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ABSTRACT

Water voles (*Arvicola amphibius*) are critically endangered in Great Britain and there is a pressing need for successful conservation strategies. Meanwhile, another semi-aquatic rodent, the Eurasian beaver (*Castor fiber*) is being restored to much of its native range including Great Britain. Beavers are known as ecosystem engineers and keystone species, creating wetland habitats. As part of the River Otter Beaver Trial in South-West England, free-living beavers were reintroduced in a location where water vole were present and being surveyed. Here, we present survey data showing the expansion of water vole into newly beaver engineered wetland areas. We 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.

INTRODUCTION

Water voles (*Arvicola amphibius*) are native to much of Europe, but in Great Britain they are critically endangered with populations thought to have declined by over 90% since the 1970s *(McGuire & Whitfield, 2017; Strachan et al.*, 2000). This is primarily due to habitat loss and fragmentation (Moorhouse *et al*. 2015), but has been accelerated by predation from invasive American mink (*Neovison vison*) (Lawton & Woodroffe 1991). Conservation efforts are seeking to improve habitat, reduce mink, and restore populations (Strachan *et al*. 2011, Moorhouse *et al*. 2015).

Water voles are territorial, semi-aquatic rodents found in freshwater habitats (Strachan *et al*. 2011). They usually spend most of their life within 1-2 m of the water's edge, feeding on vegetation (Lawton & Woodroffe 1991). Water voles favour habitats with slow-moving water, in locations where levels are fairly constant (Woodall 1993), and typically live in riverbank burrows from which they can be displaced at high flow or exposed at low flow (Richards *et al*. 2014). Habitats are favoured where there is diversity and complexity in riparian vegetation, for both forage and refuge from predation (Richards *et al*. 2014).

Another semi-aquatic rodent, the Eurasian beaver (*Castor fiber*) was formerly resident across Europe until hunted to near-extinction for meat, fur, and castoreum (Halley *et al*. 2021). Beavers create wetlands through engineering behaviours, notably dam and canal building (Brazier *et al*. 2021). Beaver wetlands contain a mosaic of habitats that support biodiversity (Nummi & Holopainen 2014) and provide ecosystem service benefits (Puttock *et al*. 2021). Previous research has shown the benefits of beaver habitat for mammal species richness (Fedyń *et al*. 2022). It has been proposed that the habitats created with slow-moving water and abundant aquatic, emergent, and herbaceous bankside vegetation, could directly benefit water voles (Stringer & Gaywood 2016). As beaver populations declined, so too did beaver-modified habitats. Now, Eurasian beavers have returned to much of their historical range, including reintroduction to parts of Great Britain (Halley *et al*. 2021).

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Key words: Water vole, *Arvicola amphibius*, Beaver, *Castor fiber*, wetlands, population dynamics, ecosystem engineering

Cover image: *Drone imagery of Clyst William Cross study site in 2021 showing complex beaver wetland creation, Alan Puttock*

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The River Otter Beaver Trial (ROBT) was a five year project led by Devon Wildlife Trust (Brazier *et al*. 2020) to investigate the effects of a wild-living population of beavers on the River Otter. A low number of beavers were discovered to be present in the catchment and following the initiation of the trial, these beavers were captured, health-screened and re-released under licence in 2015. As part of the ROBT, in 2016, a pair of beavers were released to a non-enclosed site, to enhance the genetic diversity of the population present in the River Otter catchment. Prior to release this site was not impacted by beaver. At this site water voles were present and being surveyed. Here, we present data on the expansion of water voles into a beaver engineered wetland and consider whether beavers could contribute towards water vole restoration strategies.

METHODS

Site description

Clyst William Cross County Wildlife site has an area of 10 ha and is located on the River Tale, Southwest England (Figure 1, 50°49'13.4"N 3°18'47.1"W), with the vegetation being a mosaic of grassland, fen, and woodland communities. Riparian woodland is dominated by Willow (*Salix sp.*), Hazel (*Corylus avellana*) and Alder (*Alnus glutinosa*). Following release in 2016, beavers established a territory and bred annually throughout the monitoring period, with sub-adults dispersing suggesting a healthy family group of ca. 5 animals. The site contains high quality beaver habitat, with modelling classifying habitat as 'preferred' (Graham *et al*. 2020, 2022).

Water Vole Surveys

The site was surveyed (based upon funding availability) in 2016 (pre-beaver), 2017, 2019 and 2021 for field signs in suitable areas throughout the floodplain wetland. Surveys were undertaken in spring (March-April). Whilst water vole abundance will peak in summer, signs are more visible in spring before vegetation growth. Signs included tracks, runs, holes, feeding remains, lawns, droppings, and latrines. Location was recorded via GPS (precision: ± 10 m). For full survey methodology, see Newman (2019). Spatial analysis was undertaken in QGIS v3.22.4. All field signs were mapped with a 10 m buffer to account for GPS uncertainty creating areas of activity. Buffered water vole signs were overlayed with beaver signs (detailed below) both to visualise and calculate overlap.

Beaver Sign Surveys

Beavers leave conspicuous field signs of their presence including feeding signs. This has led to the establishment of survey methodologies to quantify areas of impact and population dynamics (Campbell *et al*. 2012, Campbell-Palmer *et al*. 2020) with systematic feeding sign surveys undertaken throughout the ROBT (Brazier *et al*. 2020, Graham *et al*. 2022). Feeding signs were mapped via GPS (precision: ± 10 m). All signs were buffered by 10 m. To complement point signs, the other clear indicator of beaver engineering is surface water creation, and two surveys were undertaken to quantify areas of surface water in the release year (2016) and post-beaver impact (2019). An amalgamated 'post-beaver' layer from all buffered signs and surface water extent was created. Whilst it is recognised that ecosystem modifications by beaver are spatially and temporally variable, for this study such a layer gives a valuable spatial representation of beaver impacted areas.
Additionally, the site was surveyed via drone producing georeferenced imagery. Imagery from a February 2021 survey, using a DJI Mavic Pro 2, flown at 120 m above ground level is used for visualising beaver engineering. For details of drone surveys undertaken to monitor beaver activity see (Puttock *et al*. 2015; Graham 2022).

RESULTS

Between 2016 and 2021, water vole and beaver signs increased, both in number and spatial distribution (Figure 1). Whilst a full analysis of water vole change over time is not possible due to the absence of 2017 and 2020 surveys, the majority of the increase in water vole signs occurred between 2019 and 2021. Overall, water vole signs (Figure 2) increased from nine in 2016 to 101 in 2021 (1022 % increase). The 2016 pre-beaver survey located six signs along the site's border, presumably created by free-roaming individuals on the main channel network. These feeding signs were on the main channel bordering the site and did not affect site structure or hydrology, but are included for completeness. Following release, this increased to a total of 533 across the site by 2021 (8783 % increase).
Pre-release, the existing pond provided ca 1,404 m^2 of surface water (perimeter = 449 m), whilst the small area of the main channel created a 0.14 ha area of beaver impact. Following beaver release, surface water expanded to 6,832 m^2 (perimeter = 2094 m). These figures indicate a 387 % increase in surface water area and a 366 % increase in surface water perimeter, with overall beaver impacted area covering 3.5 ha (over a third of the site). In 2016 there were five discrete zones of water vole activity (covering 0.2 ha) with no overlap with the existing pond or the area of the main channel impacted by beaver (Figure 3). By 2021 there were eleven much larger zones of water vole activity (1.2 ha), and these have expanded into areas of newly created beaver wetland. Ten out of the eleven water vole zones show overlap with areas of beaver impact (91 %).
Superimposing the 2021 water vole signs over drone imagery clearly shows signs in newly created beaver wetland areas including ponds, canals and shallow inundated adjacent sedge, rush, and wet woodland areas.
Superimposing the 2021 water vole signs over drone imagery clearly shows signs in newly created beaver wetland areas including ponds, canals and shallow inundated adjacent sedge, rush, and wet woodland areas (Figure 4).

Figure 1. Summary maps showing location of beaver (top) and water vole (bottom) recorded field survey signs in the year beavers were released into the site (2016) and the most recent post-beaver survey year. Insert map shows location of study site in Southwest England. The main river network bordering the site is mapped based upon the OS Open Rivers Network © Ordnance Survey Limited 2021 with the direction of flow indicated by the blue arrow in the top left map.

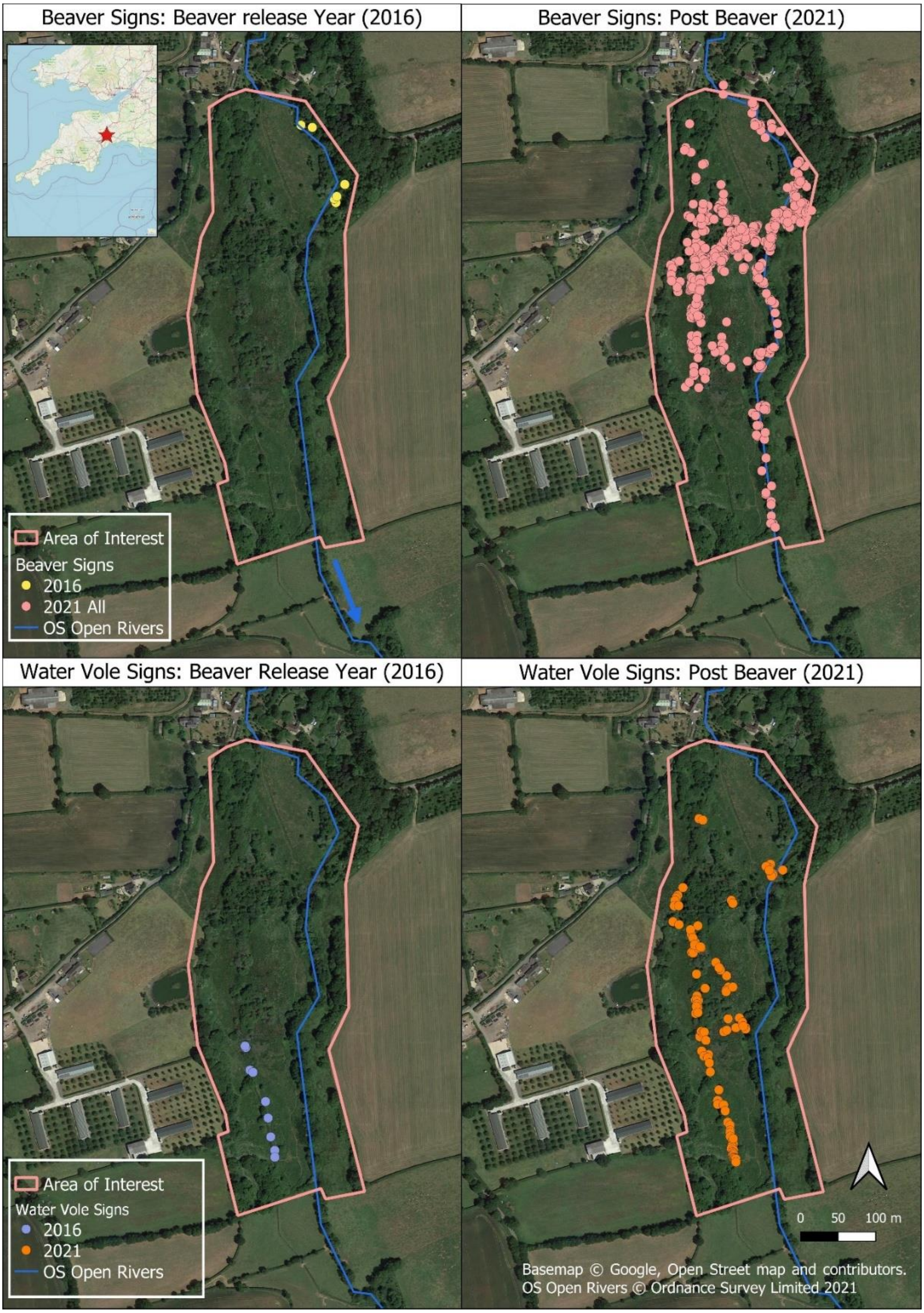

Figure 2. Water vole field sign numbers for each survey year.

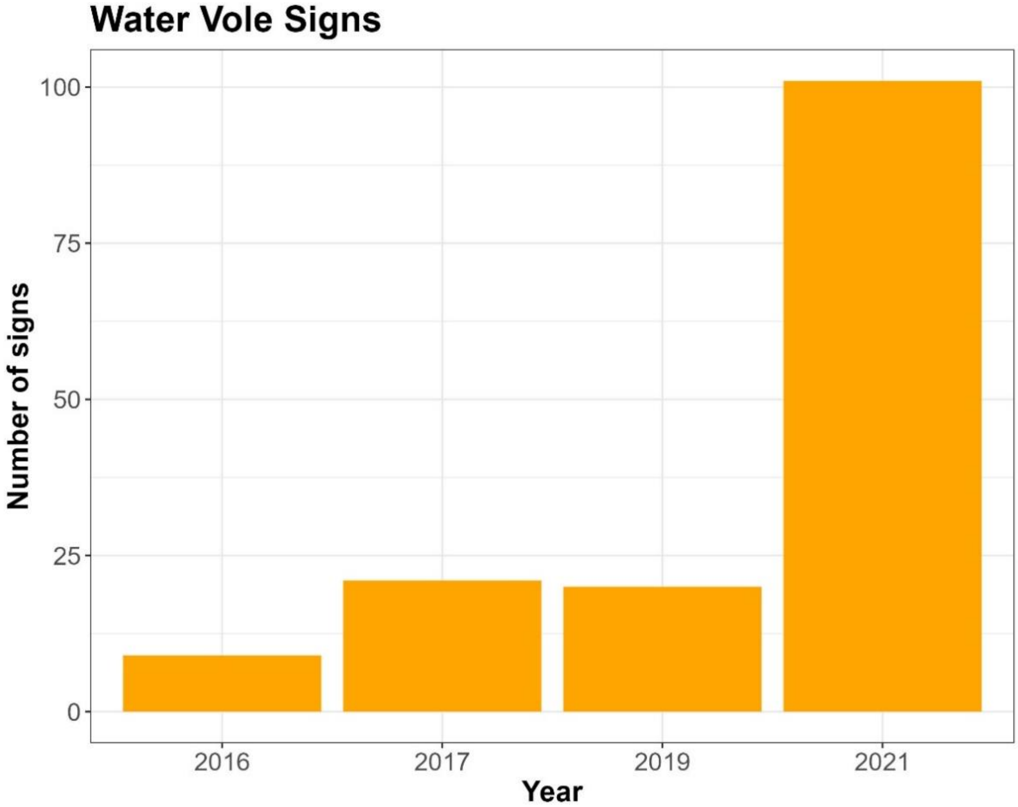

Figure 3. Overlay between water vole signs with beaver impacted areas (derived from beaver feeding sign surveys) and ponded surface water between the year beavers were released into the site (2016) and the most recent survey year (2021). Buffered layers used to represent GPS uncertainty. The main river network bordering the site is mapped based upon the OS Open Rivers Network © Ordnance Survey Limited 2021 with the direction of flow indicated by the blue arrow in the left map.

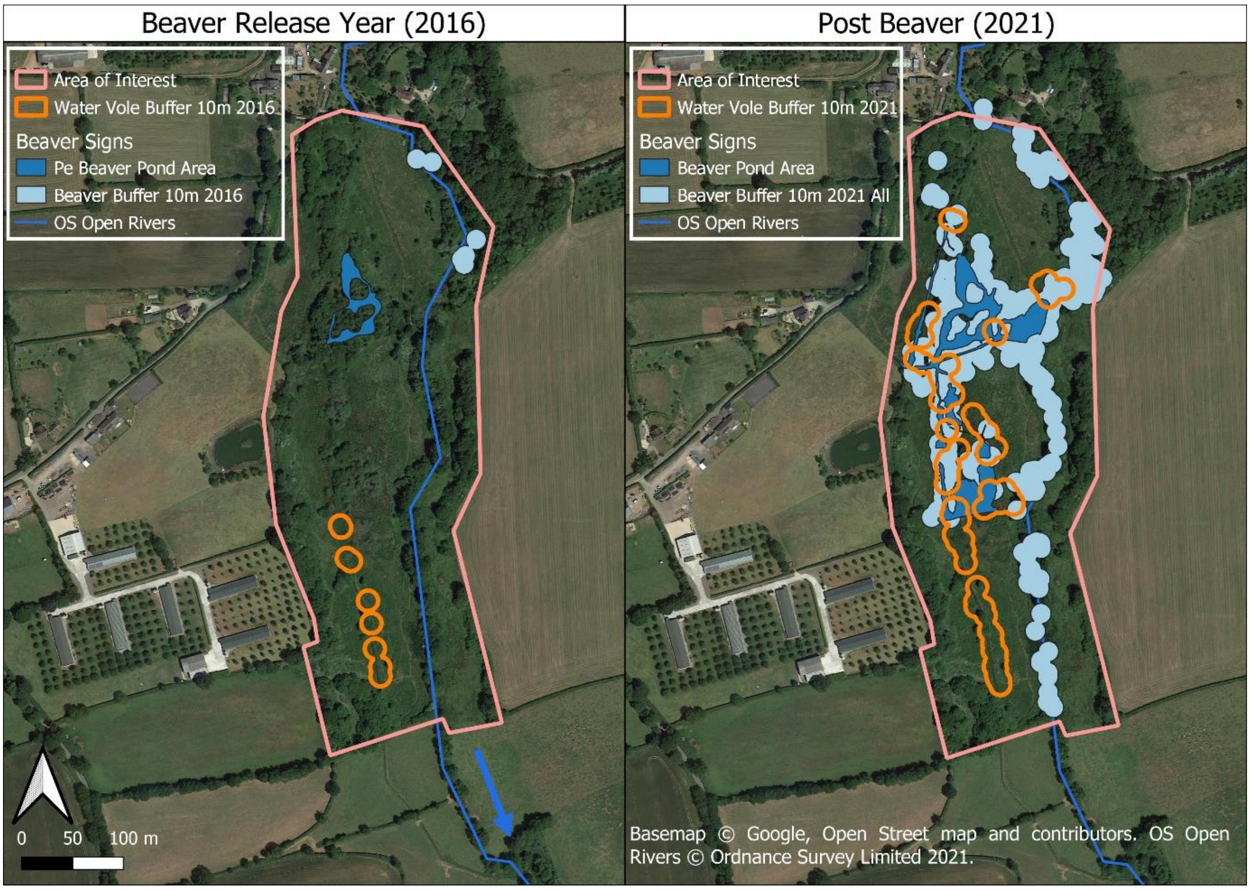

Figure 4. Examples of 2021 water vole field signs recorded in beaver created wetland areas. Background image is a drone orthomosaic of the site whilst signs represent examples of recorded water vole field sign locations recorded with GPS and buffered to account for spatial uncertainty.

DISCUSSION

Survey results show an increase in water vole signs concurrent with the transformation of the site into a complex beaver-created wetland. It is critical to highlight that this was an observational study rather than a controlled experiment which monitored all factors that could have influenced water vole populations at the site. Results show the biggest increase in water vole signs to have been recorded between 2019 and 2021 which corresponds with a continued expansion of beaver wetland area and complexity at the site. Though, as a limitation of this study other factors that could affect water vole numbers over time, such as predator abundance, climatic variability or localised vegetation type, water temperature and flow regimes, were not monitored. However, whilst the increase in signs may only reflect a modest increase in vole population size, post-beaver results show high spatial overlap between water vole and beaver impacted areas of the site, with a high number of water vole signs being found in newly beaver-created wetland features such as canals. The increase in water vole signs when they are nationally under threat provides a valuable insight, suggesting wetland creation by beavers could benefit water vole recovery. As beavers become more widespread across Great Britain, their role in supporting water vole restoration and nature recovery strategies should be considered.

We propose two mechanisms by which beaver may benefit water vole which warrant further investigation. (1) Habitat creation – beavers have significantly increased open water areas with stable water levels and extensive edge habitat for water vole burrowing and feeding, particularly in the network of beaver-created canals and ponds. Through tree felling and localised inundation, beaver activity may have also encouraged the emergence of riparian vegetation favoured by water voles. (2) Predator deflection – Mink have occasionally been recorded here on remote cameras during the ROBT. Other mammalian and avian predators were also recorded during these surveys (otter, brown rat, fox, badger, dog, buzzard, barn owl and grey heron (Newman., 2019)). 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 (Carter & Bright 2003, Moorhouse *et al*. 2008). Here, beavers are creating new wetlands which may provide water voles with resilience to predation pressures.

The benefits of beaver-created wetlands can be attributed to structural complexity, whether for biodiversity (Law *et al*. 2017) or water resource management (Puttock et al., 2021). It has been suggested that activity of water vole populations can influence vegetation composition and structure (Bryce *et al.* 2013), thereby adding further layers of structural complexity to beaver wetlands.

This study illustrates the significant value of collecting high resolution spatial data on species distribution and impact as part of restoration and reintroduction projects. To further our understanding of the relationship between beaver and water vole, additional spatial surveys are recommended across other sites where beaver and water vole distribution may overlap or sites where one species is present, but a release of the other species is planned. Whilst not always possible or practical, baseline surveys prior to release, followed by regular surveys are particularly valuable.

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