian landscape restoration	Nummi, Suontakanen, Holopainen, & Väänänen, 2019

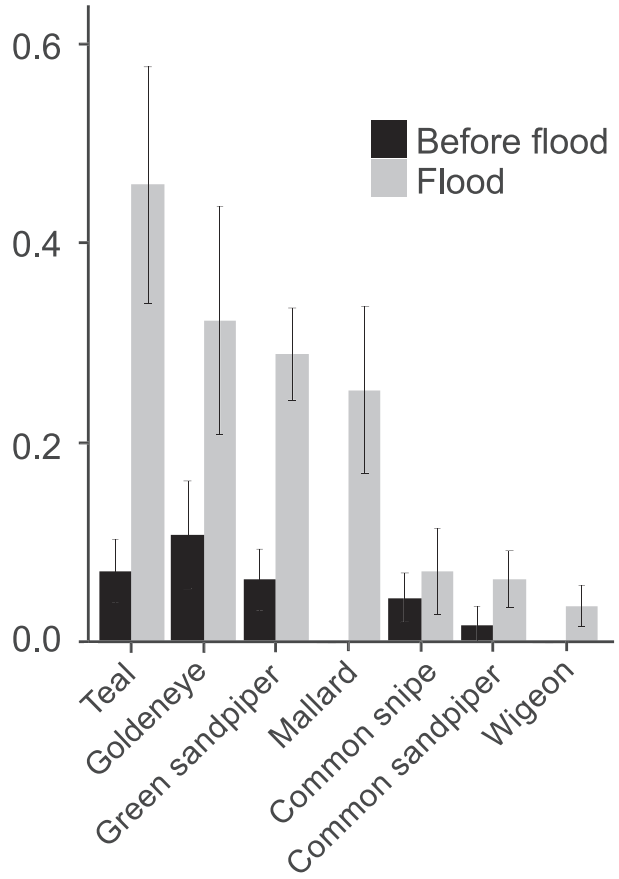

FIGURE 1 Average abundance (individuals per shore line kilometre) of ducks and waders per survey for 14 beaver ponds before and during beaver occupancy. Error bars represent ± SE

waterbird species increased following flooding, and green sandpipers, common teals and mallards significantly so (Figure 1). Common teal and green sandpiper had the greatest positive response numerically to beaver flooding, but mallard and wigeon were totally new species entering the duck guild in the beaver-modified wetlands (Nummi & Holopainen, 2014).

We also studied the effect of flood duration on the number of waterbird species, and found that the number of species increased during the first two years of inundation, and remained high during later years (Nummi & Holopainen, 2014).

3 | IMPACTS OF THE *AQC* PUBLICATION ON WETLAND MANAGEMENT

In Finland, which harbours a considerable portion of Europe's breeding waterfowl (BirdLife International, 2004), wetland creation and management have been at the core of wildlife management during recent years. Getting things done in practice involves many levels of stakeholders, from government level to landowners and wetland entrepreneurs. Below we present statements of how our article has influenced those stakeholders in different areas of wildlife management.

3.1 | Ministry of Agriculture and Forestry

The ministry leads the policy making of wetland management for wildlife.

> The Unit of Game and Fisheries at the Ministry of Agriculture and Forestry has found the publication 'Whole-community facilitation by beaver: ecosystem engineer increases waterbird diversity', along with the preceding publications of the Wetland Ecology Group of Department University of Helsinki, Finland, very useful in decision making. These publications have provided us important scientific background as well as guided us in the building of strategies for the Wildlife Governance. Wetlands, their restoration and management are one of the key elements in the ongoing attempts to halt biodiversity loss, a goal set by the European Union. The results of these studies show us that also in areas where beavers are difficult to manage it is feasible to imitate their flooding with man-made actions. (Heidi Krüger, Ministry of Agriculture and Forestry)

3.2 | The Finnish Wildlife Agency

The Wildlife Agency carries out wetland management projects and launches them to practical managers.

> The publication 'Whole-community facilitation by beaver: ecosystem engineer increases waterbird diversity' along with the preceding publications of the Wetland Ecology Group of Department University of Helsinki, Finland, were key scientific background and justification for the project LIFE+ Return of Rural Wetlands. In this project wetlands were restored and re-created to areas of agriculture and forestry in co-operation with landowners. The key focus was to enhance local-level biodiversity and boost waterfowl reproduction by mitigating the beaver-effect by artificial flooding of suitable sites and drained wetland basins. The publication was published at the end of the project further strengthening the potential of restoring biodiversity with wetland restoration and helped to guide the future of wetland restoration to focus even more on the mitigation of beaver effects by artificial flooding. The Layman's report of the project can be found at the following link. https://www.slideshare.net/Riistakeskus/laymanraportti-layman-report. To summarize, the key difference between beaver-made wetland and artificial wetland mitigating the beaver effect is: Beavers make dams where beavers want;

projects make dams where landowners want. (Mikko Alhainen, The Finnish Wildlife Agency)

3.3 | 'Kosteikkomaailma'

A private enterprise working on practical management of wetland sites.

> Kosteikkomaailma is a one-man company working on planning and guiding machine works in wetland creation, enhancement and restoration in dozens of wetland sites during the last four years in Finland. Customers are, for example, private landowners (farmers, forest owners, and hunters) and projects of wetland protection. Typically, customers like to have a wetland, which has both a lot of biodiversity, especially dabbling ducks, and opportunities for water protection. Kosteikkomaailma has found that the publication of 'Whole-community facilitation by beaver: ecosystem engineer increases waterbird diversity' along with the preceding publications of the Wetland Ecology Group of Department University of Helsinki, Finland is a very important planning tool and useful scientific evidence in wetland projects. Kosteikkomaailma has noticed that customers appreciate the results of the scientific article of 'Whole-community facilitation by beaver' because they can be applied in practice to wetland design and implementation in their own wetland projects. In addition, the results of the article suggest that man-made wetlands that are being restored or built by imitating the beaver can contribute to biodiversity and water protection. (Juha Siekkinen, Kosteikkomaailma)

The above-mentioned 'LIFE+ Return of Rural Wetlands Project' exemplifies one way in which the ecological knowledge gained from our 'Whole community' study further contributed to practical management. During the project, 48 demonstration wetlands covering 340 ha were restored or re-created. Particular emphasis was given to the involvement of local landowners in wetland management. Their attitudes were also surveyed in a study:

> The local stakeholders saw the impact of wetlands to people and environment as positive, and there were no negative attitudes. The people involved in the project had very high expectations before the restoration and they were fulfilled. The local stakeholders described that their relation was good or very good, and they valued the wetland as good sites for nature watching and waterfowl habitat. They also estimated that the wetland is not causing negative attitudes in the neighbouring areas. (Key findings of the Master's thesis by Samuli Karppinen of University of Helsinki) (Return of Rural Wetlands, 2016)

4 | CONCLUSIONS

The study by Nummi and Holopainen (2014) has given support for promoting the beaver as a tool for ecosystem and community restoration (Law et al., 2016; McCreesh et al., 2019; Willby et al., 2018). The environmental processes created by the beaver can also be imitated with man-made ponds, for example in urban areas where it is not feasible to have beavers as flood engineers (Bailey et al., 2019; Wahlroos et al., 2015). During recent decades, beaver engineering has impounded relatively large areas: according to Whitfield et al. (2015), 25,000 km^2 of aquatic habitat has been created in boreal and temperate zones in conjunction with the increase in the beaver populations. The extent of man-made wetlands can also be considerable. In the Czech Republic, for example, which does not have large natural lakes, fish ponds represent about 50% (or 560 km^2) of the country's total wetland area (Čížková et al., 2013).

Beavers and the beaver model are valuable tools in wetland management, and promoting beavers in their historical range is to be encouraged. It should be noted, however, that the beaver populations should not be left to become too dense, because benefits (e.g. for biodiversity) may weaken at that point (Nummi & Kuuluvainen, 2013; Ritchie et al., 2012).

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