River Otter Beaver Trial
Science and Evidence Report

Pink-tagged female beaver with a kit on the River Otter near Otterton in 2017

Photo: Nick Upton / naturepl.com

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The River Otter Beaver Trial is a 5-year trial reintroduction of Eurasian beavers, *Castor fiber*, into the wild in south east Devon. It began with two family groups of beavers in 2015 which have now bred and dispersed throughout the catchment. The Science and Evidence Forum have overseen a detailed research programme, the findings of which are summarised within this report.

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River Otter Beaver Trial: Science and Evidence Report

The Science and Evidence Forum

This report brings together the work of the River Otter Beaver Trial (ROBT) Science and Evidence Forum under the guidance of Professor Richard Brazier. The Forum comprises the following members, although it should not be assumed that the views expressed necessarily represent those of the organisations for whom they work:

University of Exeter
- Prof. Richard Brazier (Chair)
- Dr Alan Puttock
- Hugh Graham
- Roger Auster

Devon Wildlife Trust
- Mark Elliott
- Peter Burgess
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Environment Agency
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Devon Biodiversity Records Centre
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- Philip Sansum

Acknowledgements

The members of the Science and Evidence Forum are also very grateful to the following people for their input, and provision of text and information: Dr Sean Arnott, Prof. Stewart Barr, Andrew Blewett, Helen Booker, Tom Buckley, Gabby Chant, David Couper, Dr Sarah Crowley, Dr Simon Girling, Michelle Grist, Steve Hussey, Mike Holland, Sylvie Meller, Dr Roisin Campbell-Palmer, Chris Townend, Cynthia Underdown, Scott West, David White, Charlotte Zealley. Thanks are also due to those landowners who have permitted access for surveys and trapping during the Trial.

About the River Otter Beaver Trial

The River Otter Beaver Trial is led by Devon Wildlife Trust working in partnership with The University of Exeter, Derek Gow Consultancy, and Clinton Devon Estates. Expert independent advice is also provided by Dr Roisin Campbell Palmer, the Royal Zoological Society of Scotland, Professors John Gurnell and Alastair Driver, and Gerhard Schwab, an international beaver expert based in Bavaria.

This Science and Evidence Forum sits alongside both the Community and Education Forum and the Fisheries Forum, all of which report to the ROBT Management Group, advised and supported by the ROBT Steering Group.

← A beaver-created wetland in the lower Otter valley

Foreword and Introduction to this Report

The engineering and feeding activities of beavers bring profound changes to the health and function of our watercourses. Their reintroduction restores dynamic natural processes that once shaped our riparian landscapes. Beaver reintroduction epitomises the oft-(mis)used term ‘working with natural processes’. Some of these processes are rapid, others can take decades, even centuries to develop. The research programme that has been undertaken as part of the River Otter Beaver Trial (ROBT), must be interpreted in this context. In addition to their ecological impact, beaver activity can also have considerable socio-economic significance which can be positive as well as negative, dependent on the location of their activities and the landscapes and settlement patterns in which they occur.

It is important to note that beavers and their impacts have been well researched throughout much of Europe, Asia and North America where studies of their biology and impacts on many landscapes and the people that occupy them have been undertaken. However, it is acknowledged that site-specific science and evidence, especially that which describes beaver impacts upon lowland, intensively-farmed landscapes could be further explored.

The ROBT provided a 5-year window to observe the colonisation phase of beavers into a lowland English river catchment. In 2015 we published a detailed monitoring plan[1] http://bit.ly/ROBT-Mon-Plan which was revised at the mid-point of the Trial. We now present the results of that research.

Unlike many other beaver projects around the world, including the Scottish Beaver Trial[2,3], the River Otter Beaver Trial received very limited financial support from government for our science and evidence programme. We are therefore indebted to those organisations that have funded this work and generously provided in kind time, insight and expertise. Without this support there would have been no Trial. Decisions have been made to prioritise those areas of research most critical to the overall objectives of the Trial and we have not focused on areas where detailed, relevant evidence is available elsewhere.

This report provides an overview of the research undertaken, and is supplemented by many peer reviewed papers, commissioned reports and additional evidence that are published as a series of appendices and referenced throughout. These reports and papers can be found here: https://www.exeter.ac.uk/creww/research/beavertrial/.

Finally, as the report concludes, numbers of beavers in the catchment are now significant and will continue to expand, delivering more widespread changes in the coming years, assuming they are permitted to remain. As such, continued monitoring both of the beavers and their impacts and the delivery of an appropriate management framework is recommended to ensure that society can maximise the benefit from their presence with associated risks minimised.

Richard Brazier

Professor of Earth Surface Processes, Director, Centre for Resilience in Environment, Water and Waste (CREWW), University of Exeter
Chair of ROBT Science and Evidence Forum

References

1. Science and Evidence Forum. *River Otter Beaver Trial Monitoring Plan*. http://bit.ly/ROBT-Mon-Plan (2017).
2. Gaywood, M. *et al. Beavers in Scotland: a report to the Scottish Government.* (Scottish Natural Heritage, 2015).
3. Gaywood, M. J. Reintroducing the Eurasian beaver Castor fiber to Scotland. *Mammal Review* 48, 48–61 (2017).

Executive Summary

The research conducted as part of the ROBT has been extensive and far reaching, with many new areas of inquiry emerging from it. The approach was outlined in a Monitoring Plan published at the start of the Trial, which has guided the scientific work undertaken over the five years. Some of the key findings are as follows:

- The River Otter **beaver population** has increased significantly from the two founding family groups in 2015, to ca. 13 territories established by 2019. Only three mortalities were confirmed during the study period with the population dispersing throughout the main stem of the River Otter and the River Tale, as well as into some smaller tributaries. This increase in population reflects estimates made in the licence application and clearly demonstrates the River Otter environment will be able to sustain a healthy, expanding beaver population.

- **Public perception** questionnaires conducted nationally in 2017 found that 86% of 2,741 people supported beaver reintroduction. By 2019 a repeat survey found that 90% were supportive (n=386). When asked about legal protection if beavers were to be formally introduced, 75% felt there should be strong legal protection, 20% said limited legal protection and 5% said none in 2017. By 2019 this was 79%, 17% and 4% respectively.

- Beaver Dam Capacity modelling shows which parts of the catchment are capable of supporting **beaver dams**. A snapshot of the dams in place throughout the catchment in October 2019 identified 28 dams in six of the beaver territories. No dams have been constructed in the main stem of the River Otter, and dams in the smaller River Tale tributary have been dynamic and mostly temporary features due to the high seasonal stream flows experienced in this watercourse. Of the 594 km of watercourse within the River Otter catchment a total of 1.9 km (0.3%) was impounded by beaver dams in October 2019.

One of the Trial animals feeding on willow in the lower River Otter

Picture: David White

- Beaver dams have had a wide variety of effects depending on the nature of the watercourse and the surrounding land-use. A sequence of beaver dams constructed upstream of a village with properties at risk of flooding has seen **a reduction in peak flows** as a result of the beaver dams.

- A comprehensive monitoring programme of **Environment Agency infrastructure** has recorded no beaver related impacts. Beavers have become established in a **water supply reservoir**, and routine work by volunteers has been required to keep a spillway clear. Elsewhere, two small culverts have seen beaver activity, with one requiring regular low-level management.

- Beaver activity in five sites has **impacted land-drainage** for agriculture on floodplains, necessitating the need for management interventions. The most significant financial impact was on 0.4 ha of organic potato crop where elevated water levels restricted machinery access. A flow device (beaver deceiver) was installed on one site to reduce water levels successfully.

- The effect of beaver engineering and feeding has delivered **significant ecological benefits** with new areas of wetland habitat created and managed, with documented benefits for amphibians, wildfowl and water voles. The changes in scrub canopy structure and increased water levels have enhanced a wetland County Wildlife Site. There have been no measurable impacts on any statutory **designated sites**.

Detailed fisheries survey work has investigated the impacts of beavers on fish populations in the River Tale; the only location where beavers have built dams in a larger watercourse.

- Impacts of beaver dams on **fish populations and habitats** have been studied where opportunities have allowed. In the River Tale where beaver dams have been regularly built and washed away, a snapshot survey in 2019 of the lower 8.3 km showed 518 m were impounded by two beaver dams. Electrofishing of one of these features found total abundance in the beaver pool was 37% higher than the other three reaches surveyed, with highest total fish biomass and more trout than in either the upstream or downstream control sites. The shallow, swift-flowing conditions created where a previous beaver dam had washed away, provided good habitat for juvenile trout which were abundant. During the survey there was a notable reduction in bullhead in the beaver pool, whilst the number of minnow and lamprey were markedly greater in comparison with the other reaches.

- With so few dams coinciding with salmonid runs, there were very few opportunities to investigate the **impacts of beaver dams on fish migration** in the Otter catchment. Their physical characteristics suggest that some dams in smaller ditches and streams could represent an obstruction to free movement of some fish in specific flow conditions, but trout have been recorded passing two beaver dams during higher flows.

- There has been one site where a **small country lane experienced water encroachment** as a result of an adjacent beaver dam. This was successfully resolved by occasional reduction of the height of the dam. On another site a farm access track flooded periodically, and occasional management of the dam was necessary to resolve this.

- There have been no recorded impacts of beavers on any **forestry** plantations but small **riverside orchards** have seen beaver feeding on both windfall apples and the trees. Proactive measures to protect trees have managed this issue, and on one site the visual impact of the tree guards remains an issue. In three territories, beavers have been recorded feeding on maize with 15 m^2 impacted in one case.

Occassional trapping of the beavers throughout the Trial has allowed their health status to be monitored.

- There have been three instances where trees have been felled by the beavers onto **footpaths** between 2015 and 2019. In each case, the landowner, Clinton Devon Estates, was swift in their removal.

- **Territory Capacity modelling** work predicts that the maximum number of territories that the River Otter catchment could support is between 147 and 179.

- From a **health and biosecurity perspective**, beavers are currently considered to present no significant risk to human, livestock, or other wildlife health. Routine checks of the health and physical condition of the beavers clearly shows they are healthy and thriving.

- A summary of the quantifiable **cost and benefits** of beaver reintroduction demonstrates that the ecosystem services and social benefits accrued are greater than the financial costs incurred.

- At the catchment scale, benefits can accrue in the same locations as costs (e.g. biodiversity gains on flooded land), but also in different locations (e.g. downstream flood reduction due to floodplain inundation). Thus, **those who benefit from beaver reintroduction may not always be the same people as those who bear the costs.**

The beavers have rapidly created new wetland habitats in a number of locations throughout the catchment, many of which are detailed in the case studies at the back of this report.

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BACKGROUND TO RIVER OTTER BEAVER TRIAL

CASE STUDIES:

Background to the River Otter Beaver Trial

The Eurasian beaver, *Castor fiber*, is a semi-aquatic rodent that once lived in watercourses throughout Britain. The beaver's extensive engineering activities would have had a disproportionate impact on the prehistoric landscape relative to their abundance, and the wetland species found in Britain co-evolved and coexisted in ecosystems shaped by this species[1].

It is unclear exactly when and how the Eurasian beaver was hunted to extinction in Britain, though it is understood that these animals were highly valued for their fur, castoreum and meat. The last written record of the species in England is a church ledger which records a bounty being paid for a beaver head in 1780 from Bolton Percy in North Yorkshire[2].

The removal of this keystone species, and the subsequent drainage and engineering of our waterways and wetlands has allowed humans to transform the British countryside into an agriculturally productive landscape, where riparian wildlife is often heavily managed and consequently marginalised. The significance of the return of the beaver and the way in which these animals will interact with intensively managed and densely populated landscapes should therefore not be underestimated.

In February 2015, Devon Wildlife Trust (DWT) was issued a licence to release beavers into the wild, on behalf of the ROBT partners. This licensed reintroduction followed the discovery of a group of breeding beavers living wild on the River Otter in East Devon, and a campaign by local residents and others for them to remain. In order to address concerns that the beavers could carry a taenid tapeworm, *Echinococcus multilocularis*, not found in the UK, the adult beavers living on the river were first trapped by the Animal and Plant Health Agency (APHA) in early 2015. The beavers were given thorough health checks by APHA and the ROBT, prior to being released back into the River Otter catchment with a clean bill of health, under the licence held by DWT.

One of the Principle Outcomes outlined in the ROBT licence application was that 'the impacts of the free living beavers on the River Otter, its wildlife, the local economy and local people will be scientifically assessed and recorded to provide a solid evidence base on which the future of the population can be decided.'

The licence required ROBT partners to 'design a monitoring programme to determine and study the positive and negative impacts of the beavers on the River Otter and the surrounding land,' and the Science and Evidence Forum was established by the ROBT Management Group to develop and oversee the implementation of a detailed Monitoring Plan.

Professor Richard Brazier was appointed to Chair the Forum and ensure the ROBT monitoring work fulfils the core requirements and objectives of the Trial, and is conducted in a rigorous, scientifically objective, peer-reviewed and independent manner.

The ROBT 5-year term is due to conclude in March 2020. Defra Ministers, with advice from Natural England, are responsible for deciding the future of the beavers currently living wild on the river. This report and referenced papers contained within provides the summary of evidence and observations to inform this decision. The ROBT Steering Group will also consider the information contained within this report, enabling wider conclusions regarding the Trial to be published and communicated.

References

1. Brown, A.G., Lespez, L., Sear, D.A., Macaire, J.-J., Houben, P., Klimek, K., Brazier, R.E., Van Oost, K., Pears, B., 2018. *Natural vs anthropogenic streams in Europe: History, ecology and implications for restoration, river-rewilding and riverine ecosystem services.* Earth-Sci. Rev. 180, 185–205. https://doi.org/10.1016/j.earscirev.2018.02.001
2. Coles, B., 2006. *Beavers in Britain's Past.* Oxbow Books, Oxford.

▶ Otter residents show their support for beavers

CHAPTER 1:

Living with beavers on the River Otter

The River Otter rises in the pastoral landscape of the Blackdown Hills and flows just to the north of Honiton

Catchment Overview

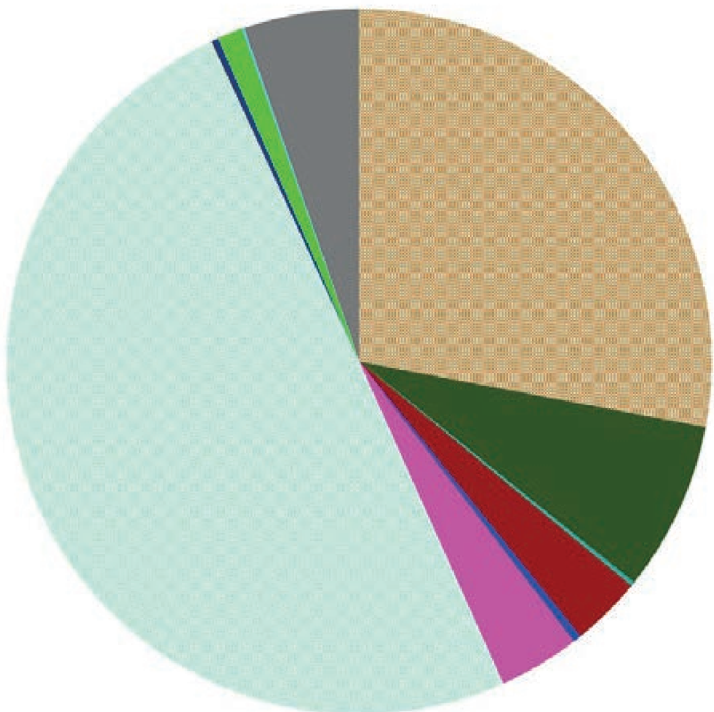
Geography of the River Otter catchment

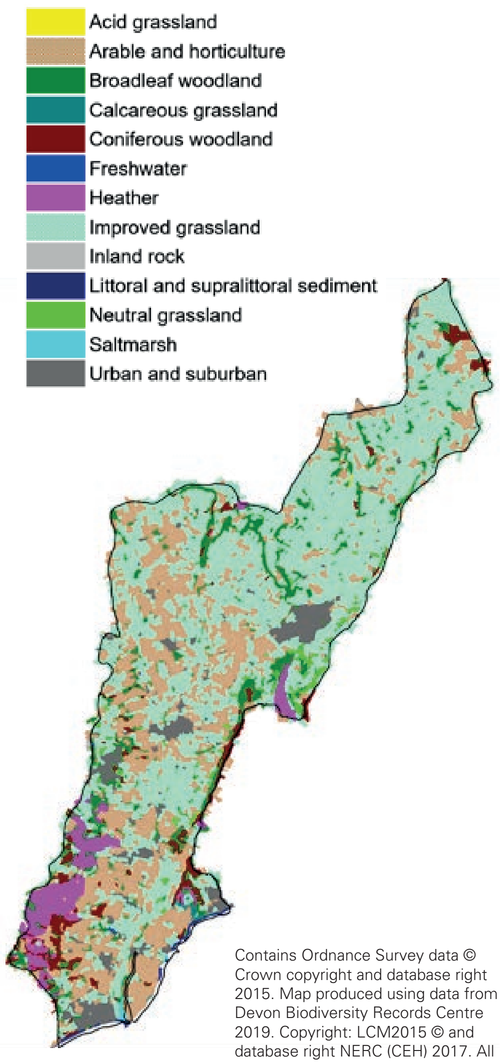
The River Otter rises in the Blackdown Hills, from a *Cretaceous* Upper Greensand scarp at 275 m above sea level, which defines the eastern edge of the catchment as far south as Sidmouth. The western boundary is formed by a ridge of *Permian* Sandstone. Between these two ridges lies an area of *Triassic* Mercia Mudstone which runs to Ottery St Mary. East and south of Ottery St Mary the geology changes to Otter Sandstone. The bedrock is overlain by alluvium and river terrace deposits, with fine sandy and silty soils.

The Otter is a predominately rural catchment, with generally small, dispersed settlements. The only towns are Honiton, Ottery St Mary and Budleigh Salterton. The northern part of the catchment is characterised by rolling hills with small field systems, enclosed by hedgerows, supporting mostly pastoral farms, whereas more intensive agricultural practices, including arable land use, dominate the southern catchment. There are several coniferous and broadleaved plantations on the greensand ridge that runs along the northern and eastern side of the catchment, with more conifer plantations around the East Devon Pebblebed Heaths to the southwest.

Figure 1.1 Land use in the River Otter Catchment

The catchment covers ca. 250 km^2 (25,010 ha). Landuse composes: 50% improved grassland, 28% arable and horticulture and 5% urban and suburban. The remaining 17% is covered by woodland, other grasslands, heathland, freshwater, saltmarsh, littoral sediment, and supra-littoral sediment[1].





Acknowledgements: The following datasets have been used in the derivation of LCM2015 Vector (GB):

- Landsat-8 satellite imagery. Data available from the U.S Geological Survey.
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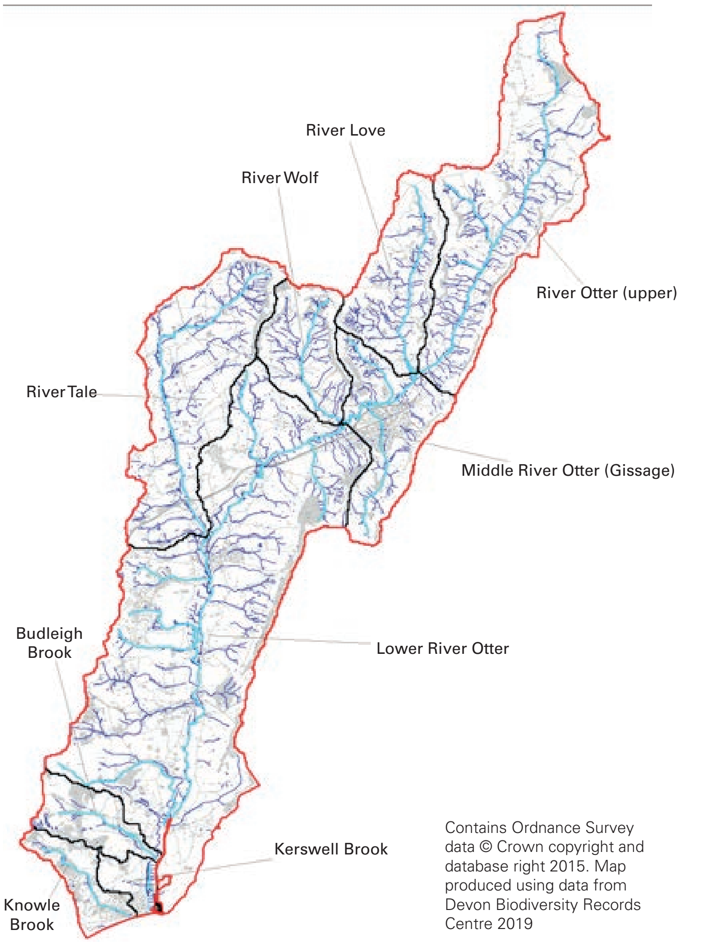
- Digital elevation data © Intermap Technologies Inc. or its suppliers 2003.
- OS open data layers – Contains OS data © Crown copyright and database right (2015).
- National Forest Inventory (NFI) data provided by the Forestry Commission © Crown Copyright, courtesy Forestry Commission (2015), licensed under the Open Government Licence.
- Boundaries from Rural Payments Agency © Crown copyright and database right and/or © third party licensors.

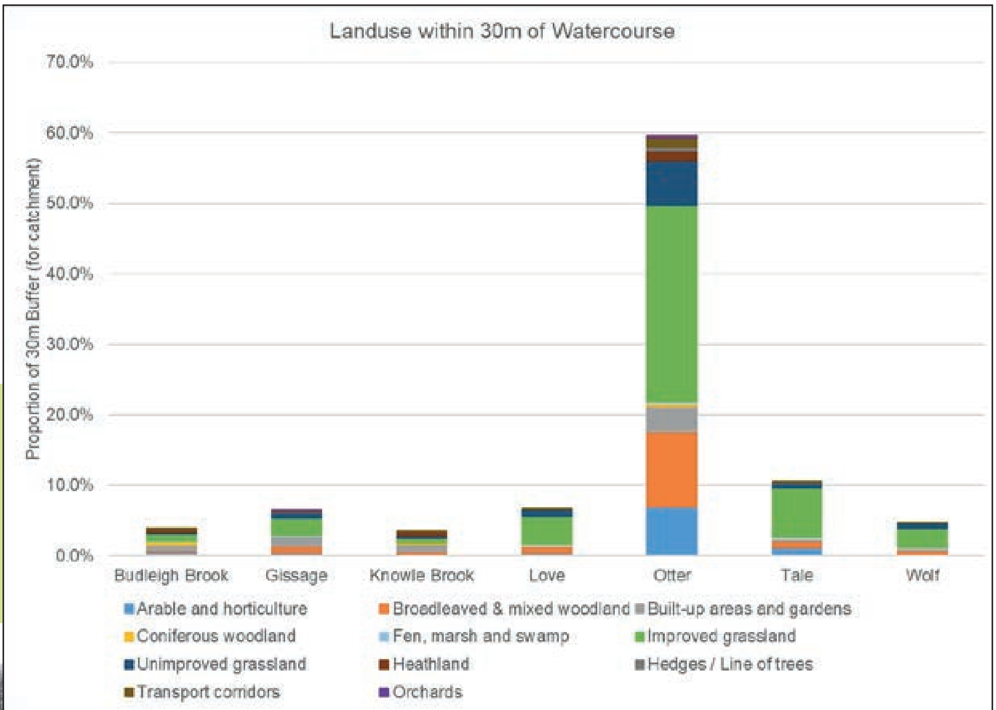
Figure 1.2 Watercourses within the catchment

The River Otter is divided into nine sub-catchments, with the main tributaries being the River Tale, the River Love and the River Wolf all rising from the Upper Greensand scarp, along with the Upper Otter. The main stem of the river is in excess of 65 km in length between the Otterhead Lakes and the sea.



Land-use adjacent to watercourses

Survey work carried out during the Trial shows that 99.8% of feeding signs are detected within 30 m of the banks of watercourses (see figure 5.1).



→ **Figure 1.3** Aerial Photographic Interpretation of the land-use within a 30 m buffer of all of the key watercourses within the catchment identifies the land-uses most likely to be affected by the activities of beavers. The total area of this buffer is 3,378 ha.

← A small buffer strip between floodplain pasture and the river provides a number of benefits.

Beaver colonisation of the River Otter catchment

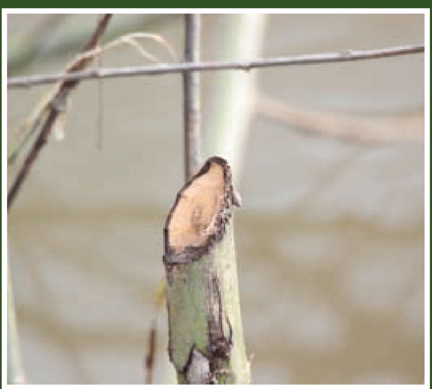
→ The ROBT team were able to increase the efficiency of survey work through the acquisition of a Trimble Geo7 GPS device that allowed the user to input data directly into a Geographical Information System (GIS).

Methods for monitoring beaver distribution

As with many mammals, surveying beaver field signs (gnawed trees, burrows, lodges, canals) is the best way of monitoring the number and distribution of territories. At the start of the ROBT, monitoring techniques developed by the Scottish Beaver Trial were adapted for the River Otter. However, repetition of detailed surveys every 3 months proved impractical across a large catchment which contains a great deal of dense, bankside vegetation. Therefore, the survey technique was revised to record feeding signs on woody material once a year (January-March), capturing a snapshot of the winter distribution of the animals (details published in Campbell-Palmer et al., 2019[2,3]). Data of woody feeding signs collected in the field were used to produce heat maps derived using a 'kernel density algorithm' within a search area of 250 m.

Figure 1.4 Browsing by beavers on trees was recorded into three impact classes using this classification

Photos: Sylvie Meller



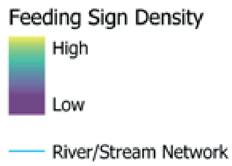
Low Impact – fewer than 20 cuts (branches or stems), all <7 cm in diameter, and / or stripped bark area <10 hands (ca. 0.2 m²).

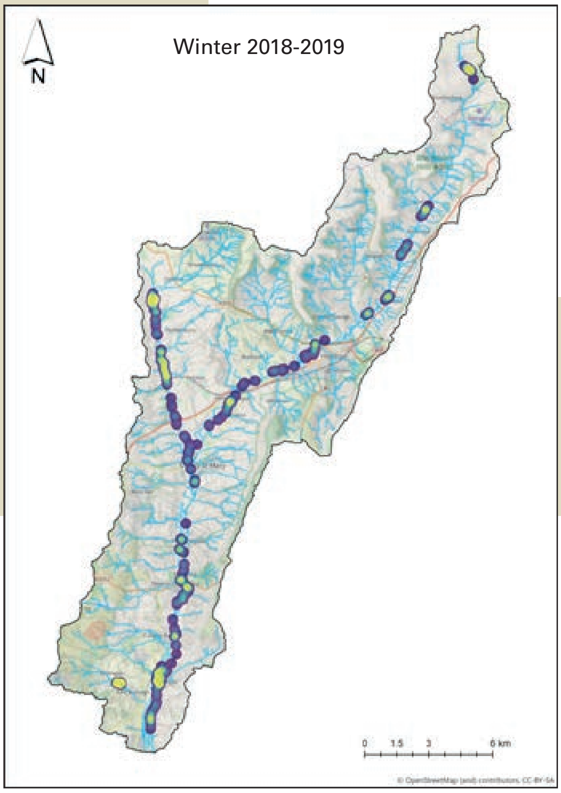
Medium Impact – greater than 20 cuts (branches or stems), or with at least one >7 cm in diameter, and / or a stripped bark area >10 hands (ca. 0.2 m²).

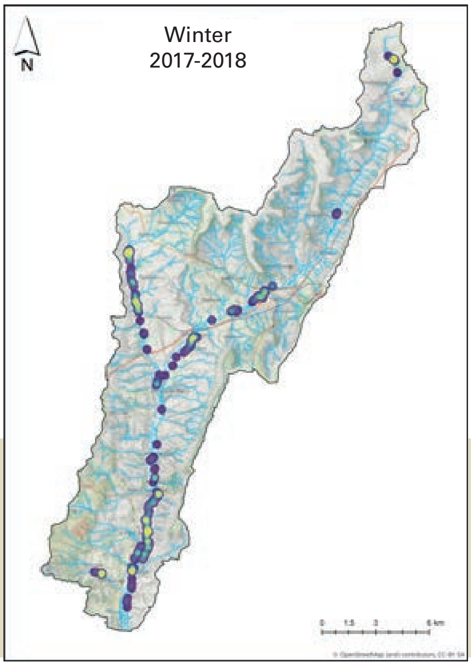
Major Impact – Tree / main stem with a diameter >20 cm, either felled or noticeably incised (i.e. beyond the cambium and noticeably into the sapwood, and not simply bark stripped).

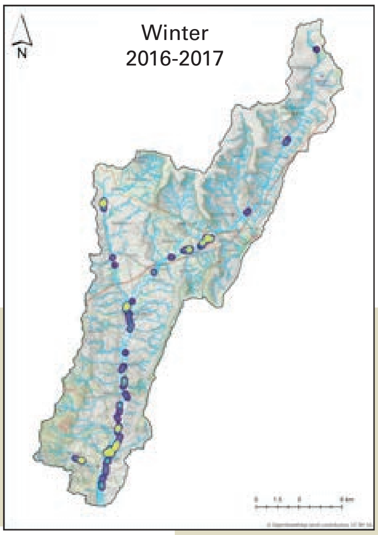
↓ In 2018-19, a total of 78 km were surveyed. Systematic surveys were undertaken annually in those parts of the catchment where beavers were known to be active and where landowners were engaged with the Trial. This area increased over the course of the Trial. It is not considered likely that significant areas of activity have been overlooked.

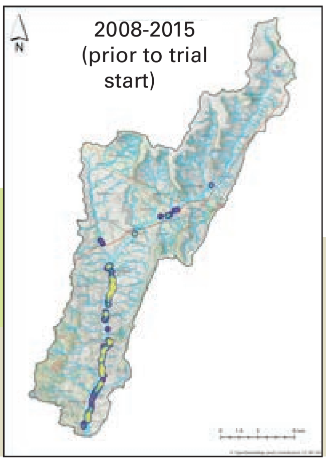
← In the winter 2015-16 survey, data were also collected on older field signs to understand the historic (pre-Trial) distribution. Some field signs clearly pre-dated the start of the Trial and can be aged using regrowth, but for many, it was much harder to determine, and the dataset (heat map) for pre-trial should be interpreted with a larger margin of error.

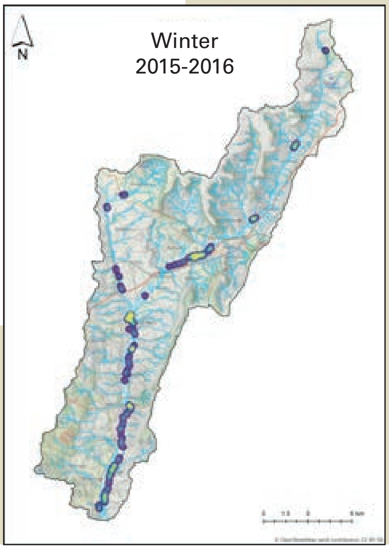












→ **Figure 1.5** Heat maps produced at the end of each survey season in March provide a useful snapshot of feeding signs throughout the catchment.

Analysis of field survey data and territory assessment

Table 1.1 Changes in estimated territory numbers from 2015-2019

Situation in April of:	Focus of activity	Known breeding pairs
2015	2	2
2016	3	3
2017	6	5
2018	8	6
2019	<13	7

Both point data and heat maps, derived from the feeding sign surveys are of great use when evaluating the expanding population of the beavers on the River Otter. Results from 2015 – 2019 clearly show how the population has expanded from a small number of territories located in the lower reaches of the Otter, to occupy much of the main river from the estuary to the headwaters, including the River Tale, the major tributary.

Beavers are 'central place' foragers[4] and therefore the frequency of feeding signs declines with increasing distance from a dwelling. This pattern is reflected in the heat maps presented in Figure 1.5. However, the key limitation of the feeding sign survey is that it identifies beaver presence only where woody material is also present. Therefore, in reaches where woody habitat is discontinuous, feeding density is similarly discontinuous. In these reaches it becomes difficult to differentiate between multiple small territories and fewer larger territories[2,3].

As the population has expanded, it has become harder to determine the numbers of territories from these data. In addition, visual observations and trapping records have been used help gauge the size of the population.

In established populations it may be possible to assign an average number of beavers in a territory to gain an estimate of the population size[5]. In small colonising populations, where many areas of feeding activity may be the result of individual animals or young pairs starting to establish territories, this approach to estimate beaver numbers is less accurate[6].

Future work: Monitoring beaver feeding activity provides a low cost but powerful tool with which to evaluate the population dynamics of beavers at the catchment scale. Whilst radio tagging/tracking can provide much more detailed information regarding the movement and territory ranges of animals, it is costly and comes with many challenges arising from their semi-aquatic and burrowing habits. We suggest feeding sign surveys should be undertaken on other wild-living beaver populations in Britain in order to enable comparison between populations and further develop the use of automated territory detection year-on-year.

Summary of the effects of beavers on the River Otter

As a keystone species, the ecosystem effects of beaver behaviour can be significant, and are also highly variable. The effects on the environment and also society are dependent on the type, location and intensity of beaver activity, and the current land/water-use in that area.

The nature of beaver behaviour means that conflicts with existing human activities are inevitable. Every attempt has been made to record and report any conflicts that have occurred over the Trial period, although these have not been significant. Where issues have arisen, timely and effective management interventions have been effective in ameliorating them and diffusing conflicts. It is vital that such a management approach is continued if beavers are to be widely accepted and their benefits maximised.

Alongside this Science and Evidence work, the ROBT Steering Group have invested considerable time developing and publishing a Beaver Management Strategy Framework which recommends how beavers and their impacts should be managed beyond 2020 in the event that they are permitted to remain on the River Otter. (ROBT, 2019[7] - **http://bit.ly/ROBT-BMSF**)

Management techniques

▶ Efficacy of electric fencing

Beaver damming

The construction of dams by beavers to impound water is one of the most important aspects of their behaviour as a keystone species[8], and the one that has the greatest potential to transform waterways, creating both opportunities and conflicts with existing land-uses.

Six of the 13 established beaver territories have seen dam building behaviour, with the case studies providing more detailed information on the effects of these dams for some of these sites.

The dams have varied in size, shape, construction materials and permanence. A snapshot survey was conducted in October 2019, and the figures provided in this report and summarised in Table 1.2. It is important to stress that many of the dams that have been studied and have caused impacts, no longer exist.

No dams have been constructed in the main River Otter. In the upper River Tale tributary, dams have been built, which regularly erode during high flows and, at times, are completely removed. At present only one dam persists in this location. In September 2019, a new dam was discovered in the River Wolf, one of the other main tributaries, and in an area where beaver activity had not previously been detected, suggesting a new territory was being established.

Three areas have seen temporary dams associated with maize cropping, where dams appear to be constructed to allow access to the maize crop. The maize stems are also used as a dam building material.

In existing wetlands and ponds, even very low dams can increase the extent of surface water and wetland habitats, significantly enhancing their water-holding capacity and ecological value. This has been very noticeable in three territories **(Case studies 1, 2 and 5).**

→ A beaver-created wetland in the Budleigh Brook

Photo: Steve Pease

Watercourse	Number of dams	Height of dam (cm)	Length of Impounded water upstream (m)
Colaton Raleigh stream (Case Study 1)	8	25	109
		40	57
		40	231
		40	42
		15	128
		50	153
		100	81
		30	12
Budleigh Brook (Case Study 2)	6	30	23
		40	44
		120	64
		30	31
		40	60
		170	70
Otterhead (Case Study 4)	11	50	17
		20	20
		40	15
		30	10
		150	104
		20	10
		30	10
		30	20
		20	5
		150	14
		50	21
River Tale (mid) (Case Study 6)	1	60	310
River Tale (upper) (Case Study 5)	1	180	208
River Wolf	1	50	20
TOTALS	**28**		**1,889 m**

← **Table 1.2** A snapshot of all the in-stream dams in the River Otter catchment in October 2019. Any mud dams and retaining banks built off the line of watercourses are not included, although these often work in tandem with these in-stream dams.

← **Colaton Raleigh stream** is a groundwater fed watercourse that originates on Colaton Raleigh Common. The watercourse has been heavily modified by land drainage and runs in a ditch network through floodplain pastures before joining the main River Otter in Otterton. Within this network, beaver dams have been built in 13 locations since September 2016. This is a low gradient drainage system and although high flows and human intervention have regularly changed the dam heights, a few have been washed out in their entirety. Three of the smaller dams have also been drowned out by other dams built downstream of them.

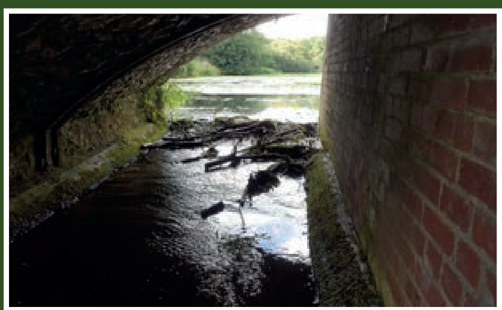
The creation of wetland habitats has been rapid and the management of three dams has been necessary to mitigate impacts on land-drainage / raised water level, including the installation of a flow device (aka a 'beaver deceiver') which is detailed in **Case Study 1**.

In October 2019, eight dams were present and due to the flat nature of the topography, 813 m of the ditch network were impounded by them.

↑ The **Budleigh Brook** rises on Bicton Common before passing through Yettington and East Budleigh. Six dams have been constructed in the channel and two of these have pushed water out of bank, with retaining bunds also built by the beavers on the adjacent floodplain.

These six dams have impounded 292m of the original watercourse and created 0.1ha of open water, in addition to other wetland habitats around the standing water.

At this location the creation of the wetland has been supported by the landowner, and is the subject of research into the beneficial impacts on flood risk in a community downstream (see **Case Study 2**). Impacts on agricultural activities have also been quantified.



→ **Otterhead Lakes.** Dams have been built in seven locations upstream of the top lake/ reservoir, although these are dynamic features due to high flows. In total 11 dams were recorded in various watercourses in this complex in October 2019. Owing to the steeper gradient here, they impounded only 246 m of watercourse (which includes the main lake with slightly elevated water levels at this time).

The beavers are continuing to build a small dam on the outfall structure to the upper lake, and this is removed regularly by volunteers on the site. Beaver dams have also been built in the overflow channel from the top lake. One was around the outfall structure which was removed, and others have been retained.

The potential implications on the water resources and supply infrastructure are discussed in **Case Study 4**.

← The **Clyst William Cross (upper Tale)** site, where additional beavers were released (to improve genetic diversity) in 2016, is where the largest number of dams have been built. In the main River Tale, dams have been built in eight different locations. The high-energy nature of this watercourse has made these dams very dynamic, often ephemeral, features. It is estimated that a total of 22 individual dams were built in eight locations on this reach of the Upper Tale over the 4 year period since 2016. Only one was in place in October 2019; a large 1.8 m high dam structure, which was impounding 208m of the stream and was bypassed by side channels cutting across the river floodplain.

Nine dams have also been built in the adjacent wetland habitat away from the main stream, including in new channels also created by the beavers, and not including the retaining earth bunds built to retain water in flat low-lying land. (see **Case Study 5**).

↓ In the **mid-River Tale,** dams have been built in four locations, often during low summer flows to access adjacent food resources (maize). At two of these sites, dams were unacceptable to some, but not all, of the landowners, and any signs of beavers starting to rebuild the dam were repeatedly removed by ROBT staff; in one case on 10 occasions over a period of three weeks. High flows commonly erode these dams and going into autumn 2019 only one 0.6 m high dam was in place. **Case Study 6** discusses the conflicts with land drainage, and associated issues between neighbours in this flat landscape.

↑ The **Cadhay stream** near Ottery St Mary was the location for the first beaver dams in the catchment. In early 2016, a 0.8 m high dam was built in a drainage ditch impounding water in low-lying pasture where a flood relief channel discharges peak-flows. This was initially removed by the landowner because of the impacts on land-drainage, and then again twice subsequently by ROBT staff. Two other smaller dams were also removed in the same ditch to prevent them becoming established. They have not been rebuilt since.

Clearing an established dam

← In the River Wolf a new dam was built across the channel in September 2019. It remains to be seen how it will withstand high flows during the winter. At the time of the survey it was 0.5 m high and impounding 20 m upstream

↑ The increased channel heterogeneity created by beaver dams, creates new riffle habitat for dippers and bullhead.

Photo: David White

Environmental opportunities created by beaver dams

Small water bodies, for example ponds, are disproportionately important (relative to their size) for freshwater biodiversity[9], yet very many ponds have been removed, or lost through succession, from intensively farmed agricultural landscapes over the last 150 years. For example, in 1880 there were 800,000 ponds in England and Wales[10], but by 1996, there were only 228,900 ponds[11,12]. As it has been shown that ca. one third of aquatic species, such as macroinvertebrates, may only be present in ponds[13] and that beaver ponds may host 50% more unique species than other wetlands[14], it is likely that the environmental opportunities, or benefits afforded by beaver pond creation will be significant.

Small dams have been rapidly established and have enhanced wetland features and diversity in the landscape. Across the catchment, damming by beavers has created many new wetlands and ponds. These ponds cover a total area of 1.5 ha with a total bank length of 3.5 km. This newly formed habitat provides essential wetland habitats for many species **(see Chapter 2)**.

↓ Beaver dams create a mosaic of wetland habitats which benefit a wide range of wetland species.

↑ Wetland habitats formed where water spills over and around a beaver dam often support important emergent vegetation communities.

Undesirable impacts on land-use caused by beaver dams

In all of the six established territories where dams have been built, some management has been necessary to mitigate undesirable impacts. It is important to note that the attitude of the affected landowner or user is heavily influenced by the ability to manage conflicts and the efficacy of the management interventions **(see Chapter 4).**

In four of these cases, the landowners have welcomed the presence of the beavers, and the ongoing management of dam heights or locations has mitigated any negative impacts. On two sites, the presence of the dams caused unacceptable impacts on land-drainage in the floodplain. They were removed by, or at the request of, those impacted landowners, without any attempt to first mitigate their impacts. When removing dams, the welfare of the beavers was considered, to avoid impacting on natal lodges.

Culvert blocking

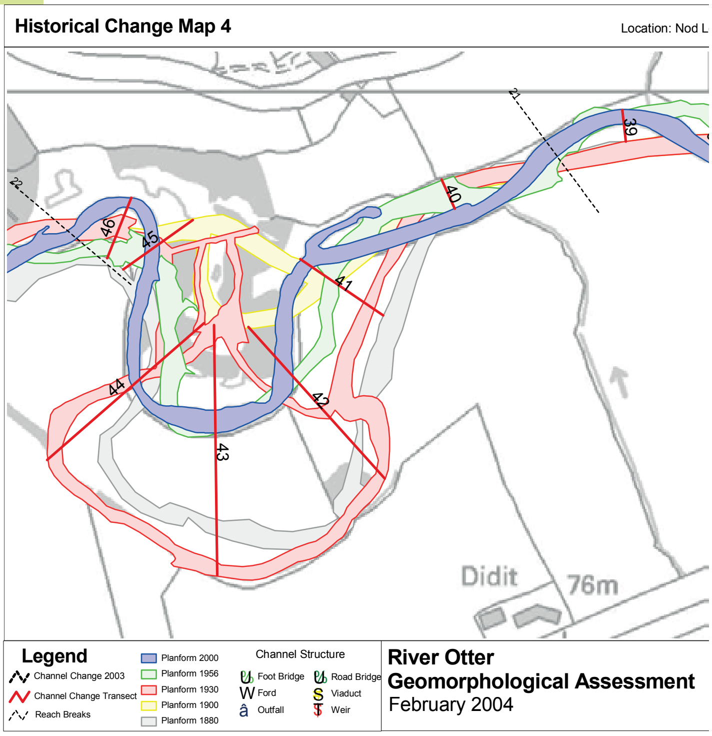
Within the Colaton Raleigh stream, the beavers have used the constricted channel provided by two culverts to attempt to impound water. A small number of beaver sticks have been removed occasionally from one of these culverts. The other culvert has required more frequent monitoring and intervention, as a result of a more concerted attempt by beavers to block it. This management regime remains effective.

Elsewhere beaver activity was thought to be the reason for a blocked culvert, but on closer inspection this was shown to be flood debris which was removed by the ROBT team.

← ROBT Staff clearing a blocked culvert

Riverbank erosion and channel planform changes

A Geomorphological Assessment of the River Otter carried out by the GeoData Institute[12] provides a useful summary of the background (pre-beaver) rates of change in channel planform. It concluded that bank erosion is system wide and occurs over 23% of the bank length and is intrinsically linked to channel adjustment. The primary drivers were identified as periods of increased flood frequency, increased bend curvature, widespread dredging and shoal removal between 1960 and 1990, and the presence of composite banks with the exposure of weaker gravel layers at the toe of most banks. An example of the ongoing change in this highly mobile river was observed prior to the start of the Trial when a major meander just south of Ottery St Mary was cut-off during a storm event, forming a new oxbow lake.



→ **Figure 1.6**
A Geomorphological Assessment of the River Otter includes detailed maps showing changes in planform that have occurred since 1880. (Copyright Environment Agency). This section near Honiton demonstrates clearly the high background rates of change that have occurred in parts of the valley since 1880.

Beaver burrows could increase channel complexity and sinuosity by acting as a focal point for erosion[13]. However, during the Trial we have observed no significant erosion caused by beaver burrows. Localised erosion was observed in two instances associated with beaver lodges. The extent was limited by the presence of established vegetation, stabilising the banks.

In the same period numerous erosion points created by dogs and cattle entering the river were observed. In areas devoid of bankside trees this erosion had greater impact than was observed associated with the two beaver dwellings.

On another occasion, beavers were witnessed digging a burrow and releasing a plume of sediment into the main River Otter. This was within an area of dense tree roots and no obvious signs of bank erosion were subsequently observed.

Beaver dams built in smaller watercourses have resulted in avulsion (channel rerouting) events and minor changes to channel planform. These areas were not covered by the Geomorphological Assessment, and so baseline maps showing historical planform change are not available.

At Clyst William Cross, beavers have constructed several dams within the main channel of the River Tale **(see Case Study 5)**. At this location, the River Tale is an incised 4th order stream with relatively large high-flow stream power. (Stream order describes the size of river and is based on the number and size of contributing tributaries; at its mouth the River Otter is 6th order). Consequently, the dams in this reach are regularly breached during periods of high flow and repaired by beavers during lower flows. The release of impounded water during a dam breach has resulted in the localised erosion of riverbanks immediately downstream of the dams. Consequently, there has been visible change with increased bankfull width and sinuosity, with sediment and gravels re-deposited creating a more mixed channel bed surface than before both upstream and downstream of the dams.

← An avulsion (channel rerouting) event has been observed on the Budleigh Brook where a beaver dam originally built in the stream, now extends across the floodplain. The new network of multi- thread channels has begun to incise, revealing rounded pebbles and cobbles, indicative of previous channel beds, deposited before the channel was artificially straightened and deepened.

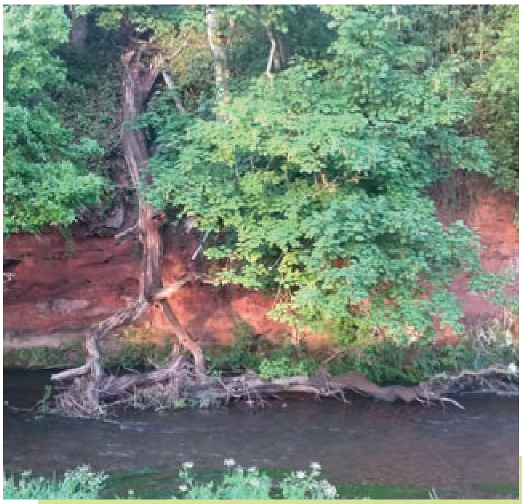
Dams during high flow event

Mobile woody material in watercourses

Woody material serves important ecosystem functions in watercourses, providing crucial substrate and habitats for many invertebrates, and shelter and food for fish[14]. Larger in-stream timber can cause geomorphological changes, resulting in creation of in-channel features such as gravel bars[15]. Large volumes of woody material can cause blockages or damage to bridges or culverts, increasing flood risk in some locations.

Beavers are actively browsing on woody trees and shrubs throughout the River Otter corridor, particularly during the autumn and winter months. Branches are frequently 'processed' by the beavers on the water's edge, and this generates many small beaver 'chopsticks' which are often wholly or partially stripped of their bark and have characteristic cut ends with teeth marks. Feeding stations are recorded on the water's edge, and mobile beaver sticks can be found some distance downstream. In the River Otter these mobile signs are referred to as 'erratics', and are recorded separately to indicate beaver activity upstream, not necessarily at the point of recording.

The felling of entire trees by beavers into the main river has been recorded on fewer than ten occasions. In all instances, they were trees with a trunk diameter of <30 cm, and they all remained attached to the bank.



↑ The proportion of in-channel woody material derived from other sources has not been assessed. During the Trial a number of larger trees have been observed entering the channel as a result of bank erosion or storm events, rather than beaver activity, particularly in the area downstream of Ottery St Mary.

→ The presence of beaver sticks is a useful way of confirming the presence of beavers upstream. Beaver sticks have been seen in the strand-line on the beach at the mouth of the River Otter, one of many 'firsts' in England for some hundreds of years.

Picture: Roger Auster

Feeding on trees

As well as feeding extensively on soft riverside and aquatic plants, beavers browse on woody vegetation throughout the year, particularly during the winter months[15]. In the River Otter catchment, overhanging tree branches and those within water courses are often favoured, and they will also feed on bankside trees.

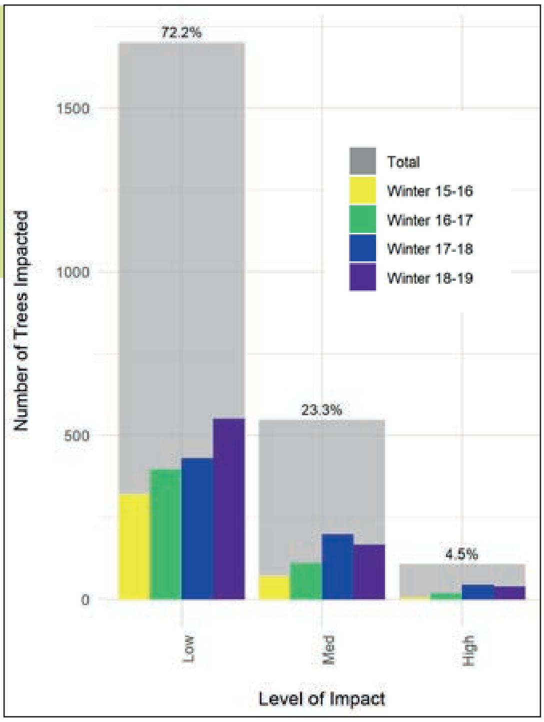
These impacts are easily detectable during the winter months and provide the basis of the systematic surveys. Initially each cut stem was mapped, and details recorded. This soon became impractical, and so each tree impacted was mapped and classified as detailed in Figure 1.4 (above). This classification was designed to represent the time that the beavers had spent at the location, and also to reflect the societal impacts of this beaver behaviour. The species affected and the distances from the watercourse are detailed in Chapter 6.

→ The visual effects of beavers on riverside trees has been subtle in the five years of the Trial, with no significant 'landscape' trees felled by the beavers. Some have been subject to extensive feeding and bark stripping and were protected. Some large poplar trees have been felled by the beavers which was allowed by the landowner. Over the same time period, some large riverside trees have fallen due to other natural causes such as high winds and bank erosion.

▶ **Beaver feeding on large willow**

▶ **Tree climbing beavers**

→ **Figure 1.7** The majority of trees were only subject to low levels of feeding. The number of trees impacted increases as the population expands. Although surveys were conducted annually, annual counts cannot simply be added as the same trees are often browsed over multiple years.



↑ There is a stand of very large native black poplar trees *Populus nigra subsp. betulifolia* within one of the largest beaver territories, but no impacts on these trees has been recorded. In two other territories black poplars have been protected.

← Within the Otterton territory, one stem of a young row of streamside aspen *Populus Tremula* trees has been coppiced.

Picture: Sue Lane

The importance of pre-emptive management

The ROBT was required to report any complaints received to Natural England, and over the five years of the trial, ten complaints were recorded regarding impacts on trees. With feeding signs recorded on trees on 2,356 occasions during the annual systematic surveys, the majority of impacts are not viewed negatively by landowners or farmers – indeed the vast majority go unnoticed.

However, pre-emptive and responsive actions by the ROBT field staff have been vital in preventing and managing potential conflicts. When feeding signs are detected on larger trees, a rapid assessment of potential effects informs the management and advice that is necessary. For example, trees adjacent to powerlines or busy roads would be protected. Any riverside orchards are also assessed and if necessary, protected. This proactive information and support provided to landowners has played a vital role in reducing conflict.

Table 1.3 Numbers and species of tree protected using different methods over the course of the ROBT.

Tree species	Sandy paint or SBR mix	Galvanised weld mesh	Total protected
Apple	8	16	24
Beech	1	0	1
Birch	2	0	2
Black poplar	2	1	3
Oak	1	1	2
Poplar	5	2	7
Willow	14	12	26
Wisteria	0	1	1
Total protected	33	33	66

→ In one site, a strip of willow and poplar trees, originally planted for bankside protection, were subject to regular beaver feeding. In these situations, rotational coppicing of trees might sometimes be used to reduce canopy height and help stabilise the bank. The beavers were providing this coppicing effect, although the landowner was concerned about some of the larger trees and so these were protected.

↑ In an adjacent catchment (The Tone), an attempt was made to publicise 'damage by beavers', however this transpired to be an elaborate hoax. Despite this, the Daily Telegraph and local BBC Spotlight covered the story.

↑ Riverside orchards need to be protected from beaver feeding. At one site, the visual impacts of the tree guards remain a concern for the landowner, as does the fact that the beavers are taking the fallen apples before they are collected.

Burrowing

A riparian beaver territory may contain many burrows[8], and their submerged entrances make them difficult to detect. Occasionally burrows have been located during the annual systematic feeding signs survey. As their entrances are typically below the water level, burrows detected are frequently those that have partially collapsed, revealing a chamber containing beaver gnawed sticks and/or bedding material or active lodges with material, covering the top of the chamber.

The natal burrows detected in the main River Otter have almost all been built into tree roots, presumably making them more stable, discrete structures.

There are <2 km of engineered floodbank in the catchment; protecting the former estuary from tidal inundation. Burrows have been built into the lower 'berm' alongside these, but not into the flood banks, demonstrating the additional benefits of setting-back engineered structures from the main river allowing for the creation of a multi-stage channel.

When beavers colonised Otterhead Lakes **(Case study 4)**, the risk of burrows impacting the engineered dams was identified. The profile and situation made impacts on the lower engineered dam unlikely, but the beavers had established a lodge in the upper lake, where the engineered dam was more overgrown and the profile steeper. Due to the age of the structure, the construction method was unknown, and so a precautionary approach was adopted, with the vegetation cleared from the dam, discouraging beaver burrowing and facilitating routine inspections. No burrowing has been detected.

→ Most burrows have been detected in semi-natural strips of bankside vegetation where they go unnoticed by land-users and had no detrimental impacts.

↑ Conflicts have arisen on one site where land is grazed close to the riverbank. Two burrows have collapsed where cattle and sheep are present, and these required back-filling by the ROBT Field Officer. This conflict could be mitigated by providing a riparian buffer strip with restricted livestock access.

↑ To alert the operators of heavy machinery, flags were installed at one site when they were harvesting maize.

Impacts on infrastructure

Environment Agency infrastructure

- In 2015 the Environment Agency identified sites in the River Otter that had the potential to be negatively impacted by beaver activity. A Memorandum of Understanding between the Environment Agency (EA) and DWT outlined a mechanism for monitoring these key EA assets for signs of beaver impacts. These sites were:
- eight hydrometric monitoring stations;
- four Flood Defence structures;
- 12 stretches of small stream, which were identified as *potentially* at risk of impact for flood defence and/or fish passage where mitigation may be needed (if considered appropriate); and
- the Land Drainage embankment that runs along the west side of the estuary.

↑ Environment Agency monitoring equipment is routinely surveyed - no beaver impacts have been recorded in any of the infrastructure throughout the River Otter catchment.

As well as the potential impacts of dams and blockages which are easier to detect, surveys also identified burrows that could undermine the integrity of engineered structures such as embankments, dams and flumes.

Initially, checks were made every two months but these became more risk-based over time. September through to March are the most effective months for such monitoring because:

- Beavers are particularly active building dams in the late summer and early spring;
- Key flood routes and culverts need to be clear prior to high winter flows;
- The bankside vegetation is dying back allowing easier access and visibility; and
- Autumn high flows are important periods for salmonid migration.

↑ In 2016, a beaver dam built in the floodplain ditch network into which a flood-relief channel discharges, resulted in standing water at the bottom of the scheme on the adjacent floodplain pasture. The farmer and ROBT staff removed this dam.

It is vital that those working with beavers are aware of key infrastructure within the catchment so that a rapid and appropriate response is made at any time of year in advance of, or in response to, signs of impact. Risk maps for the catchment should be proactively produced with partner organisations to enable this. In 2017, additional sites were added to the list by Clinton Devon Estates, and the list of sites monitored was formalised and they were given unique code numbers to reflect the reasons for their inclusion, and to make liaison with the relevant specialists easier.

Throughout the Trial period, although beavers were active around some EA assets, no negative impacts on any of the infrastructure was recorded.

↑ **Rights of way and paths**

There are 46 km of Public Right of Way which lie within 30 m of all the watercourses within the catchment. The footpaths in the vicinity of Otterton in the lower part of the valley are very heavily used with, for example, >100,000 people recorded in 2017/18. There have been three instances where trees have been felled by the beavers onto these footpaths in the four years between 2015 and 2019. In each case, the landowner, Clinton Devon Estates were swift in their removal. In total, this response took approximately one day of an Estate worker's time with a chainsaw. No other impacts on footpaths have been identified.

Picture: Ed Lagdon, Clinton Devon Estate

↑ **Other access routes**

One farm access track used by local residents as a permissive path to avoid walking on the road has been flooded to a maximum depth of 30 cm on occasions during the winter of 2018/19. This was due to the height of a beaver dam in a heavily modified watercourse, within a floodplain. The presence of the beavers and dam was being accepted by the landowners, but when this track became waterlogged, the dam was managed to bring the water-level down by up to ca. 50 cm. This same dam was submerging the corner of a pasture field and fence-posts, and so its reduction also alleviated this issue. In this situation, regular monitoring and management was straightforward. However, more sustainable, expensive solutions could be employed at this location such as raising the track level with stone, or installing a flow device. At the current time, this 'little and often' management has been the most cost-effective mitigation option.

↑ **Highways impacts**

A single highways impact was detected during the 5-year trial. A beaver dam built within 20 m of a small country lane caused impounded water to encroach slightly onto the edge of the road. The Highways team at Devon County Council were made aware and did not identify a need to intervene. The landowners, Clinton Devon Estates, have occasionally reduced the crest level of the dam to lower water levels and mitigate this impact, and allay the concerns of a local resident. The location is adjacent to the Estate's Forest yard with 24 hour access required.

← Road Traffic Accidents involving beavers

There has been one case of a beaver being hit by a car during the Trial period. This was identified as a result of an anonymous report of a dead beaver by the road in March 2018. The body was recovered, and a post-mortem examination conducted. There were no signs of any car parts near the beaver and no skid marks could be seen on the road.

The accident occurred where the main River Otter passes under a B-road just north of Honiton. It is thought the accident coincided with high river flows, which may have forced the beaver onto the road to bypass a weir located close to the bridge.

← Electricity or telecommunications infrastructure

There have been no recorded negative effects on electricity or telecommunications infrastructure. On two occasions large riverside willow trees growing adjacent to powerlines were being gnawed by beavers, and were proactively protected to prevent any detrimental impacts. In one case, in consultation with the landowner, Western Power Distribution decided to coppice the willow tree, as is normal practice when trees grow within ca. 3 m of power lines.

In total, this work took less than two days of the ROBT Field Officer's time including liaison and advisory work with the landowners.

← Forestry

There have been no recorded impacts of beavers on any forestry plantations. There is one location in the River Otter catchment where a plantation coincides with a presence of beavers. This poplar plantation in the lower reaches of the main river is within 5 m of the top of the river bank. The bank in this location is relatively high and steep, but the tree species and the proximity to the river where beavers were present (albeit at low levels) meant that this had been identified as a relatively high-risk location for impact. The trees closest to the river have been checked as part of every annual winter survey, with no feeding signs detected.

Agricultural impacts

Impacts of beaver activity on agriculture in the catchment have been recorded over the five years of the ROBT. The impacts have been localised and are divided into three categories: direct feeding on agricultural crops / fruit trees; the impacts of burrows; and the impacts of raised water levels.

Direct impacts of beavers feeding on agricultural crops

Impacts on maize (Case Study 6)

Beavers have fed on two separate maize fields in the mid-Tale territory, as well as on two maize fields near the Budleigh Brook site and on a field adjacent to the River Wolf. At one of these locations the beavers travelled 30 metres across a woody buffer strip, farm track and under a fence to access a maize field. The beaver track (approximately 0.3 m wide) led 40 metres into the maize field.

The area of crop impacted by the beavers tracking through and eating maize in the mid-Tale was estimated at 15 m^2 which would be estimated to be a gross margin loss of £1.33 for one harvest according to the data in the *John Nix Pocketbook for Farm Management*[16].

At one site there was evidence that beavers had been under a riverside fence and accessed a small area of root crop, although there was no significant damage to the crop.

Minor cases of beavers grazing on grass have been detected during survey work.

Impacts on orchards

No commercial orchards were impacted by beavers during the ROBT. Impacts on three small orchards in large rural gardens were reported, and the trees were protected. One small tree was deeply incised by the beavers, impacting on its ability to withstand strong winds, and it was replaced at a cost of £18 (including stake and tree guard).

Beavers have been recorded feeding on windfall apples in two areas, and an electric fence was used on one site as a deterrent.

Impacts of burrows (Case Study 6)

The mid-Tale site is also the only location where beaver burrows have impacted on agriculture. Two small collapsed burrows in the pasture were seen as a risk to the livestock and were infilled by ROBT staff.

On the opposite bank where the maize field was due to be harvested, there was a risk of forage harvesters causing burrow collapses, and damage to farm machinery. To keep harvesting machinery away from potential burrows, bamboo canes with flags attached were placed at 10 m intervals along a 50 m strip. The flags were clearly visible above the maize, mitigating the risk of damage to farm machinery. The standardized approach for the assessment of costs based on data from the *John Nix Pocketbook*[16] (see below) can be used to estimate the gross margin loss of leaving an unharvested strip against the watercourse. In this case a 5 m strip along 50 m of watercourse (0.025 ha) is estimated to be worth £22.10 for one harvest.

Other burrows detected during the Trial, including in the estuary, were in woody buffer strips alongside the river and did not cause conflict with agriculture.

Impacts of raised water levels on agriculture

In low-gradient intensively drained agricultural land, impacts on land-drainage can be locally significant. As shown in the Case Studies and in the Beaver Management Strategy Framework, it is possible to manage these impacts at relatively low capital cost. However, there may be an ongoing commitment of time which can be significant.

Where effects on agricultural land occur, a standardised approach to assessing the financial impact on the agricultural business was developed. This approach applied the Gross Margin data from the widely used and regularly updated *John Nix Pocketbook for Farm Management*[16] and *Organic Farm Management Handbook*[17] to the area of land affected (the approach is outlined in Appendix 1). There were two cases of this occurring within the ROBT where it was possible to provide an estimate of the gross margin (details available in **Case Studies 1 and 2).**

The Trial has recognised other potential variable costs which may result from the impacts of beavers, including; variations in financial support for farmers; staff time costs (such as those resulting from increased time to move cattle if an access route is waterlogged); costs of machinery repair (caused for example by a tractor driving over a beaver burrow); losses for landowners from reduced farm rents; wear and tear to farm tracks (if for example beaver damming increases the route required to a milking parlour on a dairy farm); fence repairs from felled trees, etc. Due to the context-dependent nature of these secondary costs, they will need to be assessed on a case-by-case basis.

← Cadhay Stream

In winter 2015/16 a series of three beaver dams was constructed in a drainage ditch in the floodplain north of Ottery St Mary. One of the three dams was 80 cm in height and 0.5 ha of the low-lying adjacent pasture was flooded and waterlogged for a number of weeks during the winter period. This dam was removed by the tenant farmer and ROBT staff. Due to the season, there was no direct financial impact on the farm business, except the time taken by the farmer to manage the dam.

← Colaton Raleigh Stream (Case Study 1)

The Colaton Raleigh Stream site received the greatest intensity of beaver management resources.

Beaver dams built in the drainage ditch that carries the Colaton Raleigh stream through this floodplain pasture have raised water levels periodically since 2016, flooding areas of pasture, particularly during the winter months. A flow device was successfully installed to manage water levels behind one dam, and management of other dams is ongoing.

0.89 hectares of grazing land for a spring-calving dairy herd was flooded upstream of the beaver dam before management interventions were initiated. After management intervention, the flooded area was reduced to 0.054 ha. Had the management intervention not been made, the estimated gross margin loss from such an area of land would have been ca. £1565 over a year. Following management, the estimated gross margin loss is up to £95 over a year. These estimates were made using data for a self-contained spring-calving dairy herd[16].

▶ Managing the effects of industrious beavers

→ Downstream of the main dam, side channels formed and re-entered the stream through a farm access gateway between two fields which became unusable as a result. Rather than lose the benefits to the wetland and watercourse, the decision was made to move the access crossing point at a cost of £900 **(see Case Study 2).**

← Budleigh Brook (Case Study 2)

The sequence of dams on the Budleigh Brook upstream of East Budleigh have had a measurable impact on the peak flows downstream and the raised water levels have impacted on 0.4 ha of Grade 1 arable land.

A backlog of water behind a beaver dam prevented the sowing of 0.4 ha of organic 'first early' potatoes. The estimated gross margin forgone was £1495. Additionally, seed potatoes had been purchased that could not be planted. This constituted a further cost of £600. These estimates were made using data for organic first-early potatoes[17].

The first early potatoes are one of two cash (as opposed to cover) crops from a 5-year rotation cycle. The second of these in the following year is usually barley. If the same area of land were affected in the following year (which is unknown at the time of writing), it is estimated from data for spring barley[17] that this would constitute a lost gross margin of £227.

↑ Otterton area (Case Study 3)

A dam in the Colaton Raleigh stream near the confluence with the River Otter has increased water levels in the corner of a pastoral field, equating to less than 50 m^2 area. A series of fenceposts in this field corner have also been partially submerged during wet periods which is likely to reduce their lifespan. This dam was impacting on an access track, which combined with concerns by local anglers about potential sea trout passage in autumn, has led it to be reduced in height on a regular basis.

Mid River Tale (Case Study 6)

Beavers constructed dams during low flow summer months 2018 and 2019 to access riverside maize crops which they foraged upon. This raised water levels in the stream, causing concern to landowners upstream. The grazed riverside fields are very low lying, and a drinking bay in the river was flooded, with a resulting accumulation of silt.

The initial removal of the dam by the neighbours was followed with extensive support from ROBT staff, regularly removing maize and sticks from the river prior to the harvesting of the maize, and the higher autumn river flows which resolved the issue. It is assumed that the removal of temporary dams built to access maize in late summer is unlikely to have any significant detrimental impact on the welfare of the beavers.

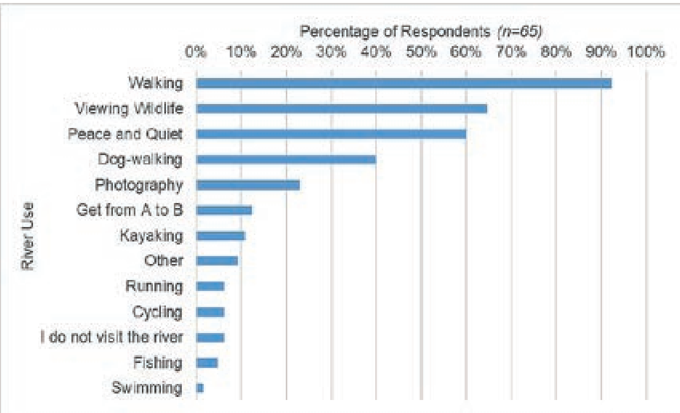
Quantitative and qualitative assessment of the socio-economic value of beavers in the River Otter catchment

Ecotourism and 'Beaver-Watching'

A family of beavers established a territory in a highly accessible public location served by a network of public rights of way. This location quickly became well publicised and generated considerable interest with some visitors travelling long distances to witness the first wild beavers in England for over 400 years.

A mail-return questionnaire of residents in this community combined with interviews with local businesses were used to study the potential impacts of beaver-watching in the village, alongside data from riverside footpath counters installed by East Devon Area of Outstanding Natural Beauty. Beyond the summary provided here, further details are available in **Case Study 2** and a full report with further findings and the methods is attached in Appendix 1.

→ **Figure 1.8** Mail-return questionnaire respondents' use of the River Otter. Respondents were able to select multiple answers.



Footpath use

Residents in the community were asked how they used the river near to their village. Walking was the most frequently cited activity by the respondents, followed by viewing wildlife. Fewer than 10% of respondents indicated that they did not use the river. A number of respondents indicated that the presence of beavers had influenced their use of the river.

→ **Table 1.4** Mail-return questionnaire respondents' responses as to whether their use of the river had been influenced by the presence of beavers.

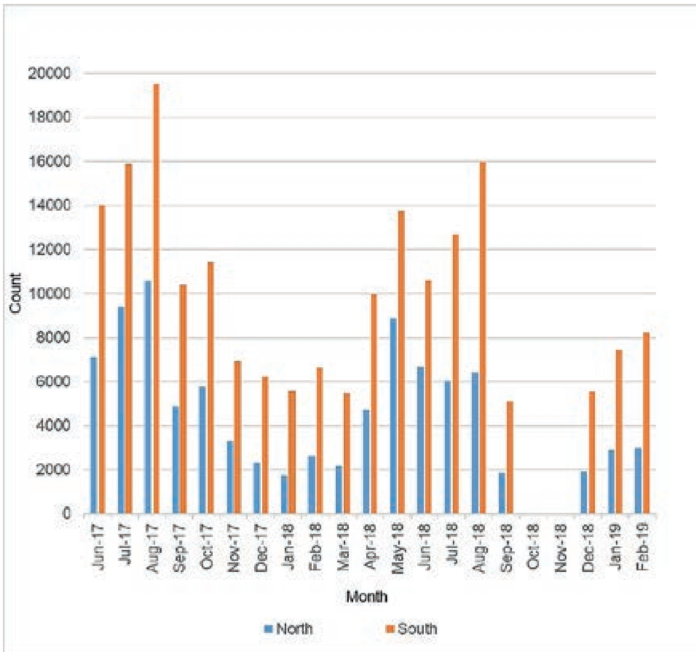
Has River Use Been Influenced?	Further Details Given
YES (n=23)	Increased time by the river
	More watchful for beavers on walks
	To see signs of beaver activity
	To see the beavers
	More likely to take visitors
	More walks in the evening
	More wildlife to see so more enjoyable walks
	More early morning walks
	More careful with the dogs on walks
	Dogs can't swim in the river anymore
	Now walk different stretches of the river as it has got too busy
	Walk less frequently
NO (n=32)	Use the river anyway
	Not changed frequency of river use
	Am a resident in the village

Two footpath counters were installed by East Devon Area of Outstanding Natural Beauty on the riverside footpath in June 2017, one to the North of the road bridge which provides access into the village, and one to the South. Data were collected until February 2019 (with the exception of October and November 2018 due to technical issues). The footpath counter data have been treated separately rather than combined as it is unknown how many visitors will have passed both counters on the same visit.

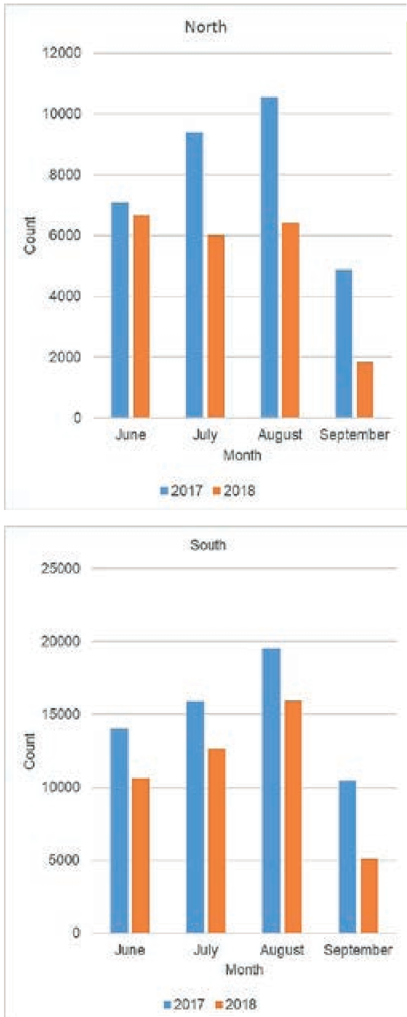
↑ During the summers of 2016 and 2017, up to 50 beaver watchers would gather on the riverbank at dusk opposite the main beaver lodge near Otterton.

In general, the footpath south of Otterton saw a higher number of monthly footpath counts, with both counters indicating increased use of the footpath in the summer months coinciding with the presence of beavers. In the summer of 2017, a family of beavers (with kits) was easily observable as they had established a lodge upstream of the village. In the winter of that year, the beavers then moved away from this location. As such, it is possible to compare the peak 'beaver-watching' months of June to September between a year where beavers were present and easily observable, and a year in which they were not.

For both footpath counters, a statistically significant reduction in footpath counts was identified between 2017 and 2018. This difference correlates with the movement of beavers away from the vicinity, which seems the most likely explanation. However a number of factors may have contributed towards this reduction in footpath use, such as differences in weather conditions.



↑ **Figure 1.9** Footpath count data between installation in June 2017 and February 2019 (Data: East Devon AONB).



← **Figure 1.10** Differences in footpath counts between the summers of 2017 and 2018 heading north from Otterton village towards the main beaver watching location and south towards the Estuary (Data: East Devon AONB).

Visitors to the village

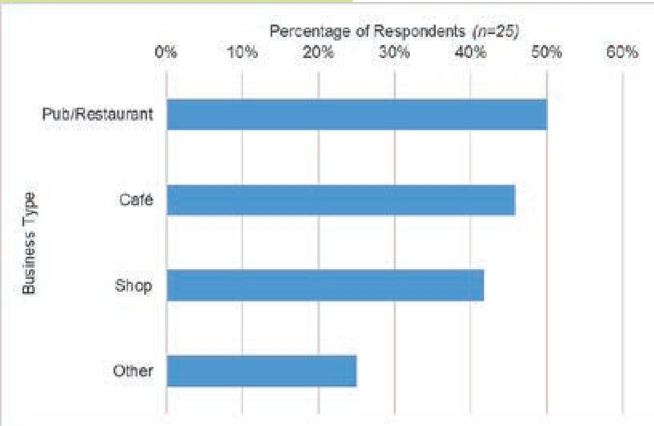
The residents' questionnaire asked whether they had observed a change in visitor numbers since 2017. The majority of respondents felt that there had been a change, 90% of whom claimed this to be an increase. 87% of those then attributed the change to the presence of beavers, whether totally or in part. Further details are in **Case Study 3** and Appendix 1.

Impact on businesses

Businesses in Otterton reported largely positive impacts in interviews, the scale of which differed dependent upon the degree to which businesses had 'used' the presence of beavers as an opportunity. Impacts included: an increase in custom; beaver-related products and merchandise; holding beaver-related event days at local businesses; the use of beavers in marketing; the potential for future beaver-related initiatives. (See **Case Study 3** and Appendix 1).

The mail-return questionnaire asked respondents in which business types they would be likely to spend money as part of a typical 'beaver-watching' experience near to the village. If respondents answered 'Other' they were asked to specify their answer. Of those who did so, 14 respondents stated that they lived in the village so they wouldn't use these businesses, two said spending in businesses wasn't necessary or that they wouldn't do so, one identified a specific business in which they would spend money, and one said they would take a picnic.

→ **Figure 1.11** Businesses that respondents indicated they would spend money in, as part of a 'beaver-watching' experience near to the village.



'Beaver-Watching' Willingness-To-Pay Value Estimates

'Willingness to pay' is a frequently used method of assigning financial values in environmental economics where the value of goods and services is not easy to obtain through conventional 'markets'. It enables, for example, the value of an experience such as a visit to a nature reserve to be estimated.

The questionnaire asked what residents would be willing-to-pay for a 'typical' beaver-watching experience on the river near to their village.

From those who provided an answer to the question, the average value obtained per respondent was £7.74 (with a range £5.78 to £9.70). Three value estimates of 'beaver-watching' activity have been calculated using this average figure cost, as illustrated in Table 1.5

These willingness-to-pay values have been obtained from residents; it is unknown whether this value would differ for visitors to the area which may include higher travel or accommodation costs.

→ Otterton Mill, situated alongside the River Otter, is one of the businesses that has benefitted from beaver reintroduction. Additional visitors, who have come to see the beavers, have generated more business, leading to opportunities for new, beaver-focussed events and products. e.g. Beaver Bitter.

Method		Footpath Counter	Value Estimate	Lower Estimate	Higher Estimate	Notes
1	Willingness-to-pay values applied to differences in footpath counts between summer months of 2017 and 2019 (North = 10,925; South = 15,506)	North	£84,559.50	£63,146.50	£105,972.50	- Assumption that the difference is due to the movement of beavers away from the area.
		South	£120,016.44	£89,624.68	£150,408.20	
2	Willingness-to-pay values applied to 0-40% of the total number of footpath counts.	North	Between £0 and £285,358.32	Between £0 and £213,097.04	Between £0 and £357,619.60	- Assumption that beaver-watchers contribute 0-40% of footpath use. >40% was deemed as unlikely due to existence of other footpath uses. - No footpath data recorded for October or November 2017.
		South	Between £0 and £639,611.93	Between £0 and £477,643.02	Between £0 and £801,580.84	
3	Willingness-to-pay values applied to 19.17% of total footpath counts as 19.17% of mail-return respondents indicated they used the river for 'viewing wildlife'.	North	£136,758	£102,126.80	£171,389.20	- Assumption that wildlife viewing was beaver related.
		South	£306,534	£228,910.40	£384,157.60	

↑ **Table 1.5** Descriptions of 'beaver-watching' valuation methods and value estimates obtained.

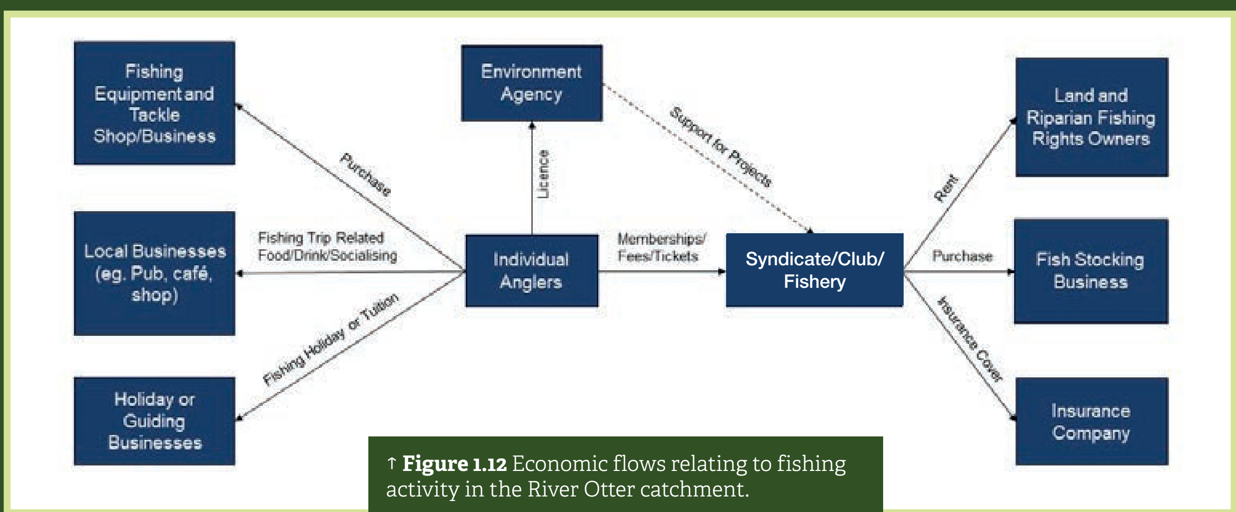
Fishing economics in the catchment

Most fishing in the River Otter catchment is recreational fly fishing for trout (brown and sea) with limited coarse fishing. Engagement with fisheries, syndicates, and individual anglers throughout the catchment and scrutiny of publicly accessible data held by the Environment Agency[18,19] were used to examine key economic focal areas including: fishing licence sales; fishing rents/rights; syndicate memberships; day/guest fishing tickets; fishing effort; fish stocking; insurance; individual angler expenses and other factors (details are provided in Appendix 1).

It is not possible to obtain a robust assessment of the economic value of fishing in the catchment due to a range of factors. For example, effort returns are incomplete or absent, incomplete records are held, and there are challenges in identifying and engaging with all anglers. However, it is assumed the annual value significantly exceeds £100,000.

The economic flows pertaining to fishing within the catchment have been identified and provide a profile of fishing-related economic activity. By doing so, we identified that if beavers are found later to impact on the recreational fishing economy (either positively or negatively) this would likely occur by first influencing an individual angler's activity. This could then have knock-on impacts on factors such as syndicates and/or riparian rights.

The impacts of beavers on angling within the River Otter catchment that were reported were limited (see Appendix 1). Predominantly impacts were indirect, such as where anglers reported that they had had their fishing session disturbed by the presence of 'beaver-watchers' some of which were perceived as confrontational toward anglers (and *vice versa*). In one instance, this led to a syndicate reporting that fishing had been affected in 40% of their stretch of river to the owner of fishing rights, who subsequently reduced the rent in that year. In terms of direct impact, one angler reported that a beaver-felled tree had obstructed their ability to wade through the river.



↑ **Figure 1.12** Economic flows relating to fishing activity in the River Otter catchment.

Summary cost-benefit analysis

A summary cost-benefit analysis is presented in Table 1.6 based upon the results of the ROBT. From the observations we have made in the Trial, the benefits of the presence of beavers in the River Otter are believed to have outweighed the costs. The most significant economic benefit is likely to be in flood alleviation. It has not been possible to address all the potential costs and benefits and so this represents as close a picture as is possible within the boundaries of the Trial.

It is important to recognise that, socially, those who benefit from beavers are not necessarily those who may incur a cost. For example, a community downstream of a beaver dam may benefit from flood alleviation, whilst the backlog of water behind the dam may encroach upon agricultural land **(see Case Study 2)**. Significant costs relate primarily to impacts on agricultural land immediately adjacent to beaver territories. Additional costs relate to impacts on trees of landscape or sentimental value, particularly those associated with gardens adjacent to beaver territories. However, we believe such impacts where they arise can be minimised through management.

Thus, if beavers are to remain in the River Otter (or become more widespread), management will need to take an holistic approach to financially support negatively affected parties whilst maximising benefits of beaver reintroduction. The *Beaver Management Strategy Framework* proposed by the ROBT Steering Group[7], in conjunction with *The Eurasian Beaver Management Handbook*[6], provides the basis for such a strategy.

→ Table 1.6 Summary cost-benefit analysis of the observations from the River Otter Beaver Trial. N.B. Costs or benefits not observed during the ROBT have not been included in this table (though work pertaining to a wide range of impacts is cited throughout the report.)

Impact Theme	Benefit (↑) Or cost (↓)	ROBT Observations	Details	Key References
Flood Alleviation	↑	• Reduction in flow rates downstream of beaver dams observed, particularly after high rainfall events. • In one case beavers dammed upstream of a community with properties at risk of flooding.	• Chapter 3 • Case Study 2 • Appendix 3	8,20–23
Water Quality	↑	• Improved water quality downstream of beaver dams. • Reduced nitrate, phosphate and suspended sediment. • Increased dissolved organic carbon.	• Chapter 3 • Case Study 4 • Appendix 3	20,24–27
Wildlife Habitats and Species	↑	• Creation of complex wetland habitats due to damming at three sites. • A County Wildlife Site has seen an improvement in its habitat quality status since beaver presence. • Tree felling increases light penetration and canopy height variability. • Increase in species surveyed at dam sites including wildfowl. • Use of beaver wetlands by water vole.	• Chapters 1 & 2 • Case Studies 1 & 5 • Appendix 2	14,28–34
Ecotourism & Business	↑	• Increase in visitors to villages where beavers are visibly present. • Business opportunities such as merchandise, events and use in marketing.	• Chapter 1 • Case Study 3 • Appendix 1	35–38

Impact Theme	Benefit (↑) Or cost (↓)	ROBT Observations	Details	Key References
Agriculture and small orchards	↓	• Waterlogging of productive land by beaver dams at three sites, with one impacting upon an organic potato crop and another upon land used for a spring-calving dairy herd. • Feeding on maize in three areas. • Time and costs incurred for management interventions undertaken by the landowners / farmers. • Feeding on apple trees observed on three sites, but tree protection has been effective in most cases • Feeding on trees and shrubs of sentimental value has occurred occasionally.	• Chapter 1 • Case Studies 1, 2, 3 & 6 • Appendix 1	6,39,40
Fishing/ Fishery	Varied	• Economic factors within the catchment identified. • Limited observations of beaver impact in the ROBT. In one location, conflict between anglers and 'beaver-watchers' had been reported. • Increased diversity of habitat for fish. • Higher abundance of brown trout, minnow and lamprey in beaver-impacted reaches assessed. • Reduction in bullhead in impounded reaches assessed.	• Chapters 1 & 2 • Appendices 1 & 2	41–44
Management interventions by ROBT team *	↓	• Management interventions undertaken by the ROBT. These vary from a single advisory visit to highly intensive and ongoing support. • Pre-emptive measures such as protecting important / vulnerable trees	• Chapter 1 • Case Studies 1,2,3, 4,5 & 6 • Appendix 1	6,7

* The costs associated with the management interventions and advisory work undertaken during the ROBT do not necessarily reflect the costs that might be incurred outside a Trial situation. The greater the allocation of resources on this is likely to reduce the levels of conflict.

Costs associated with management and operation of the River Otter Beaver Trial

The time and associated costs incurred by the ROBT team have not been fully quantified or assigned to every case study or beaver site introduced in this Science and Evidence report. Data were collected during the Trial on the time taken by the ROBT team and partner organisations working on each site, but meaningful analysis has proved difficult owing to the complex, multi-faceted nature of the support provided. Beaver activity has often spanned large reaches of river systems and has also required a mixture of outreach, engagement, volunteer oversight, and practical mitigation works (as well as the research reported herein). A significant proportion of time has been spent monitoring beaver activity in the field, and only a small component of this has been deployed toward direct mitigation intervention. It was therefore considered too complex (and potentially misleading) to assign costs to particular scenarios or specific beaver sites.

Two members of staff from Devon Wildlife Trust were employed over the course of the Trial period, equating to approximately 1.5 Full Time Equivalents (FTE), with an additional, modest, non-salary budget. The majority of time was spent delivering indirect activities, providing support and information to a range of stakeholders, enabling them to understand beaver behaviour and the associated risks and conflicts. The remainder being directly associated with monitoring the beavers, and assisting landowners in mitigating impacts, as have been outlined earlier in this chapter and in each of the Case Studies.

This is in addition to the time spent on education, communication, fundraising and management by other DWT staff.

The successful delivery of the practical elements of the Trial has been made possible by considerable support from partner organisations, especially Clinton Devon Estates, who have deployed staff time to assist in the management and mitigation of beaver activity – for example clearance of trees alongside footpaths. The Estate estimates that this equates to a total of 16 days over the five years of the Trial. A further 10 days are estimated to have been spent assisting with trapping.

The Trial has also been supported by a small team of trained and supervised volunteers who have been critical in providing additional time and support in specific situations. In total 3 volunteer days have been contributed for protecting trees from beaver activity in two territories **(Case studies 3 and 6).**

At Otterhead Lakes **(Case study 4)**, 2.5 days of volunteer time has been spent clearing beaver dam material from the outfall structures. This has been an ideal opportunity to use the Forest School students based on the site, who are also benefitting from being involved with this activity. The most extensive other volunteer task excluded here, has been analysing and extracting information from video footage collected at beaver sites, showing beaver activity and other species present.

We recognise and are very grateful to the farmers and landowners who have engaged positively with the Trial and given their time and expertise in support of the project and assisting with practical activities to manage conflicts. Staff from the Environment Agency have been involved with five sites where dams have been constructed and have maintained oversight on others.

The installation and maintenance of research equipment, and the collection of a wide variety of data has been led by a team of four from the University of Exeter, supervised by Prof Richard Brazier. Three of these researchers have contributed all their time to the project, with a fourth just working over the last 6 months. Prof Brazier has contributed ca. 0.25 FTE over the project, including significant *pro bono* time spent to write grants to fund the research reported herein.

Consultants and partner organisations have also provided much of their time and energy for free. Dr Roisin Campbell-Palmer, and Dr Simon Gurnell from the Royal Zoological Society for Scotland have provided extensive time for health screening and production of their reports (Chapter 5 and Appendix 5). The University of Southampton have also collaborated on the collection and analysis of fisheries data over the course of the Trial, some of which was funded by the Trial. Additional expertise by national specialists like Professors John Gurnell and Alastair Driver has been provided but not fully quantified.

In addition, many individuals and organisations have been involved with the steering groups, working groups and forums and have provided this time for free, for which we are very grateful.

Key documents in Appendix 1

- River Otter Catchment Overview (DBRC – September 2019)
- Infrastructure Monitoring Locations (DWT / EA – October 2017)
- Beavers and Agriculture (UoE – November 2019)
- Beavers, a Rural Community and Ecotourism (UoE – November 2019)
- River Otter Fishing, Economics and Beavers

The appendices are available to view at https://www.exeter.ac.uk/creww/research/beavertrial/appendix1/

NB. These appendices will be updated with other relevant supporting documents, not necessarily listed here.

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CHAPTER 2:
Biodiversity, including fish species

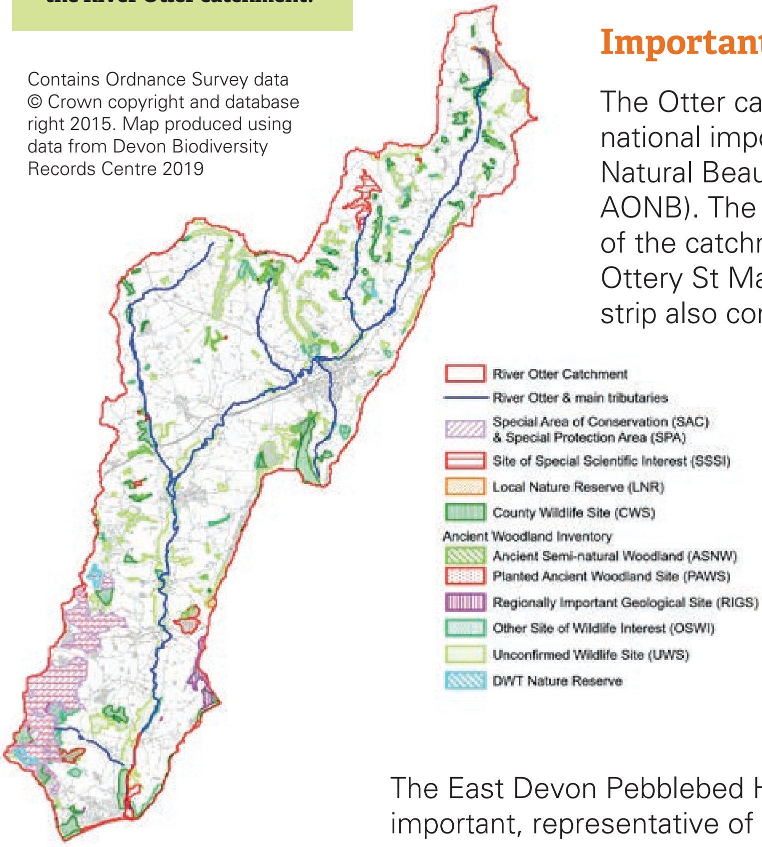
Beaver wetland on Budleigh Brook

Photo: Steve Pease

Overview of the ecology and protected areas of the River Otter catchment

↓ **Figure 2.1 Map showing the designated sites within the River Otter catchment.**

Contains Ordnance Survey data © Crown copyright and database right 2015. Map produced using data from Devon Biodiversity Records Centre 2019



Important habitats and designated sites

The Otter catchment is located within two landscapes of national importance recognised as Areas of Outstanding Natural Beauty (East Devon AONB and the Blackdown Hills AONB). The Blackdown Hills AONB covers the upper reaches of the catchment, north of Honiton, while the area south of Ottery St Mary includes the East Devon AONB. The coastal strip also comprises part of the Dorset and East Devon Jurassic Coast World Heritage Site.

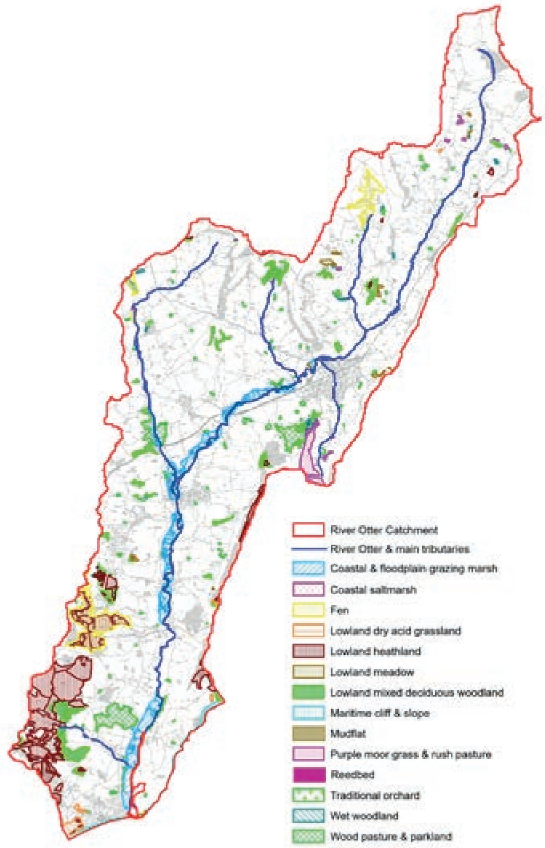
Of the 12% of the catchment that supports important wildlife habitats, lowland heathland covers the largest area, mainly in the south-west of the catchment (the East Devon Pebblebed Heaths). In addition, there are also smaller heaths to the north and east. Coastal and floodplain grazing marsh is the second most abundant habitat found alongside the main River Otter from Honiton to Budleigh Salterton.

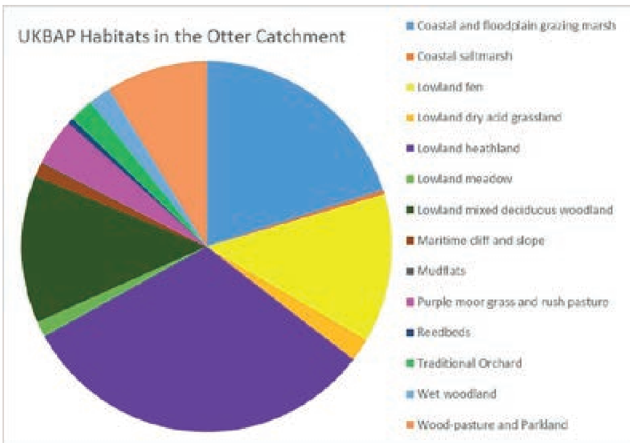
The East Devon Pebblebed Heaths were designated as a SSSI as 'nationally important, representative of the inland Atlantic-climate, lowland heathlands of Britain and north-west Europe.' It is the largest block of lowland heath in Devon (1,133 ha) supporting a diverse range of heathland communities. It supports a wide range of birds and invertebrates, with 24 species of dragonfly and damselfly, including the southern damselfly, *Coenagrion mercuriale,* and small red damselfly, *Ceriagrion tenellum,* rare butterflies such as the pearl-bordered fritillary, *Boloria euphrosyne,* and silver-studded blue, *Plebejus argus,* and heathland birds such as the nightjar, *Caprimulgus europaeu*s, Dartford warbler, *Sylvia undata,* and the hobby, *Falco subbuteo*.

They are also designated as a Special Protection Area, as they support breeding populations of European importance of Dartford warblers and nightjars, and as a Special Area of Conservation (SAC) for the northern Atlantic wet heaths, European dry heaths, and southern damselfly populations.

There are five other SSSIs in the Otter catchment, including two geological SSSIs:

- Hense Moor SSSI includes some of the best remaining examples of lowland mixed valley bog in Devon, with a mosaic of different habitats.
- Hense Moor Meadows SSSI contains herb-rich meadows with unimproved neutral grassland and fen communities.
- Otter Estuary SSSI contains a wide range of saltmarsh communities which together with additional areas of tall herb fen and scrub, supports significant populations of overwintering wildfowl and waders. Otterton Point is an important location for vertebrate palaeontology.
- Budleigh Salterton Cliffs geological SSSI exposes the full thickness of the Lower Triassic Budleigh Salterton Pebble Beds.
- Ladram Bay to Sidmouth geological SSSI is an important site for coastal geomorphology, with a series of well-developed cliffs, stacks and shore platforms cut in the red sandstones of the Keuper (dolomites, shales and claystones) representing one of very few assemblages in southern Britain.





↑ **Figure 2.2 Map and chart showing extent of different Biodiversity Action Plan (BAP) habitats within the River Otter catchment. These make up 12% of the catchment area.** Contains Ordnance Survey data © Crown copyright and database right 2015. Map produced using data from Devon Biodiversity Records Centre 2019

There are two Local Nature Reserves (LNR):

- Fire Beacon Hill LNR is a lowland heathland site, supporting heathland birds such as the yellowhammer, *Emberiza citronella,* Dartford warbler and nightjar.
- Otterhead Lakes LNR consists of two lakes and landscaped gardens of the former Otterhead House, with surrounding wet and dry woodland, grassland, and freshwater streams and ditches.

There are 90 County Wildlife Sites (CWS) covering 1,131 ha.

County Wildlife Sites are sites of county-level importance for wildlife, designated on the basis of the habitat or the known presence of particular species. There are 90 CWSs in the Otter catchment - 80 of these are in Devon (1,074 ha) and 10 are in Somerset (57 ha).

The sites range in size from a pond with amphibian interest that is less than 0.1 ha to Gittisham Hill, a 137 ha site with purple moor-grass and rush pasture, wet heath, and wet woodland. Other CWS habitats include wet and dry woodland, unimproved neutral and acid grassland, spring-line mire, wet and dry heath, and parkland. Half of the sites contain wet or dry woodland, and many of these are found associated with the headwaters, rather than the main river. Key sites include the Otterhead Lakes Reserve at the head of the catchment, which covers a 1.5 km stretch of riverbank and contains a complex of habitats including wet woodland and marshy grassland. This links to four CWSs just downstream that also contain wet woodland and marshy grassland, providing nearly 3 km of semi-natural habitat along the river.

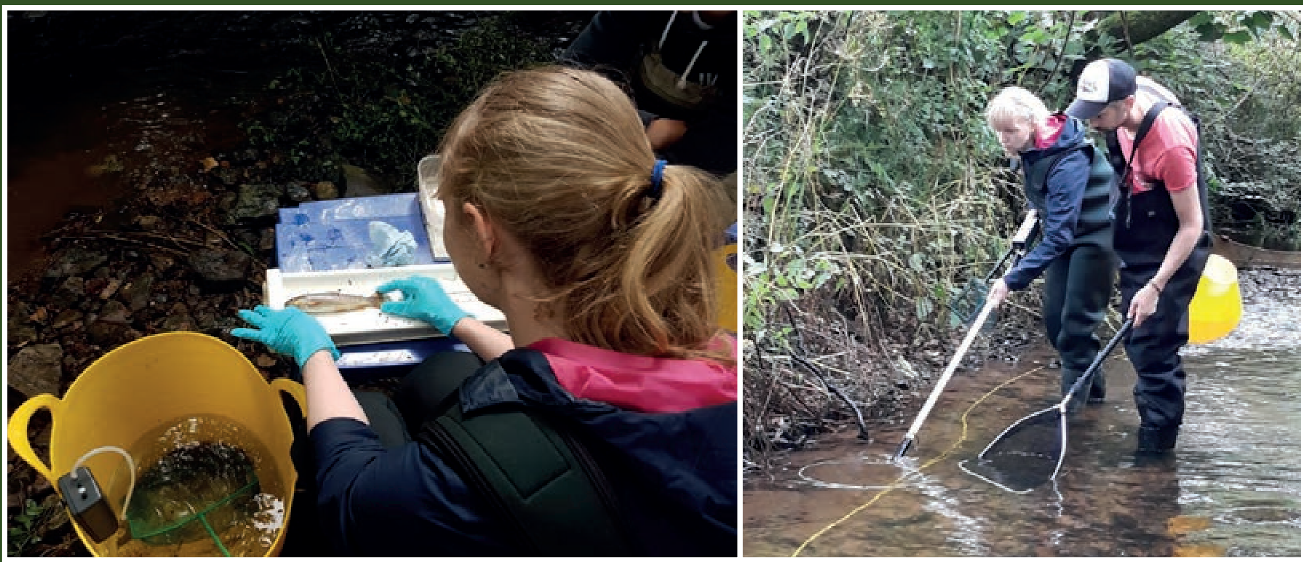
Other key sites include Wolford Lodge, a large area of spring-line mire and semi-improved neutral grassland at the top of the River Wolf tributary, with woodland CWSs either side; and Clyst William Cross, an area of tall-herb fen and unimproved marshy grassland on the River Tale.

Fish populations in the River Otter

The River Otter catchment was once recognised as an important river for breeding Atlantic salmon, *Salmo salar*, although the species has undergone dramatic population declines in recent years. The River Otter is known locally for its trout, *Salmo trutta*, and important for a number of other fish species such as bullhead, *Cottus gobio*, stone loach, *Barbatula barbatula*, European eel, *Anguilla anguilla* and brook lamprey, *Lampetra planeri*.

Atlantic salmon are listed in Annex II of the Habitats Directive, and are a UK Biodiversity Action Plan (BAP) Priority Species. European bullhead are listed in Annex II of the Habitats Directive. Brook lamprey are listed in Annex II of the Habitats Directive and Annex III of the Bern Convention. European eels are a UK Biodiversity Action Plan (BAP) Priority Species and covered by the European Eel Regulations.

Photos: Andy Vowles



Detailed electrofishing surveys conducted by specialists from the University of Southampton (UoS) of the main River Otter in September 2015 caught eight species and 1067 individual fish. The combined sample of fish from the three electro-fishing reaches consisted of 43.4% bullhead, 37.9% minnow *Phoxinus phoxinus*, 10.2% stone loach, 3.3% brown trout, 2.3% three-spined stickleback *Gasterosteus aculeatus*, 1.9% lamprey *Lampetra* spp., 0.9% European eel and 0.09% Atlantic salmon.

The same research team conducted a detailed survey of three reaches in the River Tale in October 2016 and July 2017. Six fish species were captured in both 2016 and 2017 and in similar numbers (555 in 2016 and 543 in 2017). The European fish community composition was similar between years, with bullhead, stone loach, brown trout and eel being the first, second, fourth and sixth most abundant species in both 2016 and 2017. Survey work by the same team in 2019 on four reaches on the same stretch captured the same six species (as above also with minnows and brook lamprey), and also detected three-spined stickleback, on this occasion.

The Environment Agency requires salmon and sea trout fishing licence holders to submit an annual 'catch return' for salmonids[1]. Between 2010 and 2017 there was a reported catch of 705 sea trout on the River Otter (576 of which were released). Annually there was considerable variance in the reported numbers of sea trout caught, with the lowest being reported as 27 in 2012, and the highest reported as 152 in 2014. Across the same years there were only three salmon catches reported on the River Otter, two of which were in 2013 with the other in 2017. All of the salmon caught were reported as released.

The Water Framework Directive (WFD) ecological status of the sub-catchments; the Lower Otter, Middle Otter and Wolf, are all classified as Poor in the 2016 assessment, e.g. due to man-made barriers to fish. The River Love and the Upper Otter have also been downgraded from Good to Moderate, with the Tale being the only area showing an improvement from Poor to Moderate since 2012 (not as a result of beaver presence).

The issues identified included elevated levels of phosphates and phytobenthos caused by poor soil management on arable farms, and poor nutrient management from livestock, though there was also sewage discharge from waste-water treatment. The Middle Otter and River Wolf also had man-made barriers to fish movement. Diffuse pollution alongside man-made barriers are likely to contribute significantly to the depleted nature of fish populations in the Otter catchment.

↓ Brook lamprey are often found in slower flowing areas where finer sediments are deposited.

↓ Minnows are commonly encountered in glides and pools in the River Otter and provide an important food source for many other species.

↓ Trout require a variety of habitats to be present to complete their life cycle. Some trout migrate to sea (sea trout) before returning to the river to spawn. Exact reasons why this occurs remains unclear.

▶ **Otter on main river**

▶ **Family of 3 otters on River**

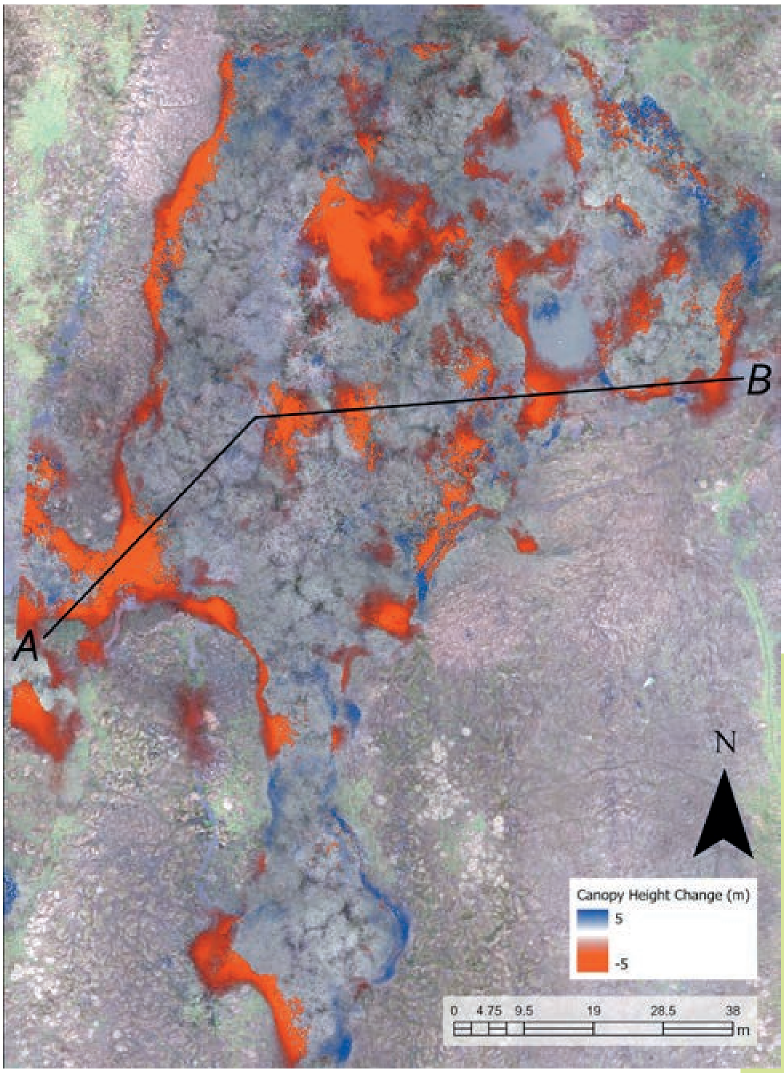
↓ Eurasian otters are found throughout the catchment and picked up with camera traps.

Other key species present

The River Otter catchment overview (Appendix 1) provides more information on some of the species for which the catchment provides important habitats. These include Eurasian otter, *Lutra lutra*, European water vole, *Arvicola amphibious*, and a number of species of specialist *Odonata*; most notably the southern damselfly, *Coenagrion mercuriale,* and small red damselfly, *Ceriagrion tenellum*. Populations of great crested newts *Triturus cristatus* are also present in isolated parts of the catchment.

Fourteen species of bat have been recorded in the catchment including western barbastelle, *Barbastella barbastellus*, grey long-eared, *Plecotus austriacus*, greater horseshoe, *Rhinolophus ferrumequinum,* and the lesser horseshoe, *Rhinolophus hipposideros.*

Effects of beavers on ecology and protected areas

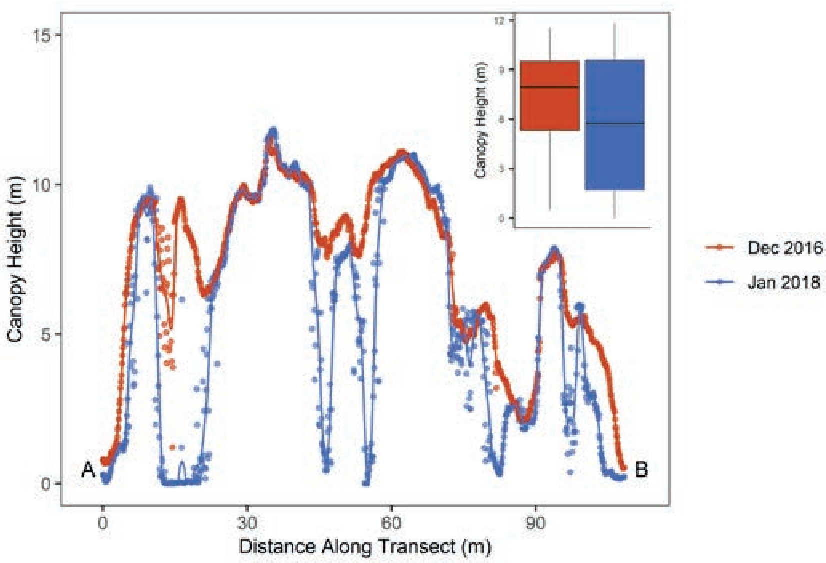


Impacts on vegetation and canopy structure

It is widely acknowledged that the foraging behaviour of beavers on woody riparian vegetation alters the structure of vegetation in beaver-occupied river reaches. This alteration is reported to improve habitat for a range of species such as birds[2,3], bats[4], and a range of terrestrial species e.g. otters, pine marten etc.[5] due to the increases in canopy variability and increased dead wood abundance[6]. Despite the many references to this phenomenon, little information quantifying this structural change currently exists.

← **Figure 2.3** In total, Clyst William Cross CWS was surveyed four times between December 2016 to January 2018 using a drone to capture images. Photogrammetry software was used to create a time series of 'orthomosaic' images (geo-rectified aerial image maps) and a Canopy Height Model (CHM) (3D height model describing canopy extent and elevation). Results revealed that areas of riparian woodland, where beavers are foraging, had a structure which differed significantly from riparian woodland not impacted by beavers. Beavers were found to reduce mean canopy height and increase the variability in canopy heights. This impact on riparian vegetation drives two key changes: a greater range of canopy heights and therefore habitats made available to different species, and increased light penetration in areas of dense riparian woodland enabling the regeneration of understory vegetation.

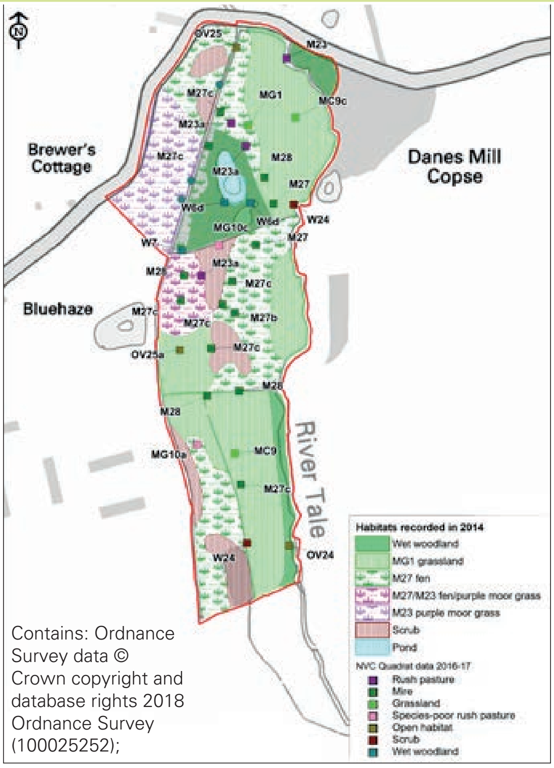
↓ **Figure 2.4** A transect A-B shows that tree stands impacted by beaver foraging were not removed completely, rather gaps in the canopy were created, enabling light penetration, and increasing the variability in plant/tree heights.



Vegetation communities

Detailed work has been conducted elsewhere on the impacts of beavers on aquatic macrophytes and plant communities[7–10] and it has not been deemed necessary to repeat that work here. The understanding of impacts on aquatic macrophytes will be built upon by Kye Davies, as part of his NERC-funded aquatic ecology PhD just getting underway with the University of Exeter and Devon Wildlife Trust.

↓ In addition to the canopy structural survey work carried out at Clyst William Cross CWS, botanical quadrats and transects have been used to assess plant communities and species present so that these changes can be monitored over time.



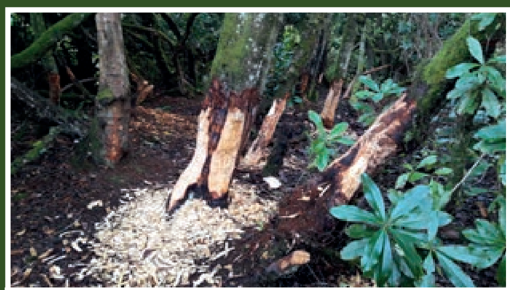
← More detailed botanical transect surveys have been undertaken by expert volunteer Christopher Hancock in 2017, 2018 and 2019, and this could be used in the future to understand how the change in vegetation structure is impacting on the plant species present.

Effects on invasive non-native plant species

← The invasive plant Himalayan balsam, *Impatiens glandulifera* is found throughout much of the River Otter catchment (except for the River Tale where concerted effort by the Tale Valley Trust has eradicated the species). In some parts of the lower river it is the dominant bankside plant. The beavers have been recorded feeding on it, but are unlikely to be having any effect on its abundance or distribution, either positively or negatively

Photo: David White

↑ On one site, a stand of Bohemian knotweed *Fallopia x bohemica* growing within 10 m of the water's edge appears to have been used by the beavers as dam building material – in a similar way to their use of riverside maize. The plant appears to be growing in the dam where it has been deposited, although there is no certainty about whether it was placed or was washed there.



← The beavers have been feeding regularly on both *Rhododendron ponticum* and cherry laurel *Prunus laurocerasus*, including using it as lodge and dam building material.

↓ Fortunately, there is very little Japanese knotweed *Fallopia japonica* in the catchment. There is a stand at one location where the beavers were resident in 2015, and a camera trap caught an image of them feeding on it on one occasion.

→ Otterhead Lakes in Taunton Deane District, Somerset, is designated as a Local Nature Reserve and a County Wildlife Site. This neglected Victorian planned landscape includes the 'lost gardens' of Otterhead House (demolished in 1952) with terraced walks and drives as well as two former walled gardens. The most obvious features are the two remaining Otterhead Lakes and the River Otter. Semi-natural habitats now make up the reserve including alder and willow carr, dry deciduous woodland, unimproved neutral grassland, and freshwater streams and ditches. Parts of the reserve are successively carpeted with snowdrops, daffodils and other narcissi and bluebells. Primroses, foxgloves and marsh marigolds are present in large numbers as well as other native plants including various species of ferns. To date impacts of the beavers have been to increase the diversity and extent of wetland habitats around the top lake and over time this is likely to increase.

Impacts on designated sites

The effects of beavers on statutory designated sites have been very limited within the trial period. Beavers have not been recorded within the East Devon Pebblebed Heaths (SSSI, SPA, SAC), and there has been no observable effect on the landscape of the East Devon or Blackdown Hills AONBs or the Dorset and East Devon World Heritage Site.

Adult feeding at Otterhead (Nick Upton)

River Otter Estuary SSSI

Since the beginning of the Trial in 2015, beavers have been recorded within the River Otter Estuary SSSI which is designated for a number of different features. The SSSI notation written in 1986 describes the river 'terrace' upstream of White Bridge, as a dense growth of willow, *Salix* spp, scrub and tall herbs providing undisturbed cover for many breeding birds, particularly for summer visitors such as reed and sedge warblers, *Acrocephalus scirpaceus* and *A. schoenobaenus,* as well as listing other key species breeding on the site.

Between April and June 2016, a detailed breeding bird survey was conducted within this site so that any changes in habitat structure that resulted from the beaver activity could be assessed. A total of 42 species were recorded on site during the 2016 breeding season, of which 13 were confirmed to have bred, 20 were considered likely to have bred and three possibly bred. It is worth highlighting that the SSSI citation lists a number of bird species which historically used to breed and are no longer present as breeding birds. These are serin, *Serinus serinus*, lesser spotted woodpecker, *Dryobates minor*, little owl, *Athene noctua,* and shelduck, *Tadorna tadorna*.

Since 2016, the effects of the beavers on the willow scrub has been negligible, with no significant trees coppiced, and no impact on the canopy or vegetation structure which might influence breeding bird communities. Should changes in canopy or vegetation structure occur in the future, breeding bird surveys could be conducted, and results compared with the baseline data collected in 2016.

Clyst William Cross County Wildlife Site

The effects of the beavers on the vegetation structure and scrub dynamics of the Clyst William Cross CWS have been previously introduced, and the array of new wetland habitat features and mosaic of habitats that are being created by the activities of the beavers are outlined in **Case Study 5**. The site is designated as a County Wildlife Site and described as supporting a variable marshy community with some areas dominated by rushes, *Juncus* spp., yellow flag iris, *Iris pseudacorus*, and small patches of purple moor-grass *Molinia caerulea* and sedges, *Carex* spp. In 1993 when it was originally surveyed, the site was grazed 'extensively' with cattle, and fencing has since fallen into disrepair and the grazing of the site has ceased.

In May 2014, a detailed habitat survey and condition assessment was carried out. Habitat assessments follow a standardised methodology and are tailored to each vegetation community. Management of each habitat is also assessed, as well as any potential threats to the designated site features.

In 2014, the overall condition of the site was categorised as 'red' (declining). The description concluded that 'The recent lack of management has encouraged dominance of the site by hemlock water-dropwort *Oenanthe crocata*, and rank grass growth and as such the botanical diversity at this site has reduced.'

In 2019 the condition assessment was repeated and reclassified the site as 'amber' (recovering). Although this survey did not record a significant change in the vegetation community (in particular the dominance of hemlock water-dropwort due to lack of grazing), there is evidence that the beavers are beginning to impact on this issue positively. For example, by construction of channels between the main river corridor and the pre-existing ditch system, the hemlock water-dropwort dominance is now being broken up and this process provides a natural agency for the litter removal specified by the JNCC[11] as being necessary to maintain plant species diversity in fens which are not regularly grazed. In the longer term this would influence greater structural variability and plant diversity as channels, channel edges and litter mounds create conditions where less competitive plants and light demanding species can become established.

↓ Since 2016, the beavers have been increasing the diversity of wetland habitats present within the Clyst William Cross CWS with resulting improvement to site condition.

▶ **Wildlife using beaver dams**

Fish populations

The diversity and abundance of a river's fish community is a reliable indicator of the health of that aquatic ecosystem[16]. Fish communities are heavily influenced by the physical habitat structure, the hydrological regime and water quality, all of which are interrelated, and can be influenced by the activity of beavers[17].

→ Until recently European eels were common and provided an important food source for otters and many bird species, but populations have been declining rapidly in recent years. Wetland habitats created by beavers have the potential to be an important habitat resource for them.

Photo: Ros Wright

The River Otter catchment has depleted fish populations resulting from chronic diffuse pollution, poor habitat diversity and man-made barriers to fish migration. Eight species of fish were recorded in the catchment during the Trial period. The life stages of these various species have different requirements. Therefore, in order to support a diverse and healthy community of fish, a wide variety of river habitats, flow regimes and channel features would ideally be present. Indeed, the presence of more surface water in a catchment is likely to lead to more habitat for fish, especially during periods of drought.

Whilst the effects of beaver damming have the greatest potential to impact aquatic ecology and fish populations, the impacts of beavers coppicing bankside trees, changes in bankside canopy structure and degree of shading will also exert significant influence[17].

▶ Heron catching elver

The approach taken to monitoring impacts on fish populations

Beaver dam building activities have been limited to a few locations and, in line with what is suggested by the Dam Capacity Modelling work (Chapter 5), no dams have been built in the main River Otter. Priority was given to understanding the health of the overall fish populations and aquatic ecosystem when viewed at a catchment or sub-catchment scale. It was also recognised that any significant changes to fish populations that might be attributed to beaver activity might only be observed over a longer time frame, rather than in the relatively short period afforded by the Trial.

A small number of dams in the catchment may prevent fish passage under certain flow conditions. As a result the Fisheries Forum were concerned this may impact on salmonid populations, and this has been considered as part of the Beaver Management Strategy Framework[18] (Appendix 7, https://www.devonwildlifetrust.org/sites/default/files/2019-07/Appendix%207.pdf).

Through the establishment of a Fisheries Forum, local fishermen and scientists have provided their knowledge and insights into the importance of different parts of the catchment for salmonid populations. It was clear throughout that detailed quantitative information was limited, with information on the other fish species present being even more so.

University of Southampton provided a quantitative baseline survey for part of the middle River Otter catchment where beavers were active, and salmonids were present. Whilst this baseline understanding established the presence of eight species of fish, as detailed above, no dams have been built and thus no direct impacts have been recorded.

When beavers first began building dams in the River Tale, this provided an opportunity to monitor fish populations in an area where beavers might influence habitat structure and start to have a measurable effect over the Trial period. Detailed electrofishing surveys were carried out by University of Southampton in 2016 and 2017 where a control / impact design was employed. Electrofishing surveys were then repeated in August 2019 in four stop-netted reaches using the same multiple-pass method (Appendix 2). The reaches comprised an upstream and downstream scientific control, a beaver pool and an area previously impounded by a beaver dam.

Westcountry Rivers Trust were commissioned to carry out a fisheries habitat survey for the lower 8 km of the River Tale that included the two reaches where beavers had constructed dams across the channel. These surveys provided an understanding of potential beaver impacts from two dams on the whole Tale sub-catchment.

Beaver dams were also constructed in two 3rd order streams in the lower part of the River Otter catchment with historical records for sea trout and a single salmon.

Camera trap video evidence of trout swimming over beaver dams was obtained during high flows in the Colaton Raleigh stream in 2016 with some of these fish providing a food source for herons.

↑ In total 1.9 km of the 594 km of watercourses within the River Otter catchment was impounded by beaver dams in October 2019, which equates to 0.31%. This includes 813 m of floodplain ditch system in the Colaton Raleigh stream.

Heron with trout

Observations of trout jumping a beaver dam on the River Tale were also made in November 2019. However with such a small proportion of the catchment and fish population impacted, tagging fish (to electronically track their progress over a limited number of beaver dams), was considered impractical. In order to significantly add to the scientific understanding of fish passage around and through beaver dams, it will be necessary to study a watercourse where higher numbers of fish and dams are involved[19,20]. There are likely to be many more suitable catchments than the River Otter for this research.

The influence of beaver dams on water quality and the hydrological regime is considered elsewhere in this report (Chapter 3). The relationship between beaver activity and fish populations in lowland streams and rivers will also be the subject of more detailed research (Kye Davies PhD project, Sept 2019>).

← The ROBT is very grateful to the members of the Fisheries Forum and an associated Working Group established with members of the River Otter Fisheries Association and South West Rivers Association for their generosity with their time and expertise.

Photo: Alastair Rogers

Impacts on fish populations in the River Tale

Beavers have built dams in two stretches of the River Tale **(Case Studies 5 and 6).** The stretch at Clyst William Cross has seen the most significant change and has been the subject of the most detailed research on the impacts on fish populations. Electrofishing surveys were conducted in August 2019 around the main *in situ* dam and immediately downstream of where a previous dam had been washed out. These surveys were undertaken by the same team from the University of Southampton who surveyed this part of the River Tale, including the two control reaches, in 2016 and 2017.

In the beaver pool (glide), a reach where flow was impounded upstream of the dam, water was deeper and velocity was slower in comparison with both the upstream and downstream controls and the reach immediately downstream of the old, defunct, beaver dam. The latter was generally shallow and swift flowing, characteristic of good quality riffle habitat.

The slow flowing water in the beaver pool deposited fine sediment/silt (ca. 57% of streambed material), in contrast to the upstream and downstream control reaches and the area immediately downstream of the dam which were dominated by gravel (37–71%). The effect of the beaver dam on the physical characteristics is broadly consistent with results from July 2017. Then, a beaver dam (which has since collapsed) also increased depth, reduced velocity and promoted fine sediment deposition.

Total fish abundance was similar immediately downstream of the old beaver dam (161 fish) and in the control reaches (upstream: 174, downstream: 153). Total abundance in the beaver pool was 37% higher than the other three reaches (260). The two beaver impacted reaches (beaver pool and immediately downstream of the old beaver dam) contained the largest number of brown trout, supporting different life stages of the species (mature adults in the pool, juveniles in the riffle downstream of the old dam). Although there was a notable reduction in bullhead, the number of minnow and lamprey was markedly greater in the beaver pool in comparison to the other reaches. Furthermore, it was the only site to support the three-spined stickleback; a species not recorded in either the 2016 or 2017 surveys.

Differences in the fish community composition were reflected in the Bray-Curtis similarity comparisons (Appendix 2 - lowest values = greatest difference). The beaver pool was most different when compared with the control reaches and the site downstream of the old beaver dam. These differences are driven by the contrast in habitat type brought about by the beaver dams i.e. some deep slow water, some shallow faster water. Thus, if variability in fish habitat within a channel reach is considered desirable, beaver dams and consequent channel change will help facilitate diverse channel characteristics.

↓ In 2018 the summer dam created by the beavers to access maize in the lower River Tale was removed on a number of occasions over the course of 2 months. A new riffle is all that remains as a result of the gravel deposition that occurred when the dam was in place.

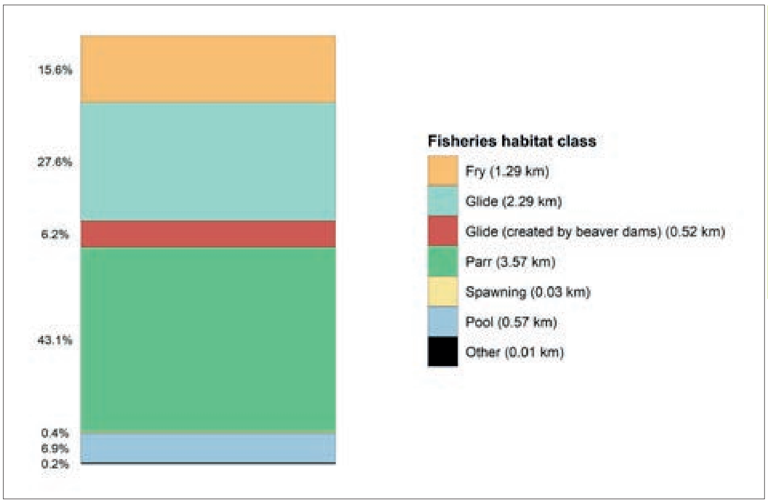
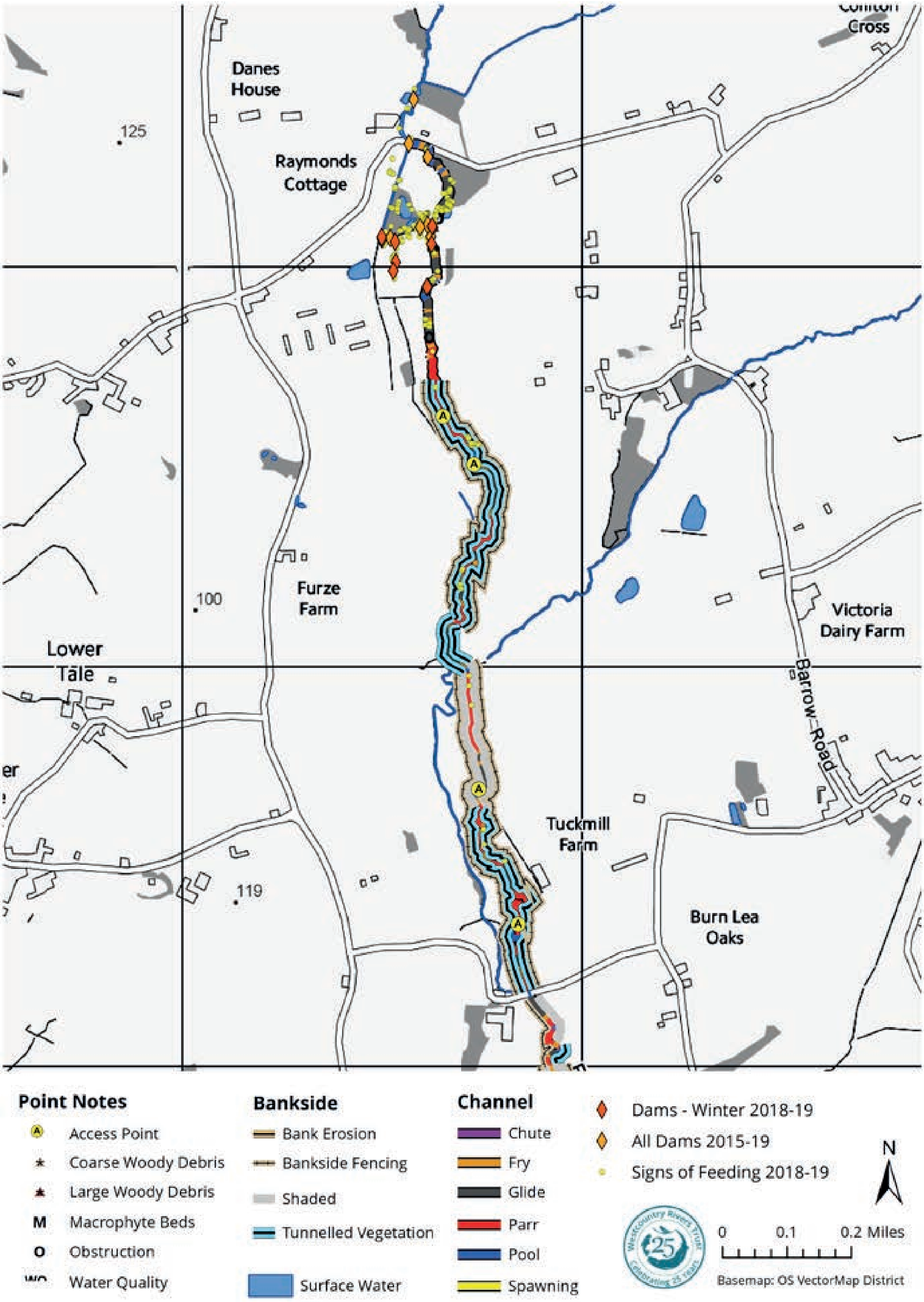


Figure 2.5 A survey of the lower 8.3 km of the River Tale by Westcountry Rivers Trust (WRT) in 2019 quantified the salmonid (salmon and trout) habitats present. The habitat types are broken down into the various stages of the salmonid life cycle using WRT's fisheries walkover manual. (Sample map below).



↑ European eels made up 2.3% of the fish caught during the 2019 survey.

Photo: Ros Wright

Figure 2.6 Results of electrofishing survey work by the University of Southampton on a short stretch of the River Tale demonstrates that the effects of a dam in reducing velocity and increasing depth in the resulting pool (glide) has a marked effect on the fish community. The beaver pool supports the highest total fish biomass with more and larger trout than either the upstream or downstream controls. In contrast the shallow, swift flowing conditions created where the previous beaver dam had washed away provided good habitat for juvenile trout which were abundant.

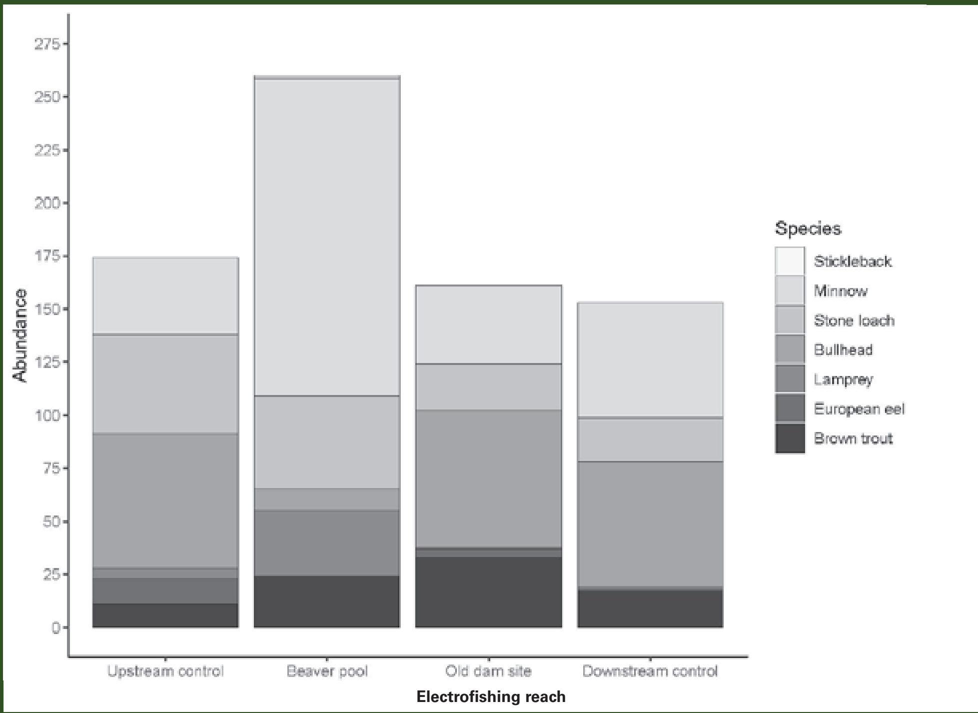
Brook lamprey and bullhead are both species of conservation concern, with numbers severely in decline largely due to habitat degradation. This survey has shown that beaver pools are significantly better habitats for lamprey, as indicated by the numbers caught, than upstream and downstream control reaches, or riffles downstream of beaver dams. This is due to the availability of silty/fine sediments in slow-flowing waters, needed to rear juvenile lamprey. In contrast, bullhead require fast-flowing, riffle habitats, that are (ideally) clean of fine sediments, as is shown by 64 individuals being captured in the riffle downstream of the old beaver dam (compared with 63 and 59 in the up- and downstream control respectively, and 10 in the beaver pool).

The beaver pool was the only location to contain any three-spined stickleback and also three times as many minnows, when compared with other reaches (150 in the beaver pool) illustrating the role that beavers can play in providing diverse habitats for fish.

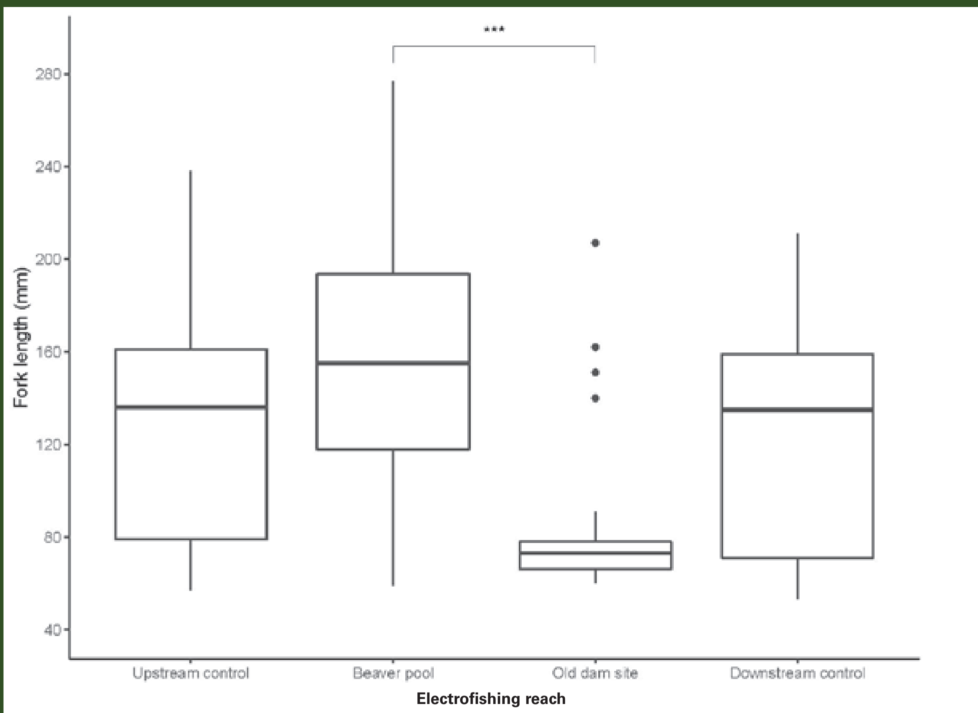
River restoration by beavers

Routes for fish passage over dams

→ This image illustrates part of the reaches surveyed upstream and downstream of the beaver dam highlighting the contrasting habitats present.



← Total abundance of fish within four reaches sampled in August 2019 including a beaver pool (glide) formed by a dam in place throughout 2019, and a reach immediately downstream where a dam had been washed out in 2018. Bars are stratified by fish species.



← Fork length of brown trout in the four reaches sampled in August 2019. The horizontal lines represent the median value, and boxes define the 25th and 75th percentile. The whiskers represent maximum and minimum values, excluding outliers. Outliers (> 1.5 x the interquartile range) are shown as dots. Significant differences are highlighted with horizontal lines above boxplots.

Impacts of changes in canopy structure on fish

The River Tale is heavily shaded throughout its course and this will affect the productivity of salmonid recruitment. Where beavers are coppicing trees in these areas (figure 2.3), then the juvenile development stages of the salmonid life cycle could benefit due to increased macroinvertebrate production, if there is suitable habitat present, providing more potential prey[21]. The *ad-hoc* nature of this coppicing needs to coincide with the right areas and be in proportion, as some cover is required in habitats for adult fish such as pools, which helps to keep rivers cool - especially important in our changing climate[17].

Temperature effects of beaver dams were not monitored in the ROBT due to logistical and financial constraints. Peer-reviewed data from elsewhere[22], show that stream temperatures are buffered i.e. reduced in summer, with cooler and deeper water, enhancing refugia for species such as salmonids. The overall variability of water temperatures in beaver-dammed rivers is also greater, supporting a wider diversity of aquatic life.

Before

After

The high energy River Tale at Clyst William Cross has demonstrated the most interesting effects of beaver damming on fish habitat. Since 2016 a sequence of dams has been repeatedly built and washed away during high flows, resulting in significant changes to the channel morphology. During periods when dams impound water, sediments and gravels are deposited in the pools, and erosion of the banks around the dams has occurred. As dams breach during high flows, fine sediments are flushed downstream and larger sediments redistributed, creating new riffles and gravel beds. This has resulted in a noticeable increase in bed level height in these reaches and a wider, more meandering and multi-threaded channel. With the creation of new dams elsewhere, the process is repeated. This results in the restoration of dynamic morphological processes and an increase in habitat variability within the reach, including deep pools, mobile gravels, extensive in-channel woody material, eroding banks and other natural features.

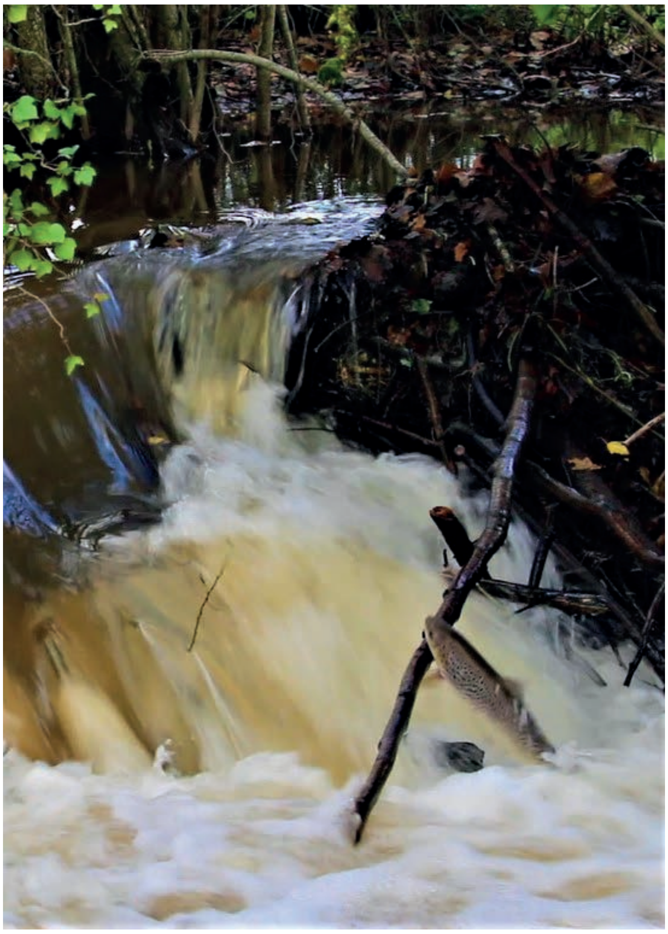
Fish migration over beaver dams

On 26th November 2019, sea trout were observed migrating at a beaver dam site at Clyst Williams Cross. The trout were jumping and attempting to make their way over the dam of approximately 1.5 metres in height (from river bed to dam crest). Following prolonged rainfall, the high flows had overtopped the crest of the dam and created a focused stream where the trout were jumping.

A number of successful attempts were witnessed from both small and large trout. Five film clips of successful attempts were captured of fish of different sizes successfully passing the dam. The successful attempts mostly occurred when a fish jumped halfway and then used an unbroken tongue of water to swim up the remainder.

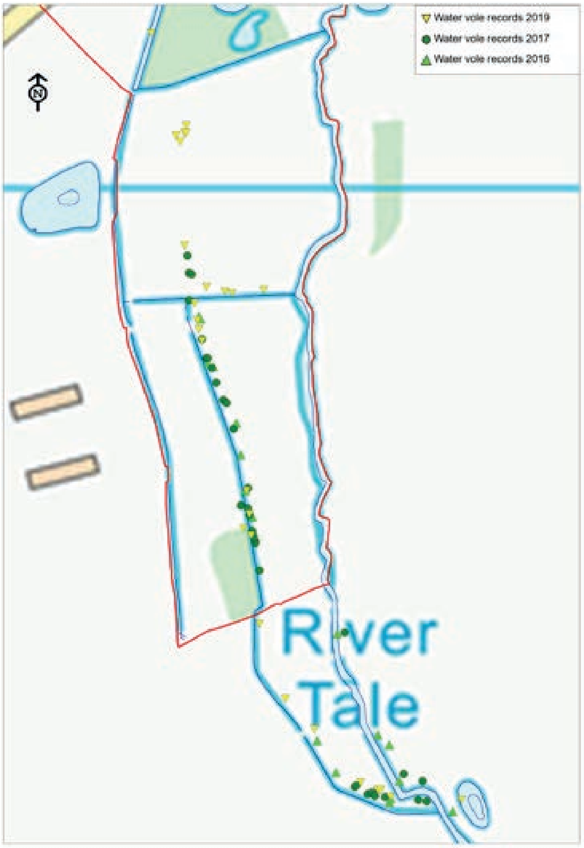
Many attempts were unsuccessful due to factors such as jumping from too far back, jumping in the wrong direction, or being obstructed by an overhanging piece of woody material. Six film clips of failed attempts were captured, demonstrating examples of each of these reasons.

The films demonstrate that sea trout were attempting to pass the dam and that, in high flow conditions, this dam was passable for some fish.



Fish jumping beaver dam on River Tale (Video: Roger Auster)

Photos: Roger Auster



↑ **Figure 2.7** Water voles have responded positively in response to the increase in aquatic habitats created by the beavers with an increase of approximately 200m of water meadow habitat now available to them.

Mammals

Water Vole *(Arvicola amphibious)*

Between 2004 and 2010 the Devon Water Vole Recovery Project trapped mink and reintroduced water voles in the River Tale. In June 2016, the Devon Mammal Group funded mammal specialist Mervyn Newman to survey the entire River Tale for riparian mammals, including water voles and otters, to gain a baseline understanding of populations early in the colonisation of beavers into this important sub-catchment. A more detailed survey for water voles and other mammals was conducted of the Clyst William Cross site in 2017 which mapped the distribution of water voles but did not detect any significant difference from the previous survey. Signs of otters were once again found throughout the main River Tale corridor but were not recorded in the adjacent wetland habitat.

Mervyn then repeated his survey of the Clyst William Cross site in Spring 2019. He concluded that despite the presence of mink in the area, the water voles were now utilising new rewetted sections that were holding a depth of water (30 cm or more) as a result of beaver damming. Since 2017, the beavers have increased the amount of water channel available for water voles by over 200 linear metres.

Anecdotal account of beaver interaction with a badger by David White on 18th July 2016

"At dawn we saw a badger come down to the river for a drink. It then moved off up a steep riverside bank; lost its footing and fell some 10 to 12 feet into the water below. It hit and broke a dead branch during its fall which made a considerable noise. This commotion immediately attracted the attention of the adult male beaver who was some 30 yards away. He very rapidly swam to the badger and without hesitation, attacked it, biting its nose and possibly its leg. The beaver may then have realised the badger was no threat to him or his family and swam off.

The confused badger swam around in several circles, and I was able to take this photograph before it left the water and limped away."

Photos: David White

Field Observation by local naturalist and photographer, David White

Otter *(Lutra lutra)*

↑ Otters rely on natural holes in riverbanks as holt sites, and spraints found inside collapsed beaver burrows indicate that they are being used for this purpose.

The River Otter supports a healthy otter population, and their interaction with beavers is of interest to many stakeholders. Beavers and otters are both frequently encountered along the same stretch of river in the evenings. Being unlikely to dig their own burrows, otters rely on natural holes in riverbanks as holts. On two occasions since 2015, otter spraints (droppings) have been recorded by ROBT surveyors in the chambers of collapsed beaver burrows in the lower River Otter catchment.

One of the main natal lodge sites in the lower valley is frequented by otters which have been seen fishing and playing in the adjacent deep-water pool on many occasions by ROBT staff and local beaver watchers.

There is also a suggestion that otters may predate on young beaver kits. Clear evidence of this is difficult to come by. Anecdotal information suggests increased otter activity around natal burrows during the period where young kits are present, and more defensive behaviour by adult beavers towards otters at this time. A video of a beaver acting defensively towards an otter was taken in July when kits were emerging.

Otter using beaver created habitats

Lucky footage of otter by drone (Daniel Cawthorne)

"In June and July I was often waiting for daybreak during peaceful periods on the riverbank hoping to see young beaver kits. I became aware that, on these occasions, I had more otter sightings than I would normally expect and always at or near the beaver burrow. These sightings included otters moving fast on the surface. They were obviously not fishing and I believe they were opportunistically hunting hoping to find an unattended beaver kit to predate. Over a two week period between 17th June and 5th July 2016, I had at least eleven otter sightings."

Photo: David White

Bird species

In 2017 and 2019, breeding bird surveys were conducted at Clyst William Cross CWS. The conclusions were that the current habitat continues to favour a diverse range of birds, particularly those that depend on more open woodland habitat with low canopy structure and the presence of dense scrub for nesting, for example willow warbler, *Phylloscopus trochilus,* and chiffchaff, *Phylloscopus collybita*. The assemblage also includes woodland, riparian and wetland species reflecting the mosaic of habitat conditions within the site. Observations on the beavers' use of the site suggests that their influence maintains a dynamic scrub community, suitable for migratory warblers which are a feature of the site's breeding bird fauna.

No significant difference in the species diversity of the site or in the numbers of territories of individual species was detected between the two surveys. Subtle changes observed may be due to chance factors, differences in detection between surveys, wider changes in the fortunes of bird species populations or as a result of the alteration of the available habitat accruing from beaver activity.

Several additional species were recorded in the 2019 survey. Although breeding evidence for some of these was inconclusive it supports the interpretation that, if there is any beaver-mediated influence on the site's breeding bird assemblage, then it is most likely to be positive.

In the lower part of the valley where open water and marshy grassland conditions have been created, large numbers of ducks, waders and herons have been attracted **(see Case Study 1)**.

↓ The marshy grasslands that have been created periodically by the beavers have attracted many snipe, *Gallinago gallinago.*

Photo: David White

Dippers have recently been recorded around the new wetland created by the beavers on the Budleigh Brook

Photo: David White

▶ **Heron catching frogs**

↑ Teal, *Anas crecca*, and other wetland birds have flocked to the open water created in the floodplain by beavers during the winter months.

Photo: Sylvia Meller

↑ One beaver-created wetland in the floodplain has supported passage migrants such as common sandpiper (photo) *Actitis hypoleucos* and green sandpiper *Tringa ochropus* which were frequently observed foraging on the waters' edge and along the tops of the dams.

Photo: David White

Wildlife using beaver dams

← Research into the amphibian responses to increases in aquatic habitats have not been conducted on the River Otter to date. Within the Enclosed Beaver Project site in West Devon, annual counts of frogspawn have shown the number of breeding pairs of common frogs, *Rana temporaria*, have increased from 10 pairs in 2011 to 681 pairs by 2017. This corresponds with a significant increase in available spawning habitat as a result of the construction of 13 beaver dams along 180 m of 1st order stream.

Photo: Nick Upton / Naturepl.com

Key documents in Appendix 2

- Clyst William Cross surveys (various)
- Water Vole (and other mammal) surveys of River Tale (various)
- Fisheries surveys (various)
- Breeding bird surveys

The appendices are available to view at www.exeter.ac.uk/creww/research/beavertrial/appendix2/

NB. These appendices will be updated with other relevant supporting documents, not necessarily listed here.

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CHAPTER 3:
Ecosystem Services

Flooding in the lower River Otter Valley

Photo: David White

→ Where the river flows across the lower floodplain, the sandy nature of the soils and floodplain deposits makes the planform very mobile, with channel meanders, oxbow lakes and channel cut offs, where the river is allowed to flow overbank.

Character of the River Otter hydrology

The Blackdown Hills are the highest elevation in the River Otter catchment and its principal source. Numerous headwater springs feed into the River Otter and associated tributaries including the Gissage, River Wolf, Vine Water and the River Tale. The lower half of the Otter catchment is underlain by a major sandstone aquifer comprising the Otter Sandstone and the underlying Budleigh Salterton Pebble Beds. Both of these strata yield significant quantities of groundwater, which provide the strategic fresh water supply for local communities and are the major component of the flow regime of the River Otter and associated tributaries during dry periods. Hydrological and hydrogeological processes in the catchment are known to be complex.

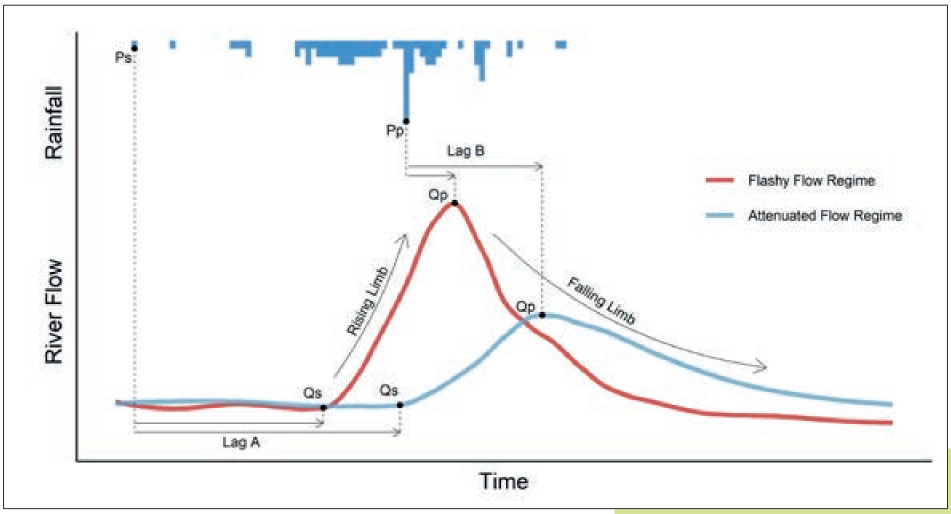
↓ The geology of the River Otter provides important baseflows from groundwater and also makes it a very spatey or flashy catchment, which reacts quickly to heavy rainfall in the Blackdown hills.

There is a large difference between the maximum daily mean flow recorded at Dotton, and the maximum instantaneous flow. The flow record at Dotton gauging station on the River Otter for the period 1963 – 2018 shows a mean daily flow of 3.22 m^3s^{-1} and a measured Q95 (the flow exceeded for 95% of the time, on average) of 0.97 m^3s^{-1}. The Q95 represents 30% of the mean daily flow. This is a relatively high percentage and reflects the strong groundwater influence of this river system. Surface water runoff in the Otter catchment is also significant with floods in the catchment characterised by a very rapid rise and fall of water levels, with high flood peaks.

Understanding how beavers can influence flood risk

Natural Flood Management (NFM) interventions are gaining momentum, as more sustainable catchment-based approaches to flood risk management are implemented nationwide[1]. In parallel with the ROBT, a variety of approaches to 'Working with Natural Processes (WWNP)' have emerged[1] and it is argued that beaver reintroduction is the epitome of such an approach, delivering multiple benefits. Understanding the role that beaver dams could contribute in reducing flood risk by storing water in headwaters/floodplains has formed a central part of the investigation into hydrological change presented below. The monitoring experiments described provide data to test whether changes to high (flood) flows in the River Otter might be attributed to beaver activity.

Figure 3.1 describes the difference between a 'flashy' or fast response hydrograph (in red), that is typical of intensively-managed landscapes, where the emphasis on water resource management is to move the water from the land to the watercourse as fast as possible, and a more natural, or attenuated, hydrograph (in blue). Of note, the flashy hydrograph rises fast, peaks high and falls fast, with a short duration before water levels return to baseflow. Such hydrographs respond very quickly after heavy rainfall especially when the soil is saturated or has poor infiltration characteristics or is impermeable due to compaction or urbanisation. In contrast, the attenuated hydrograph rises slowly, with a delayed response to rainfall, peaks at a lower level, with a longer duration and often a post-storm baseflow that is elevated, even during dry periods. As such, flashy, or fast response flow regimes pose a greater risk to communities downstream and attenuated flow regimes will reduce flood risk.



↑ **Figure 3.1** The key hypothesis that the hydrological research tests is whether beaver dams deliver the attenuated hydrograph response (in blue) when compared with pre-beaver flows (in red) or whether flows into beaver dam complexes (in red) might be attenuated as they pass through beaver dams (in blue). 'Lag A' illustrates the time lag between the start of a rainfall event (Ps) to the start of a flow event (Qs); 'Lag B' describes the lag time between peak rainfall (Pp) and peak flow (Qp).

In order to understand the role that beavers might have on flooding, analysis is required to understand flow regimes before beaver reintroduction or upstream of beaver-impacted landscapes. Such work permits comparison with flood regimes after beaver dams have been built, or downstream of beaver dams to draw conclusions as to the potential for downstream flood attenuation. Ideally this work is undertaken at a number of different scales and locations.

Implications of changes to the observed flood regimes in terms of flood risk to communities downstream can theoretically be quantified using the above data. However, such extrapolation is highly complex, requiring site-specific data in terms of both how beaver dams impact floods and socioeconomic analysis of flood risk changes for society in flood-prone locations.

In order to deliver this understanding, research is being undertaken by the team at the University of Exeter on a number of other beaver sites around the country. These include (as well as the ROBT sites): Pickering, the Forest of Dean and Cornwall beaver projects.

The team have also been monitoring flows on a first order stream where it passes through the Enclosed Beaver Project site in West Devon since 2013. The findings of this work have been published in peer reviewed journals[2,3]. Between 2011 and 2016, 13 dams were created by beavers along 183 m of first order stream increasing the surface area of ponded water from 90 m^2 to 1800 m^2. Within the ponds ca. 1,000,000 litres of water are stored at any one time.

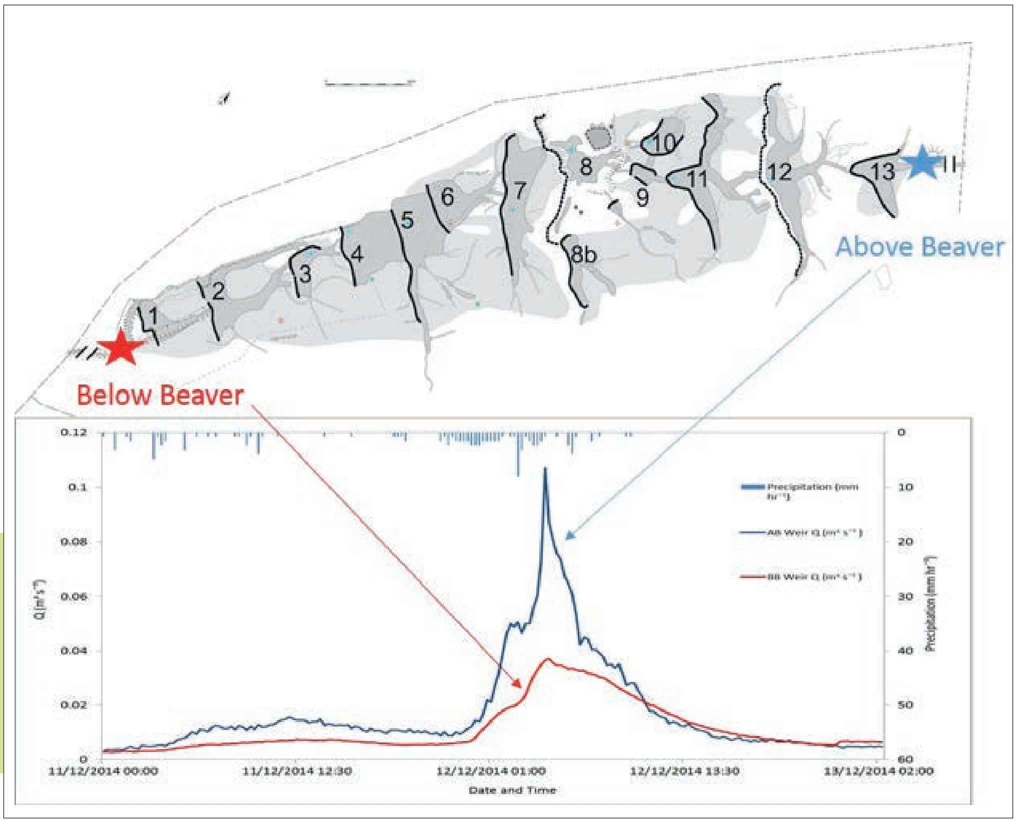
▶ BBC Springwatch piece about Enclosed Beaver Project

The beaver dams slow the flow of water. During storms, on average, peak flows were 30% lower leaving the site than entering. The lag time between peak flow entering the site and peak flow leaving the site was on average one hour, over a distance of only 183 m. Even in saturated conditions and for the largest monitored flood events, similar effects are observed due to the hydraulic roughness of the dams and felled trees and the leaky nature of the dams.

This research provides strong evidence for the role that beavers could play in reducing flood risk at a catchment scale, even during prolonged wet periods. The water storage and gentle release effect also results in elevated baseflows from the site, maintained even when periods of drought led to no flow into the site. Such baseflow maintenance is critical for aquatic ecology and water supply downstream, especially during times of drought, when many species suffer due to the lack of water[4] or high temperature of water[5].

▶ Beaver dam on River Otter after heavy rain

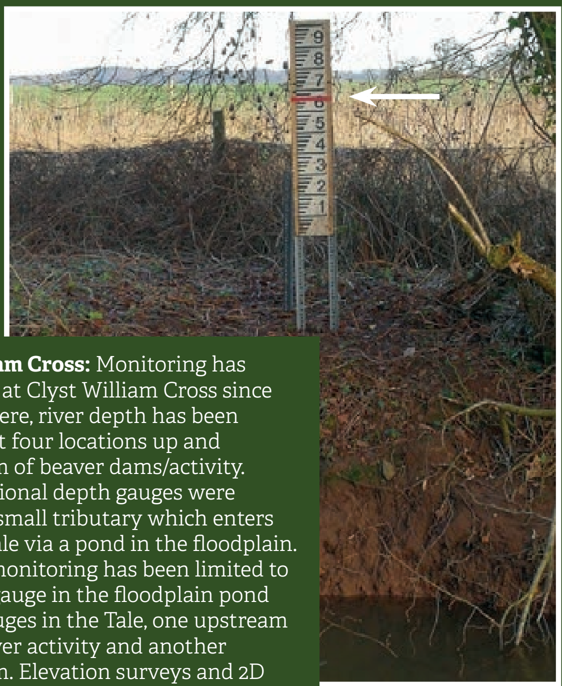
▶ BBC 2 Politics Live piece about beavers and flooding



→ **Figure 3.2** Map showing sequence of 13 beaver dams along 183 m of watercourse at Enclosed Beaver Site, with graph showing an example of flow data measured upstream (blue) and downstream (red) during a single high flow event.

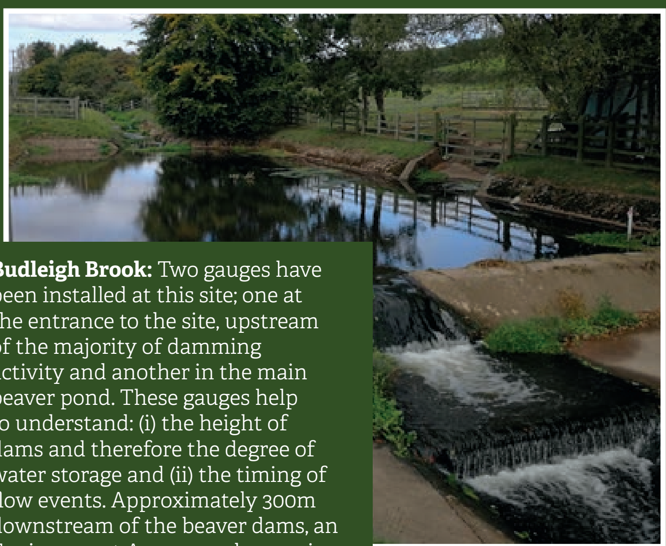
Overview of hydrology monitoring work undertaken on River Otter

With the objective of detecting any significant impacts of beaver dams on flows, hydrological monitoring equipment was installed in four of the beaver territories where beaver dams were built. The installations were designed to complement the network of hydrometric monitoring stations managed by the Environment Agency.

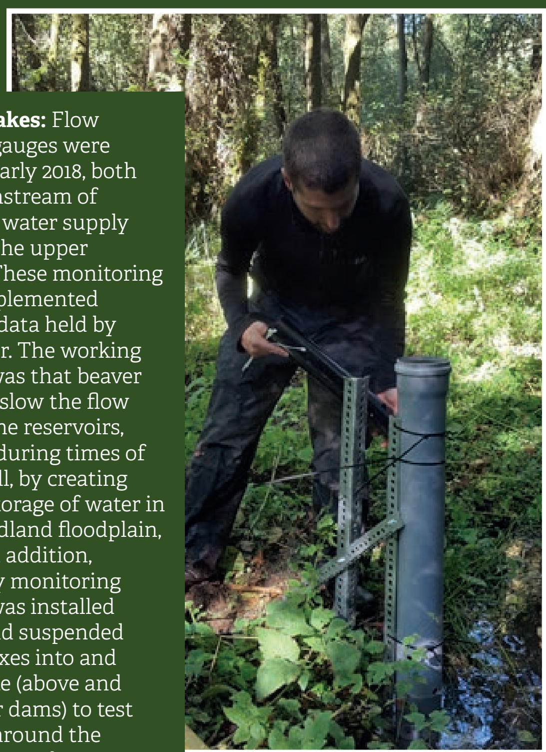


Clyst William Cross: Monitoring has taken place at Clyst William Cross since May 2016. Here, river depth has been measured at four locations up and downstream of beaver dams/activity. Three additional depth gauges were placed in a small tributary which enters the River Tale via a pond in the floodplain. From 2018 monitoring has been limited to one depth gauge in the floodplain pond and two gauges in the Tale, one upstream of core beaver activity and another downstream. Elevation surveys and 2D hydrological modelling of this site has enabled the installation of a stage board to demonstrate the height a beaver dam would need to reach to cause water to back up to the road bridge upstream.

Colaton Raleigh Stream: The main beaver site on this watercourse was instrumented in 2016 and data were collected showing how water levels responded to the construction of beaver dams. Four depth gauges were placed within the channel, one upstream, two within beaver ponds and one downstream of damming activity. However, due to upstream alterations to the channel (not relating to beaver activity), the majority of flow is no longer conveyed along this channel and consequently, in November 2018, all gauging equipment was removed from the site.



Budleigh Brook: Two gauges have been installed at this site; one at the entrance to the site, upstream of the majority of damming activity and another in the main beaver pond. These gauges help to understand: (i) the height of dams and therefore the degree of water storage and (ii) the timing of flow events. Approximately 300m downstream of the beaver dams, an Environment Agency early warning gauging station records water depth at 15 minute intervals (picture). With records dating back to July 2009, this gauge provides vital pre-beaver flow data to compare with post-beaver flows over the last 2-3 years. This depth data has been used to estimate river flow using established weir rating equations[6].



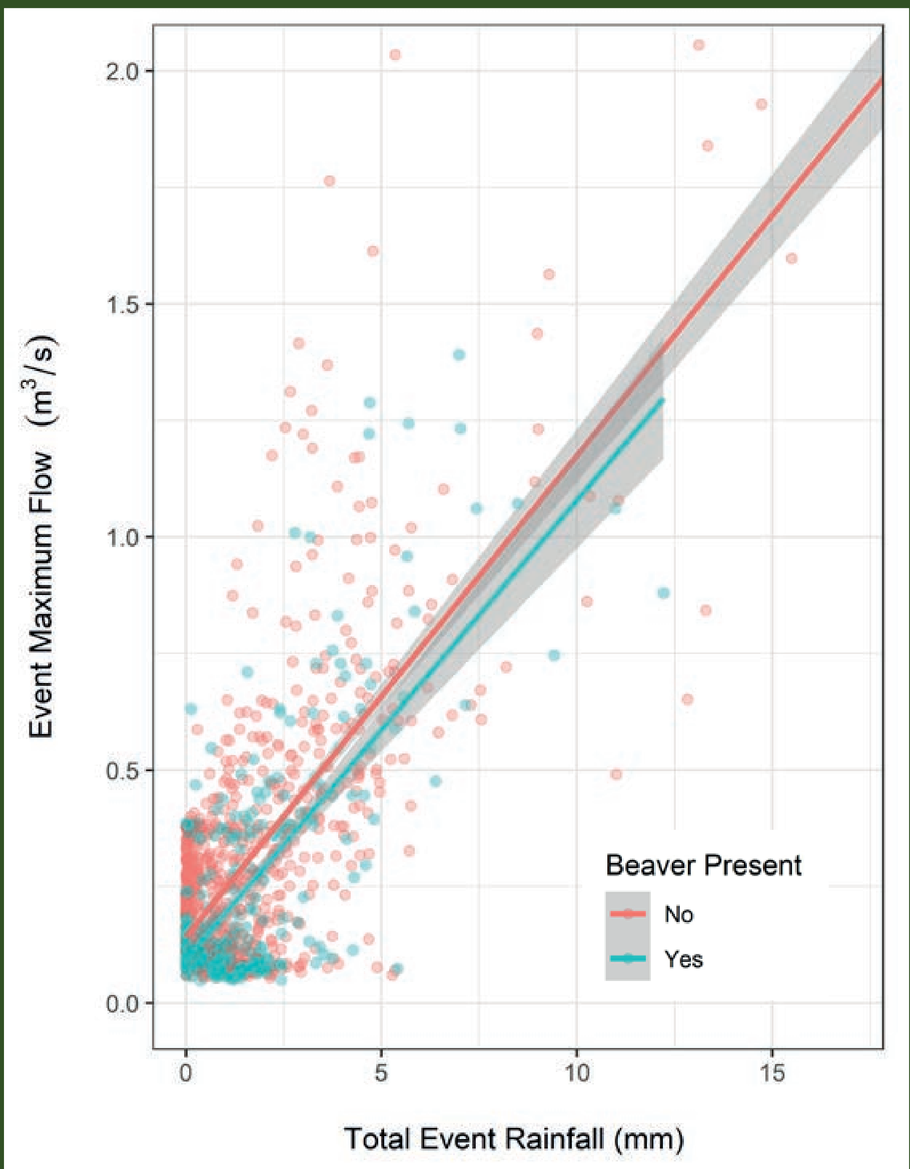
Otterhead Lakes: Flow monitoring gauges were installed in early 2018, both up and downstream of the drinking water supply reservoir in the upper catchment. These monitoring stations supplemented longer-term data held by Wessex Water. The working hypothesis was that beaver dams would slow the flow of water to the reservoirs, particularly during times of heavy rainfall, by creating significant storage of water in the wet-woodland floodplain, upstream. In addition, water quality monitoring equipment was installed to understand suspended sediment fluxes into and out of the site (above and below beaver dams) to test hypotheses around the impact of beaver dams on reservoir siltation[3].

Preliminary findings from work undertaken on the River Otter

Using automated identification of when rainfall and flow events occur, we have begun preliminary analysis of these data. This investigation indicates that there are detectable and significant differences in the hydrological response to rain events pre- and post-beaver, i.e. beaver dams attenuate floods, as we have recorded elsewhere[2].

The accompanying **Case Study 2** illustrates change in the hydrological regime upstream of a flood-prone village in the Lower Otter catchment. As the case study details, the pre-beaver hydrology (recorded at the EA gauging station 300 m downstream of the beaver dams since 2009) is markedly different to that observed since beaver damming began in 2017. For the same amount of rainfall on the catchment, peak flow is reduced (post-beaver), demonstrating downstream flood attenuation. The mechanism of this attenuation is, at least in part, attributable to the observed increase in the duration of the falling limb of the storm hydrograph – evidence of the slowing effect of the beaver dams (see Figure 3.1 for explanation and Figure 3.3 for changed relationship between total rainfall and maximum flow due to beaver damming).

↓ **Figure 6.4** Relationship between total rainfall and maximum flow for hydrological events before (red) and after (blue) beaver dams were constructed. After beavers constructed dams, downstream flows were more likely to be lower for a given amount of rainfall.



At the other hydrological monitoring sites, Clyst William Cross, Colaton Raleigh Stream and Otterhead Lakes, no measurable change to flow volumes have yet been observed, though significant changes to the patterns of water storage have been recorded, with additional water being stored in the floodplain. At Clyst William Cross there is now 6,880 m^2 of standing surface water on the floodplain, compared with 1,400 m^2 before beavers were reintroduced. Colaton Raleigh stream **(Case Study 1)** showed an increase in surface water out of channel, prior to reduction of effective dam height at the request of landowners, whereas the area of new standing water at Otterhead lakes is now 5200 m^2.

Already at Otterhead, the data collected show that water arrives upstream of the beaver dams rapidly (and also loaded with sediment – see water quality section) and is slowed through a series of up to seven dams, before entering the reservoir – i.e. increased lag times. Water levels in the reservoir have also increased due to beaver damming of the outlet, but have reduced after removal of these dams to protect the reservoir spillway at the request of the water company.

Risk associated with dam failure

Concerns have been expressed regarding the risks associated with sudden failures of beaver dams. Dam failures, particularly in high energy environments, may cause infrequent and significant pulses of water and sediment[7].

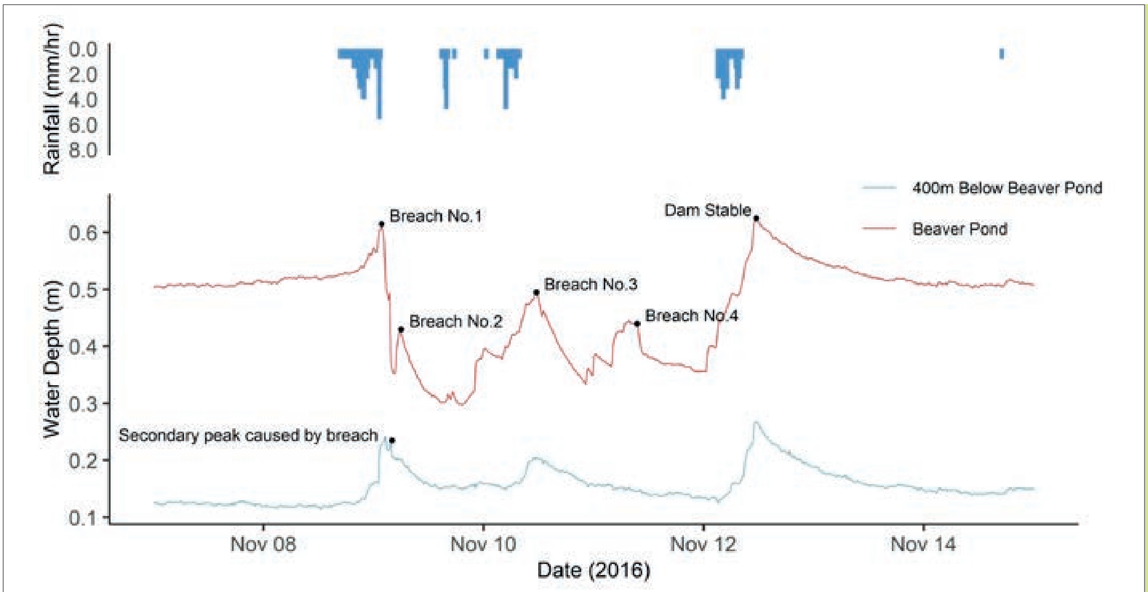
Beaver dam collapses typically coincide with significant discharge events[8] and are more common in alpine environments where seasonal meltwater can dramatically increase river flows[9]. Hydrological monitoring across beaver sites in 1st to 4th order channels throughout Britain since 2014 has been undertaken, and complete failure of established dams has rarely been observed. On 1st to 3rd order channels, dams are commonly stabilised by vegetation, over time becoming an integral component of the landscape.

On larger, 4th order channel reaches where dams are less frequently built, small temporary dams built during low flow conditions are eroded when normal or high flow conditions resume. When such dams do break down it is often gradual, and they store comparatively less water. They often erode slowly from the top or, following a partial 'blow out', the material is gradually washed away.

Damage to dams of varying magnitudes has been observed during high energy winter storm events (Figure 3.3). This damage is typically more severe on larger streams which experience higher stream power. In dam sequences, the impact on downstream flow regimes is mitigated/negated by the overall combined impact of the dam sequence (often associated with dense riparian vegetation) rarely producing discernible downstream flood pulses. Damage typically manifests itself as partial breaches in dams. These breaches are commonly repaired by beavers overnight.

The most significant collapses observed have not been to dams themselves but to adjacent stream-banks. This has occurred in two locations. One was on a 4th order reach in the River Tale and another on a 2nd order reach outside of the River Otter catchment. In both of these cases, the erosion led to increased channel complexity, providing new habitat types, and beavers subsequently rebuilt dams in or adjacent to the site of the collapse.

Only one case of damming has been observed on a stream of 5th order. This was however in the River Inny (Tamar catchment). The dam was built during very low flow summer conditions and would have been expected to have been breached during high flow conditions. However, it was removed by fishermen before this could be confirmed.



← **Figure 3.3** Watercourse hydrograph immediately upstream of beaver dam (red) and 400m downstream (blue) during a partial breach of the dam during a high flow event in November 2016. During the high flow event that caused the breach, there is a lower secondary peak observed downstream which is likely to be the result of the dam failure. It is also possible to see how the beaver dam collapsed and was rebuilt several times before it re-stabilised.

High flows leading to bank collapse

Overview of water quality monitoring work undertaken and equipment installed

The approach to understand beaver impacts on water quality has employed two different techniques: (1) water chemistry monitoring and (2) monitoring change in macro-invertebrate species as an indicator of ecological status.

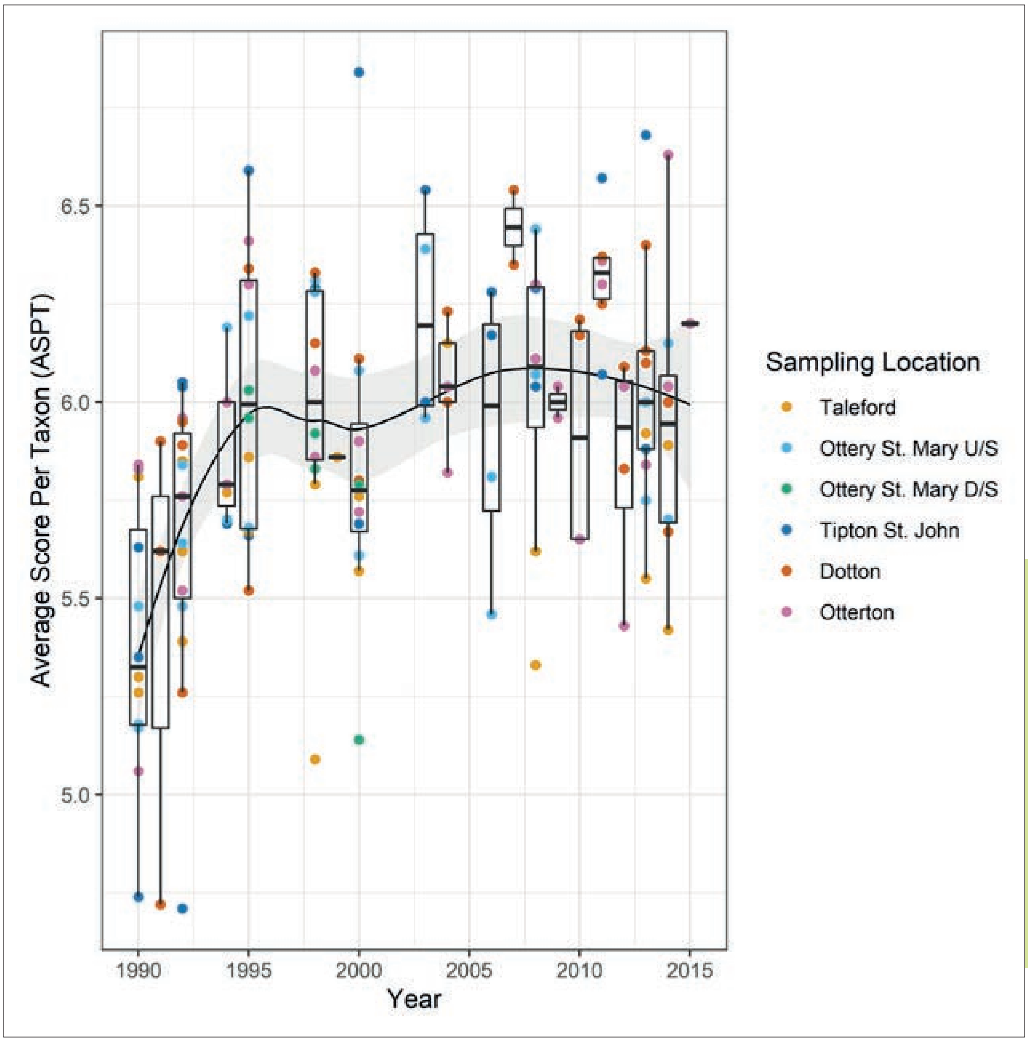
Both of these approaches are in line with EA methods to monitor freshwater health in the River Otter catchment as part of the drive to improve freshwater ecological status under the Water Framework Directive (WFD). The ROBT water quality research has focussed on the Otterhead Lakes site **(Case Study 4)**, wherein suspended sediment has been the key variable of interest. The macro-invertebrate survey work has been undertaken at a number of sites where beaver dams are present, to quantify ecological status both up and downstream of beaver dams and within beaver ponds (the processing of these data is ongoing). Routine EA invertebrate monitoring data has been used to understand the current ecological status of the River Otter.

↓ To complement the aquatic invertebrate sampling carried out by the EA, additional samples have been collected from routine EA monitoring sites, using comparable techniques. This information will contribute to current understanding of the impacts of beaver dams on macro-invertebrate communities as they evolve.

Use of aquatic macro-invertebrates to monitor water quality

Through analysis of the EA macro-invertebrate data obtained during the 1990s (see Figure 3.6 for details) there was a clear increase in the invertebrate biomonitoring metrics (Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT)) at most sampling sites. This can be attributed to improved farming practices, catchment management and wastewater treatment, thus reducing both diffuse and point source pollution. In general, recent surveys suggest that the river is therefore in moderate condition. The pattern of water quality status in the river mirrors that of lowland rivers in agricultural systems across the UK. The headwaters tend to be in the best condition and as the river progresses downstream it is subject to increased pollutant loading, with the worst condition in the lower reaches. Isolated low-scoring surveys confirm there are still significant nutrient loading pressures on the river. There is no clear change in the data set to suggest that beavers have, as yet, had any impact (either positive or negative) on water quality at EA monitoring sites in the River Otter catchment.

→ **Figure 3.5** Locations and description of EA invertebrate sampling locations.



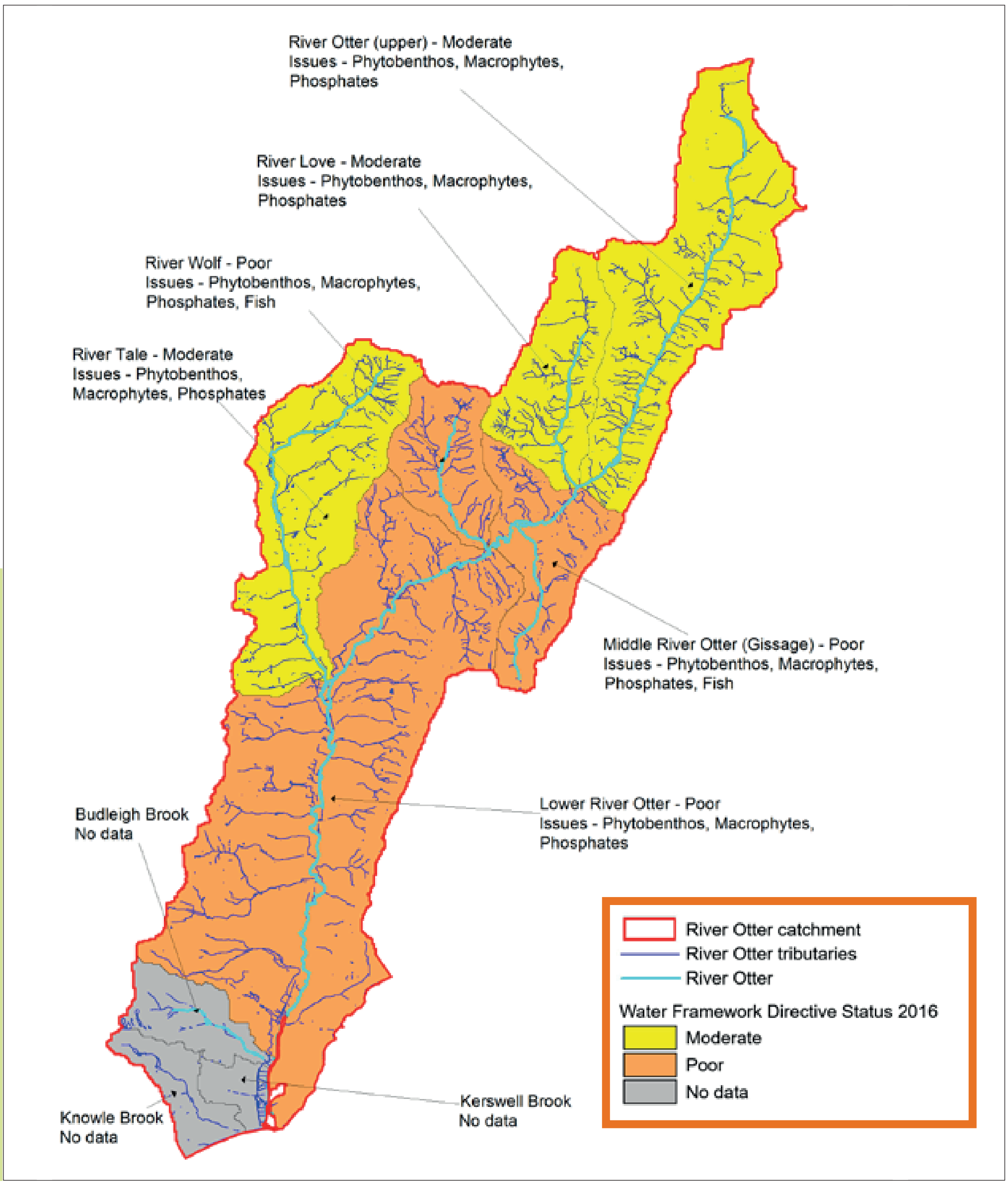
← **Figure 3.6** Plot indicating the change in the average (BMWP) score per taxon (ASPT) (i.e. per macro-invertebrate species) for all ASPT (EA monitoring sites) between 1990 and 2015. The trend line indicates the change in ASPT across all sites combined. These data provide a valuable baseline for understanding future impacts of beavers on water quality and the macro-invertebrate community in the River Otter.

Macro-invertebrate samples from dam sites (Clyst Williams Cross and Budleigh Brook) have been collected by the University of Exeter. The processing of these samples is ongoing and will provide a valuable understanding of the early-stage response of the macroinvertebrate community to beaver dam construction in the River Otter catchment.

Changes in macro-invertebrate communities associated with beaver activity

Beavers are known to alter the structure and function of habitats, positively impacting benthic riverine invertebrate communities in the reaches they inhabit. Principally, by turning rapidly moving (lotic) reaches into slow moving (lentic) habitats, the community composition alters accordingly. Therefore, it is typical to see a greater number of lentic species within ponds. These ponds, especially where they are watercourse fed or connected to floodplains, also collect a considerable volume of fine sediment which would otherwise be transported downstream, improving downstream habitat condition. In addition to the formation of ponds, beavers also provide numerous other habitats (e.g. canals and accumulation sites for woody debris), all of which will contribute increased macro-invertebrate biodiversity. For a review of the impacts of beaver on macro-invertebrate communities see Stringer and Gaywood (2016)[10].

Impact on Ecological Status of Waterbodies



→ **Figure 3.4** The most recent Water Framework Directive classification shows the ecological status in 2016. The impact of beavers on this is unlikely to be significant in the short term, although their presence over time is likely to be responsible for significant improvements in water quality as dams in the headwaters reduce sediment and nutrient impacts downstream.

Water quality work being undertaken at the Enclosed Beaver Project, West Devon

In addition to the results presented above, water quality is being monitored at the Enclosed Beaver Project in the Tamar catchment by the University of Exeter in partnership with Devon Wildlife Trust[2,3,11].

As well as impacting the storage and flow of water, impoundment behind dams can affect the quality of water leaving beaver impacted sites and the amount of diffuse pollutants transported downstream. By slowing and filtering the water, beaver dams cause sediment and nutrients to be deposited in ponded waters. In this case, the source of the material is intensively managed grassland, which elevates levels of sediment (from soil erosion), and also nitrogen and phosphorus, from manures, slurries and fertilisers that are added to the land (and are bound to the sediments). By the time the water has flowed through the sequence of 13 beaver dams, a high proportion of these diffuse pollutants has been removed from the water, settling out in the ponds.

Each instrumented weir above and below the site was equipped with an automated water sampler. These 'pump samplers' allowed researchers to collect one litre of water every time water depth changed by 2 cm, during high rainfall events. Sampling storms is important as this is when the water has most energy and most erosive capacity resulting in diffuse pollution. Samples were analysed in University of Exeter laboratories for suspended sediment, nitrogen, phosphate, and dissolved organic carbon content.

Additionally, ground-based surveying was undertaken of all ponds within the site to quantify sediment (and associated nutrient) storage and gain an increased understanding of the mechanisms by which the site was influencing downstream water quality.

Full water quality results are published in Puttock et al., (2017)[2], whilst sediment and nutrient storage results are published in Puttock et al., (2018)[3]. Both these papers are included in Appendix 3 with summary results provided below.

Implications for mitigating diffuse pollution from agriculture

Loss of sediment and nutrients from agricultural landscapes is a serious and chronic problem, which is widespread globally. It results in unsustainable soil loss, with the land also becoming less fertile, becoming depleted of nutrients, and requiring greater fertiliser use and causing downstream water quality problems such as eutrophication. Pollutants such as sediment, nitrate and phosphate, negatively impact on ecological status and water quality downstream[12]. The presence of beavers at the Enclosed Beaver Project has been shown to play a significant role in filtering these pollutants from water[2].

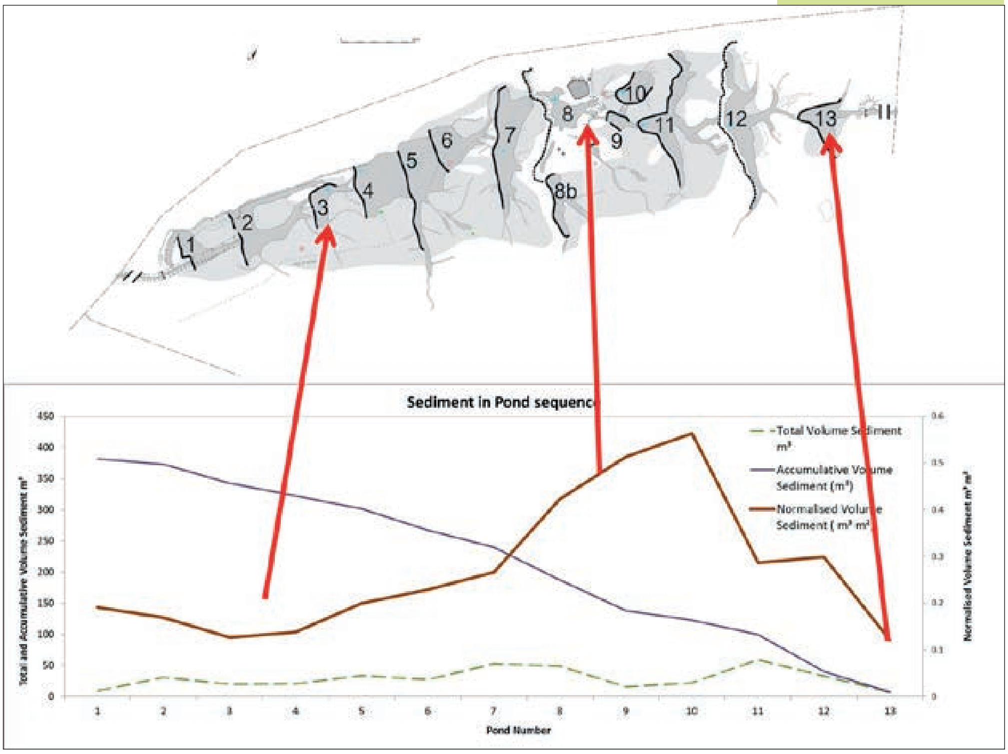
Impacts on Sediment

During storm events, each litre of surface water leaving the beaver-modified site has 3 times less sediment than the water entering the site. On average 112 mg l^{-1} of sediment enters the site and under 40 mg l^{-1} of sediment leaves the site during stormflow[2].

Site surveying showed that 13 ponds held over 100 t of sediment (normalised average of 70 kg m^2 ponded extent). Associated with this sediment was 15 t of carbon and 1 t of nitrogen[3].

It is clear that pond size has the greatest control over storage; larger ponds hold more sediment per unit area, although position in dam sequence may play a role too. It was estimated that over 70 % of sediment within the ponds was sourced from the farmland upstream. Thus, beaver ponds may have a role to play in mitigating negative impacts of soil erosion and diffuse pollution from agriculture. At the time of sampling, it is estimated that ponds would have over 50% remaining storage capacity, even without continued modification by beavers of the site over time to maintain/increase capacity[3].

↓ **Figure 3.7** Sediment storage within beaver ponds.



Key documents in Appendix 3

- Flooding, Beavers and a Community in the River Otter catchment – UoE November 2019
- Structure from Motion Photogrammetry poster – UoE April 2018
- Summary Paper on Beaver Dam failure – UoE November 2019

The appendices are available to view at www.exeter.ac.uk/creww/research/beavertrial/appendix3/

NB. These appendices will be updated with other relevant supporting documents, not necessarily listed here.

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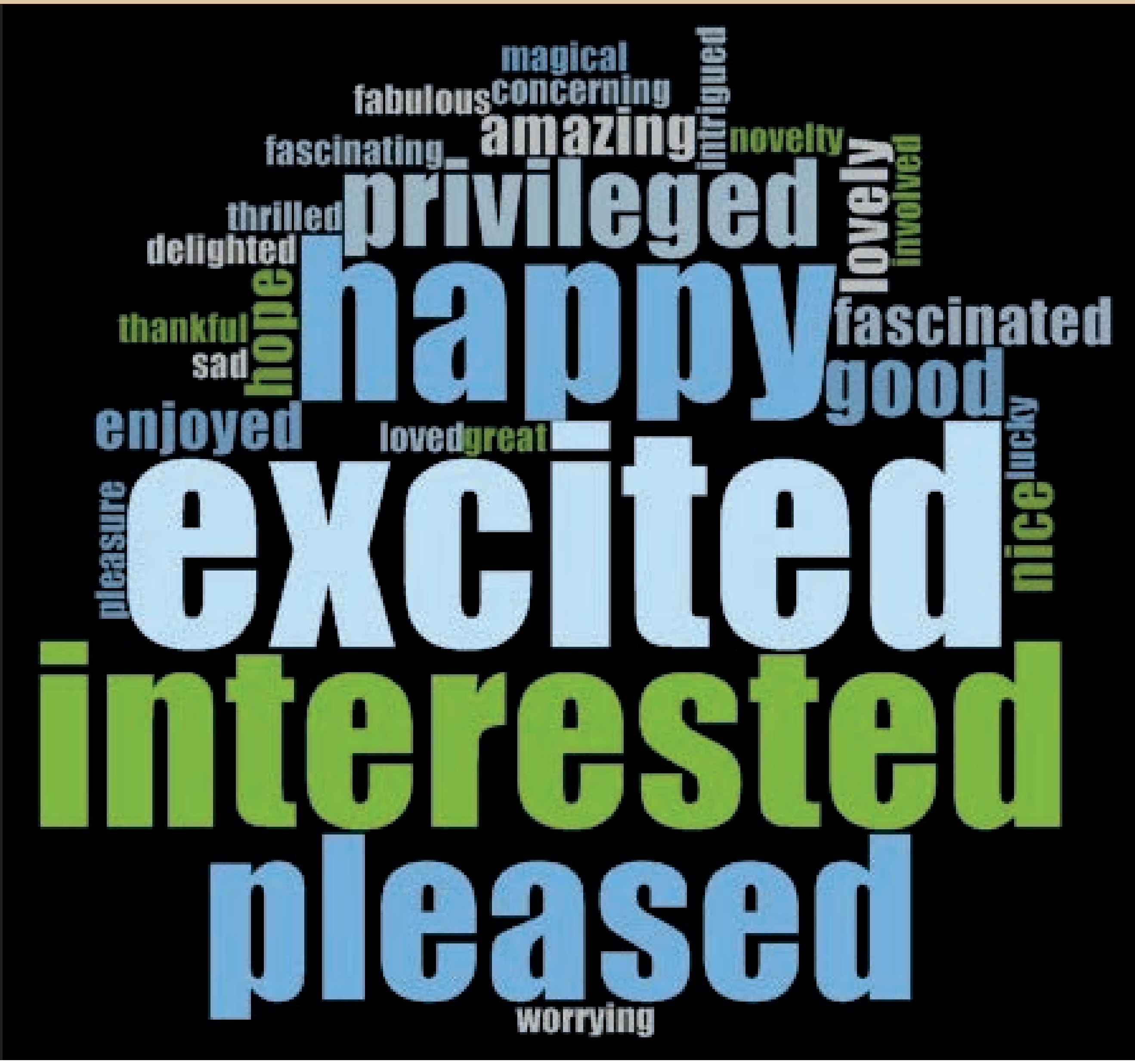
12. Bilotta, G. S. et al. Assessing catchment-scale erosion and yields of suspended solids from improved temperate grassland. *Journal of Environmental Monitoring* 12, 731 (2010).

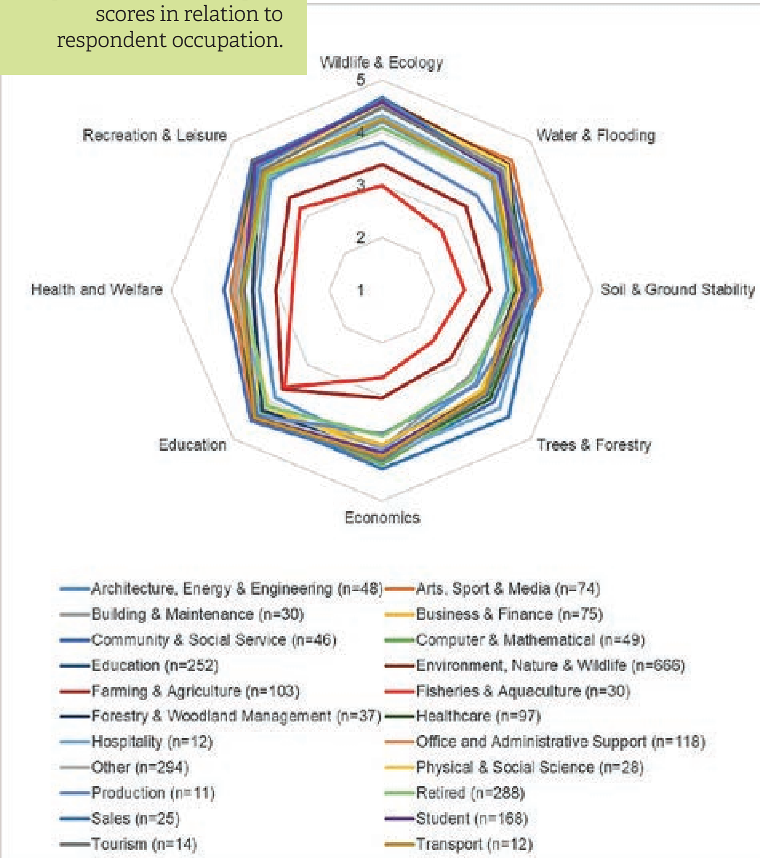
CHAPTER 4: Social Attitudes and Perceptions



Frequency analysis of 'emotional response' words used in mail-return questionnaire in Otterton (**Case Study 3**) when respondents were asked to describe how they felt when they had seen beavers or signs of their activity.

Social attitudes in Britain – A nationwide survey

↓ **Figure 4.1** Respondents' perceived beaver impact scores in relation to respondent occupation.



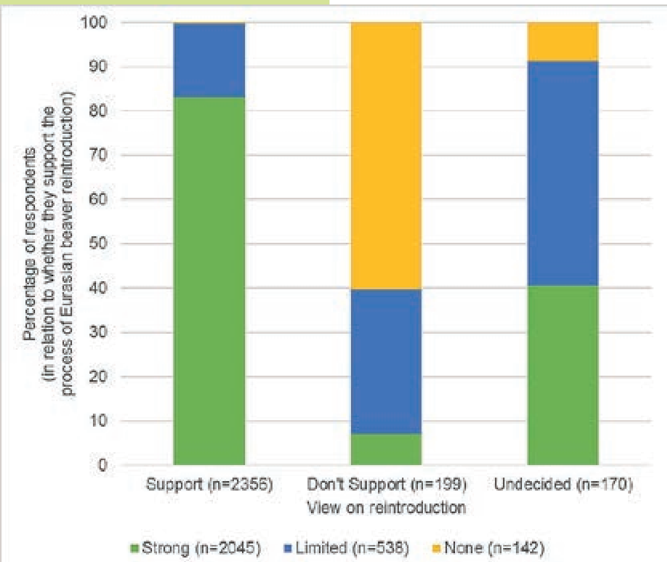
In 2017, a nationwide online opinion survey was conducted by the University of Exeter which received 2,759 responses. The survey was conducted from an impartial viewpoint and has been subject to scientific peer review[1]. This paper by Auster, et al. (2019)[1] is provided in Appendix 4.

The first set of questions was wide ranging, including themes such as beaver impacts on wildlife/ecology, water/flooding, soil, trees/forestry, economics, education, health/welfare and recreation/leisure. In each of these areas of focus, respondents were asked to indicate their view on a scale. Score 1 = Very Negative, 2 = Somewhat Negative, 3 = Neutral, 4 = Somewhat Positive, 5 = Very Positive.

The majority of survey respondents averaged a score at the positive end of the scale for all of the impact areas (Figure 4.1). The average scores for respondents whose occupation was in 'Farming and Agriculture' or 'Fishing and Aquaculture' were not as positive as the others. When looking in more detail within the scores given by respondents from these occupations, a diversity of opinion was observed with both positive and negative views of potential impact expressed. The impact area in which these two occupations generally exhibited a more positive view of potential beaver impact was in 'Education'.

All respondents were given the opportunity to provide a reason for their answer for the impact score. For each of the eight impact areas, a summary of the reasons given as to why respondents indicated their scores (broken down into whether their views were positive, negative or neutral) are provided in Appendix 4.

↓ **Figure 4.2** Respondents' views on level of legal protection required for beavers if they are formally reintroduced across Great Britain, in relation to whether respondents support the process of beaver reintroduction. Reasons for respondents' views are provided in Appendix 4



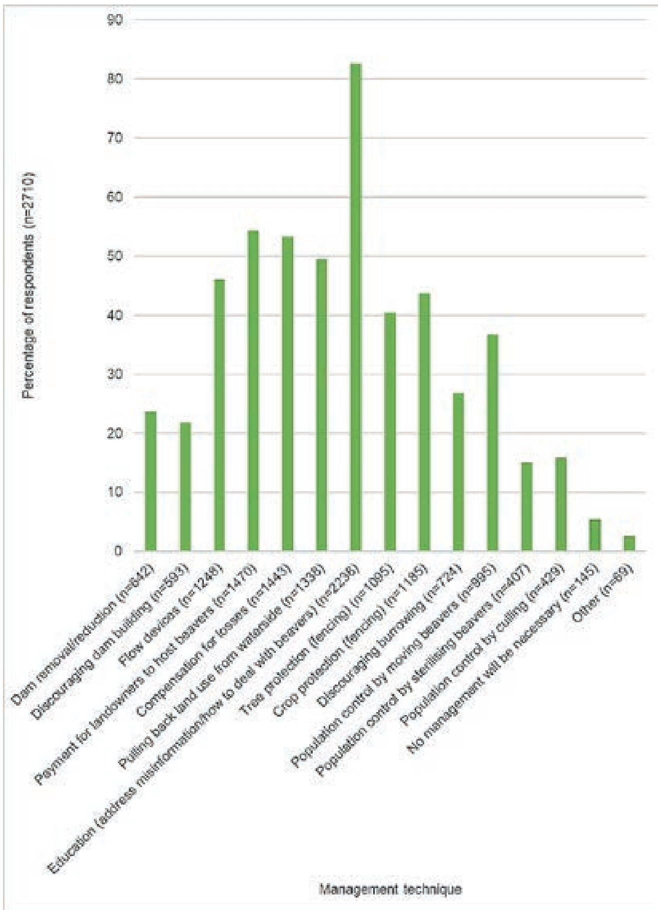
The survey then included questions regarding their attitudes towards the potential management of beavers in the scenario that they were formally reintroduced. Questions focused upon: views on the level of legal protection for beavers that would be required; whether respondents would support particular beaver management techniques (Figure 4.3); who should take responsibility for beaver management funding (Figure 4.4) and management in practice (Figure 4.5). (Note, this survey took place prior to the Scottish Government listing beavers in Scotland as a European Protected Species).

Respondents who supported beaver reintroduction were most frequently associated with a view that they should be given strong legal protection (if formally reintroduced). The reasons given most frequently cited the protection of beavers against cruelty or persecution, and the ability to establish and sustain a viable beaver population.

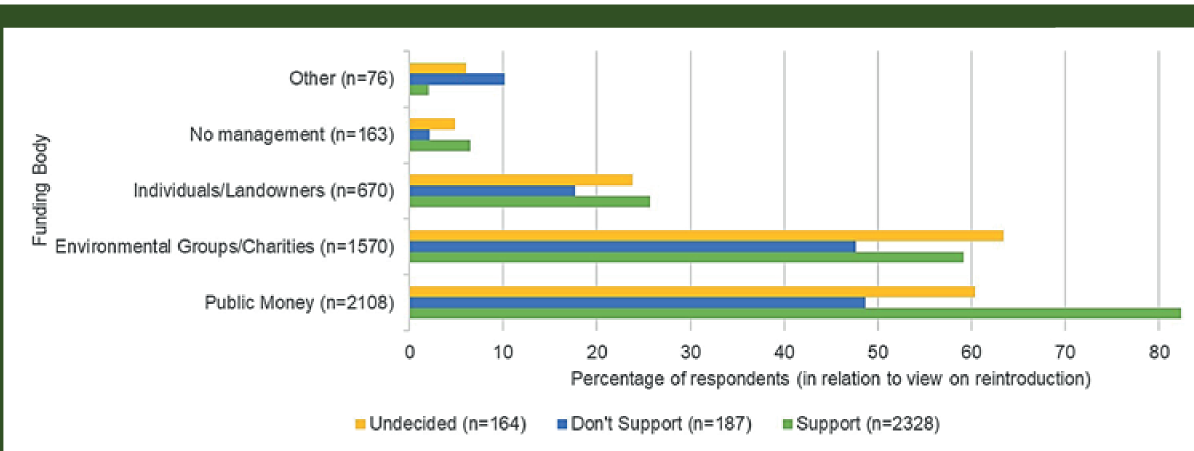
Those who did not support beaver reintroduction most frequently thought that beavers should not be given any legal protection and most frequently suggested that legal protection would make it difficult to manage negative impacts when necessary and that affected people/landowners should be able to undertake some management themselves.

Respondents who were undecided as to whether beavers should be formally reintroduced were most frequently associated with the view that beavers should be given limited legal protection. The reasons given here were more nuanced and often included reasons both for and against the legal protection of beavers; most commonly it was cited that beavers would require some form of management.

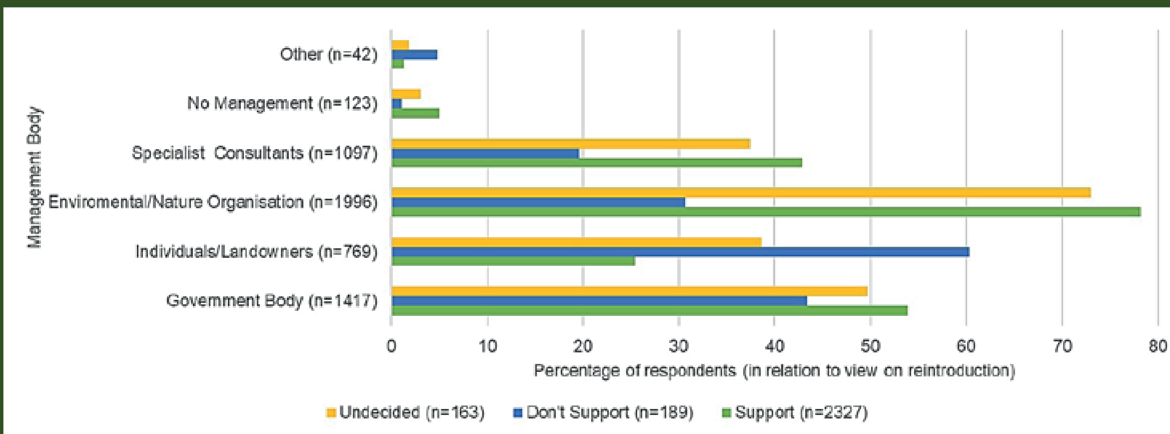
When asked about specific beaver management techniques, the indirect methods such as education, compensation and payments for landowners to host beavers on the land were the most highly selected responses. The more direct techniques, in particular population control by culling or sterilisation, garnered less support. Least supported was the view that there should be no management (Figure 4.3).



↑ **Figure 4.3** Respondents' support for potential beaver management techniques (respondents could select multiple answers).



← **Figure 4.4** Respondents' views on responsibilities for beaver management funding if they are formally reintroduced across Great Britain, in relation to whether they support reintroduction.



← **Figure 4.5** Respondents' views on responsibilities for beaver management in practice if they are formally reintroduced across Great Britain, in relation to whether they support reintroduction.

Repeat survey in 2019

In 2019, the outcomes of the nationwide questionnaire[1] were shared with the respondents who had provided their email addresses at the time of the survey. Respondents were invited to leave their address to receive the survey outcomes. With this email, an invitation was issued to take part in a short follow-up survey.

The follow-up repeated four of the questions asked in 2017[1] in order to assess changes in attitude amongst the same group of people. Using the email addresses that had been voluntarily given at the time of the original questionnaire, 1,992 respondents were successfully invited to take part in the repeat survey (72.20% of the total number of original respondents). Of these, 386 participants took part (19.38% of those invited, 13.99% of the total number of original respondents) between 13th and 28th August 2019.

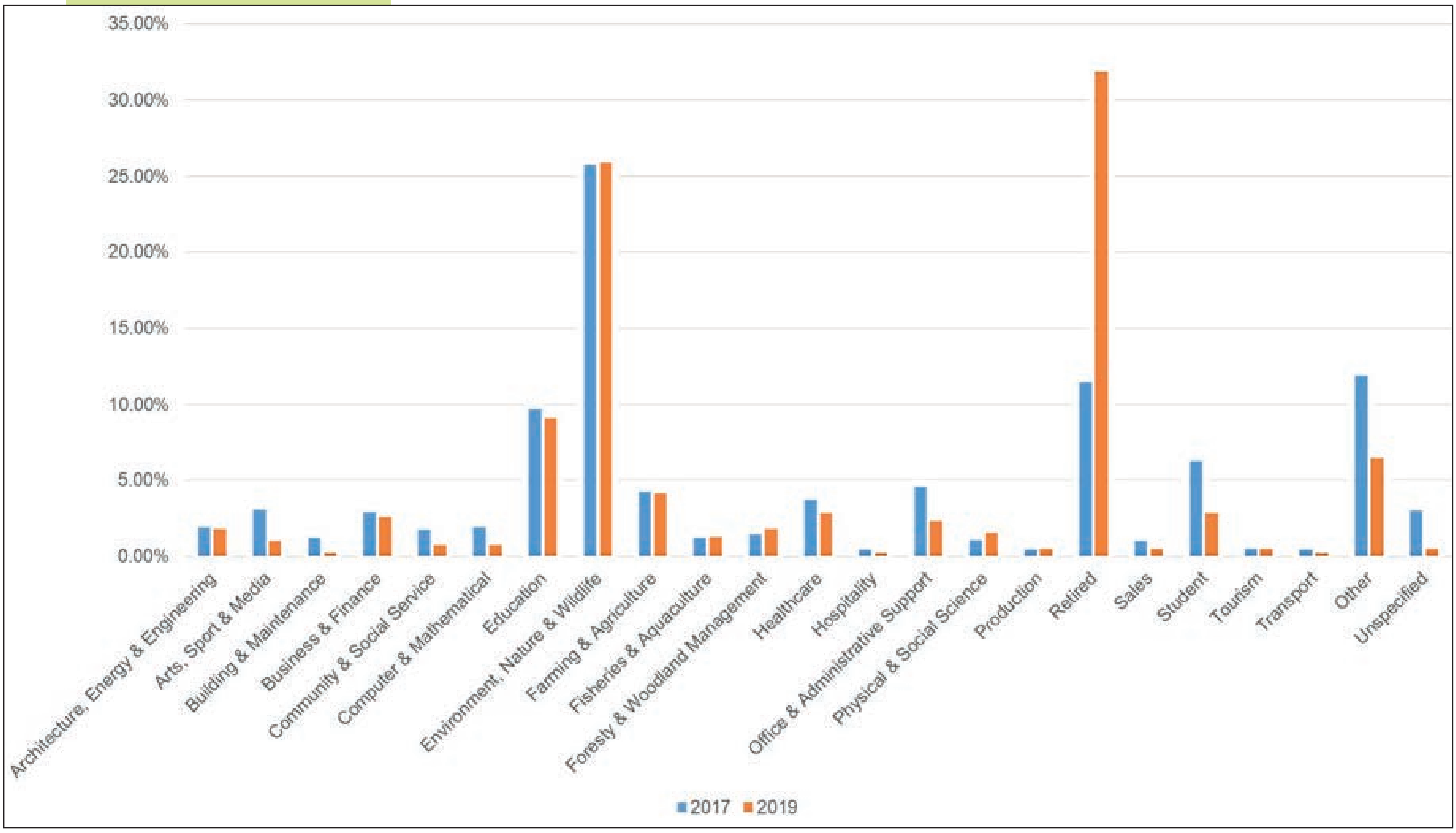
On this occasion, respondents were not asked for the reason for their answers as the respondents had already given time to the much longer original questionnaire. A number of questions in the original questionnaire asked respondents for the reasons for their views, the results of which are available in Appendix 4.

There was a statistical difference in the percentage of respondents from occupational backgrounds between the 2017 and 2019 surveys. Of the two occupations identified as statistically more likely to have a more positive view of beaver impacts in 2017, the relative proportion of ‘Environment, Nature & Wildlife’ was similar (+0.14%), and there was a decrease in the proportion of ‘Arts, Sport & Media’ participants (-2.01%). Of the three occupations identified as statistically less likely to have a more positive view of beaver impacts in 2017, there was a similar proportion of ‘Farming & Agriculture’ (-0.10%) and ‘Fisheries & Aquaculture’ (+0.06%) respondents, whilst there was a large increase in the proportion of ‘Retired’ (+20.41%) respondents.

Respondents were asked whether they supported the process of beaver reintroduction in Britain. As a respondent pool on the whole, there was not a statistical difference between the years (Figure 4.7):

- In 2017, 86.25% supported the process of beaver reintroduction, 7.44% did not and the remaining 6.31% were undecided (n=2741).
- In 2019, 89.64% supported the process of beaver reintroduction, 6.22% did not whilst the remaining 4.15% were undecided (n=386).

↓ **Figure 4.6** Relative proportions of respondents of each identified occupation in the 2017 and 2019 surveys.



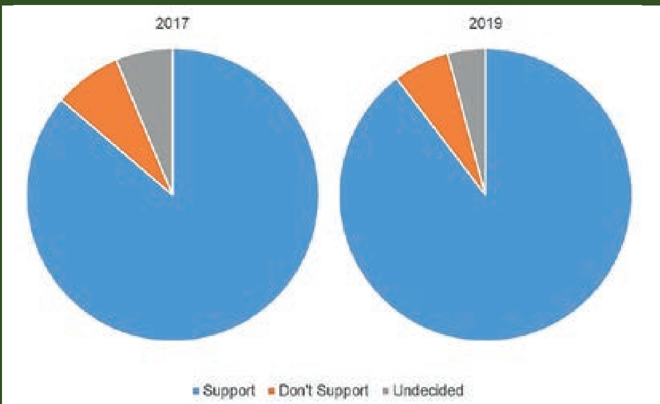
Nor was there a statistical difference found in respondents' views (as a whole) on the level of legal protection required if beavers were to be formally reintroduced (figure 4.8):

- In 2017, 74.93% felt there should be strong legal protection, 19.77% felt there should be limited legal protection and 5.31% felt there should be none (n=2732).
- In 2019, 79.27% felt there should be strong legal protection, 17.10% felt there should be limited legal protection and 3.63% felt there should be none (n=386).

Respondents were asked how much they felt they knew about the beaver reintroduction trials taking place across Britain (an additional note was added to state that the situation in Scotland was recognised to have changed and that the situation there was still included in the question).

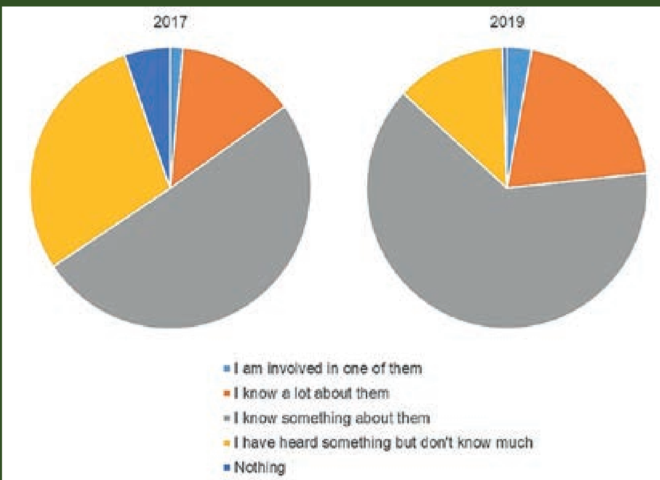
There was a statistical difference identified between the answers given in each survey (Figure 4.9). There was a decrease in the relative proportion of respondents who felt they knew 'Nothing' (-4.74%) or selected "I have heard something but don't know much" (-16.43%). Meanwhile, there was an increase in respondents who selected "I know something about them" (+13.00%) or "I know a lot about them" (+6.78%).

Finally, respondents were asked whether they felt able to express their opinions where it influences decision-makers and there was found to be a statistical difference between the surveys. In 2017, the majority of respondents answered 'No' (60.22%), with the remainder answering 'Yes' (39.78%). The opposite was found in 2019 with the majority answering 'Yes' (53.63%) and the remainder answering 'No' (46.37%) (Figure 4.10). However, as this survey was issued alongside the paper based upon the 2017 survey, it is uncertain whether this difference is a result of seeing this paper specifically or because of the wider change in circumstances in beaver reintroduction.

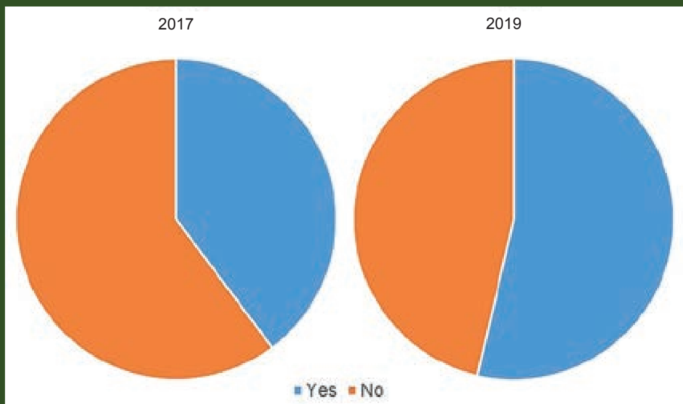


↑ **Figure 4.7** Relative proportions of all respondents in 2017 and 2019 who support or don't support the process of beaver reintroduction to Great Britain.

↑ **Figure 4.8** Relative proportions of all respondents in 2017 and 2019 who support differing levels of legal protection if beavers are to be reintroduced.



↑ **Figure 4.9** Relative proportions of all respondents in 2017 and 2019 which identified how much they felt they knew about the beaver reintroduction Trials in Great Britain.



↑ **Figure 4.10** Relative proportions of all respondents in 2017 and 2019 on whether they felt they could express their opinions where it may influence decision-makers.

Perspectives from the agricultural sector

There were 117 respondents who identified their occupation as 'Farming & Agriculture' who took part in the peer-reviewed nationwide questionnaire[1]. Respondents of this occupation were found to be statistically less likely to have a more positive view about the impacts of beavers than other respondents.

The 'Farming & Agriculture' respondents were found to have a diverse set of opinions about beaver impacts. Similarly, when asked whether respondents supported the process of reintroduction to Britain, 46.55% supported the process, 42.24% did not and 11.21% were undecided (n=116). This diversity in opinion was also observed in respondents' views on the level of legal protection that should be applied should beavers be reintroduced: 32.17% indicated that beavers should be given 'strong' legal protection, 34.78% indicated that they felt beavers should be given 'limited' legal protection whilst 33.04% felt there should be none. (Appendix 4 - Respondents' Reasons for Answers Given in 2017 Nationwide Questionnaire).

During the ROBT, there were two significant instances of flooded agricultural land due to beaver damming. The respective farmers were interviewed and asked for their views. Details of the interviews are reported in **Case Studies 1 and 2**, with the importance of good communication highlighted.

Beaver management

A key theme which was recognised in the nationwide survey[1] and which repeatedly occurred during discussions with farmers/landowners in the River Otter catchment was the question of future management if beavers were to be reintroduced. This included questions about who would be responsible for management in practice, management funding and the actual management techniques that could be employed.

A range of beaver management techniques exist, all of which are detailed in *The Eurasian Beaver Management Handbook*[2]. In the nationwide questionnaire, respondents were asked which of the management techniques they supported with the ability to select multiple options. These results are presented in Appendix 4 in relation to the respondents' occupations. In these results, the least supported option amongst almost every group was 'No Management'.

Perspectives from the angling community

The nationwide survey[1] also identified that those who identified their occupation as in 'Fisheries & Aquaculture' were less likely to have a more positive view of the potential impacts of beaver reintroduction than other respondents. One of the questions asked whether participants supported the process of beaver reintroduction to Great Britain and amongst the 'Fishing & Aquaculture' respondents to answer the question (n=34) there was a diversity of opinion observed: 44.12% supported reintroduction, 44.12% did not and the remaining 11.76% were undecided.

A method from the psychological sciences known as the 'Q-Methodology' was used to explore the perspectives that exist amongst anglers in the River Otter catchment on beaver reintroduction and its interaction with both fishing and other factors. Participants were invited to take part by first engaging with fishing syndicates throughout the catchment and asking them to refer details onwards. 11 anglers volunteered to participate in the study.

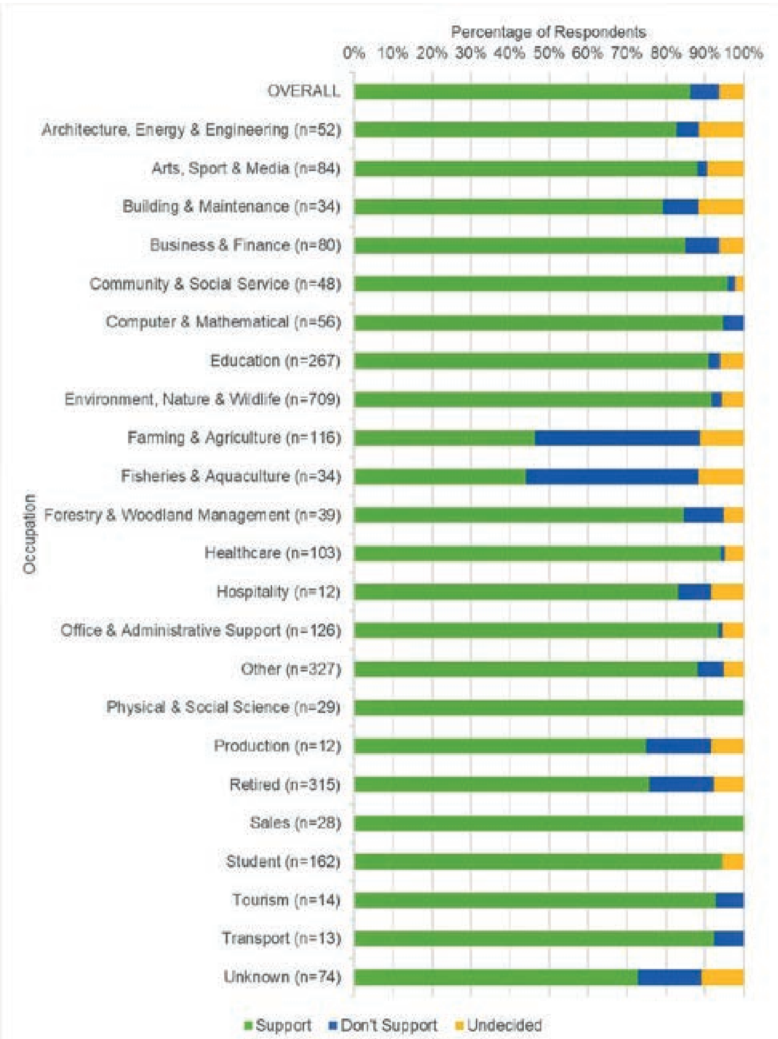
At the time of writing, this Q-Method study is under peer review[4]. Below we summarise the three distinct perspectives that were identified indicating differences of opinion within the participants:

1. The first group fished in order to engage with nature. They felt strongly that beavers would be beneficial for fish and wider biodiversity and were not too concerned about possible negatives. They were willing to accept some negative impacts upon fishing in order to obtain wider ecosystem benefits.
2. The second group viewed angling as a traditional activity which is particularly beneficial for physical and mental health. They were apprehensive about beaver reintroduction and viewed it as a possible threat towards fish and fishing activity. In particular, there was a concern about whether beaver dams would obstruct fish migration.
3. The third group exhibited a mix of the opinions seen in the other perspectives. They too saw fishing as important, including for physical and mental health, whilst they also believed that there would be benefits resulting from beaver activity. They believed that beavers should be reintroduced, but only in association with the ability to control or manage beavers and their impacts.

Perceptions of beavers in the urban environment

An urban fenced beaver project is under consideration in Plymouth, led by Plymouth City Council. In an online questionnaire targeted towards residents in the area, to which 133 respondents replied, a question asked about the respondents' views of beavers in the urban environment. The response to this question is provided here to complement the views secured through the River Otter Beaver Trial as the latter is in a largely rural area.

Comments were received from 53 of the 133 respondents and a thematic analysis of answers to the question identified the key themes which emerged. These were regarding the potential benefits, risks/challenges for beavers, concerns, management considerations and project-specific comments. Under each of these headings, subsequent themes were identified (Figure 4.12)



↑ **Figure 4.11** Levels of support for beaver reintroduction in relation to the occupations of all respondents in the 2017 nationwide questionnaire[1].

Benefits Cited	Risks/Challenges For Beavers	Concerns Cited	Management Considerations	Project-Specific Comments
Aesthetic Improvements	Cruelty	Increased Risk of Tree Felling Causing Damage	Welfare Checks	Introduce Beaver Post-Road Construction
Beneficial for Human Mental Health	Road Accidents	Costs of Management	Beavers Need Protection	Risk of Vandalism
Increase Urban Biodiversity	Space Limitations		Damage Monitoring and Reporting	
Educational Opportunity	Dogs		Need To Promote Positives of Beavers To Increase Tolerance	
Engagement of Urban Communities in Nature (Limited opportunities in cities)				

↑ **Figure 4.12** Key themes identified from an urban community on their perspectives of beavers in the urban environment.

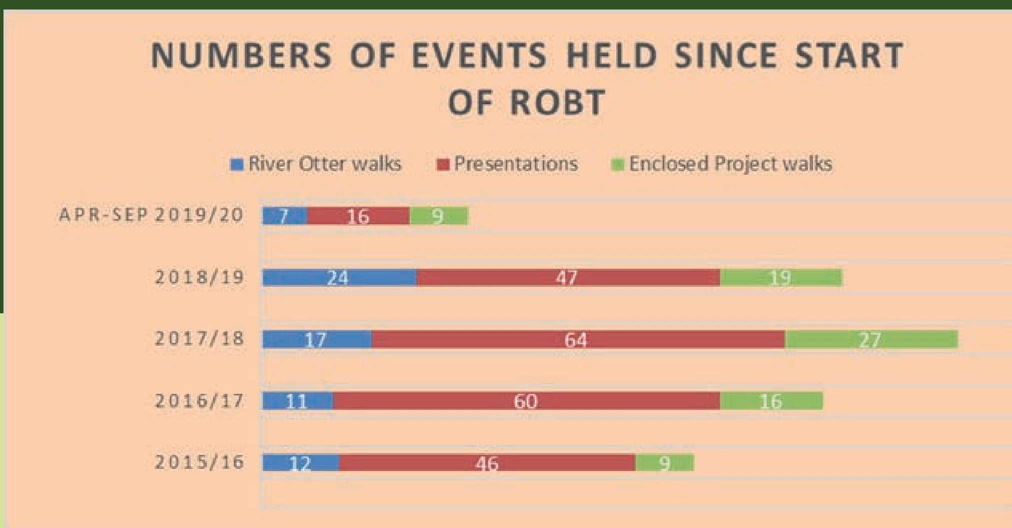
The ROBT Steering Group has established a 'Beaver Management Strategy Framework'[3] through comprehensive engagement with a broad range of stakeholders for Defra to consider if beavers are permitted to remain on the River Otter

Role of engagement activities

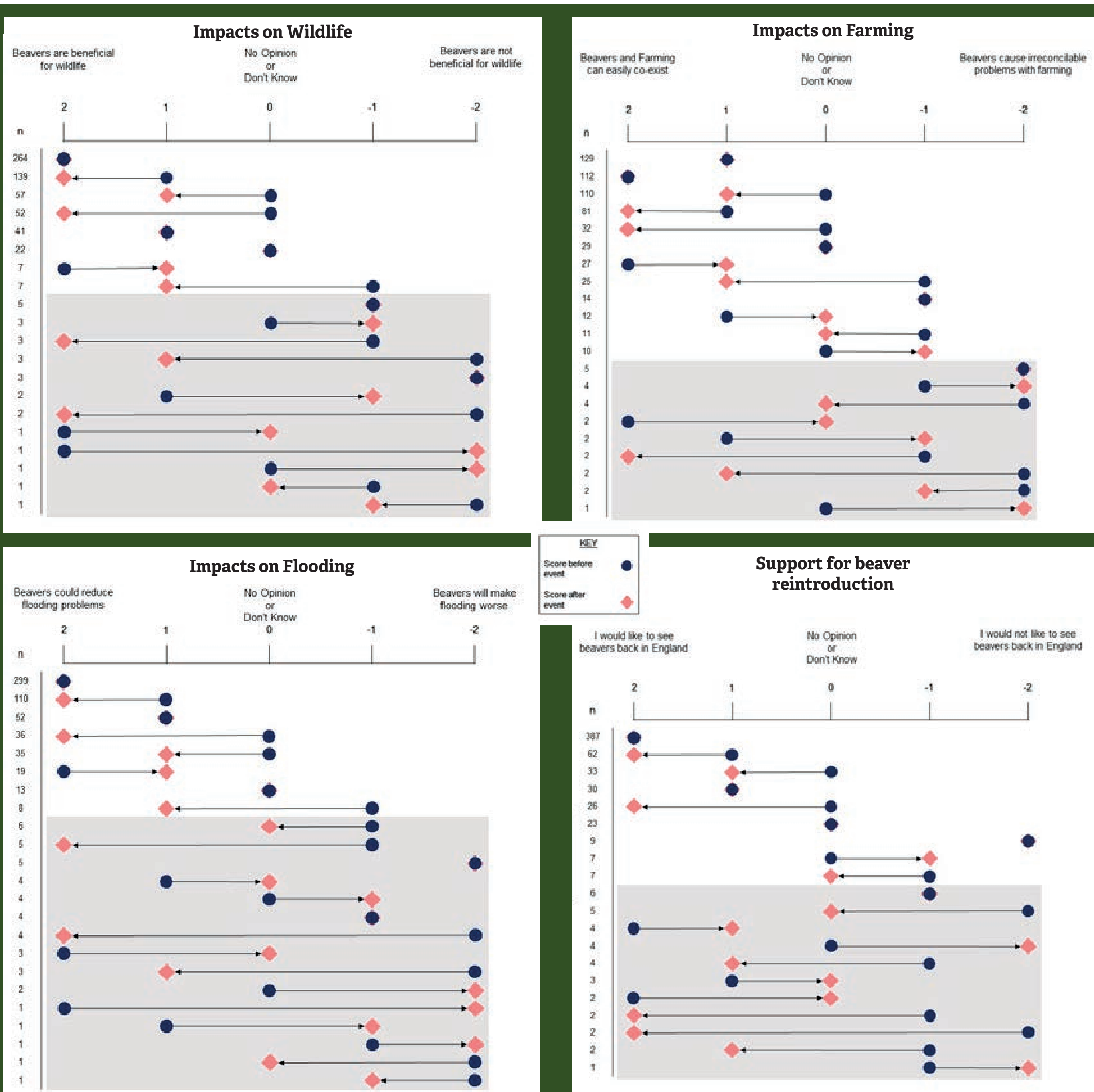
Many events took the form of a slideshow/presentation followed by question and answer sessions by the project team from Devon Wildlife Trust and other project partners, including Clinton Devon Estates and the University of Exeter. At 18 of these events attendees were issued with identical questionnaires 'Pre-' and 'Post-Event'. The respondents were asked to indicate their view of beavers in four different areas by providing a score on a scale between two opposing statements. The results showed differences in responses 'Pre-' and 'Post-Event' which indicate that there were attitudinal shifts between the completion of each survey. Further details (including where there were differences between the groups of attendees) are included in Appendix 4.

The results indicate that the role of objective, evidence-based engagement activities in beaver reintroduction can influence attitudes positively. Further research would be required to assess whether this attitudinal change persists beyond the event itself and whether it would influence behaviour. It is possible that this could play a role in addressing conflict issues. It will be important that engagement events remain evidence-based to prevent attitudinal shifts based upon misinformation.

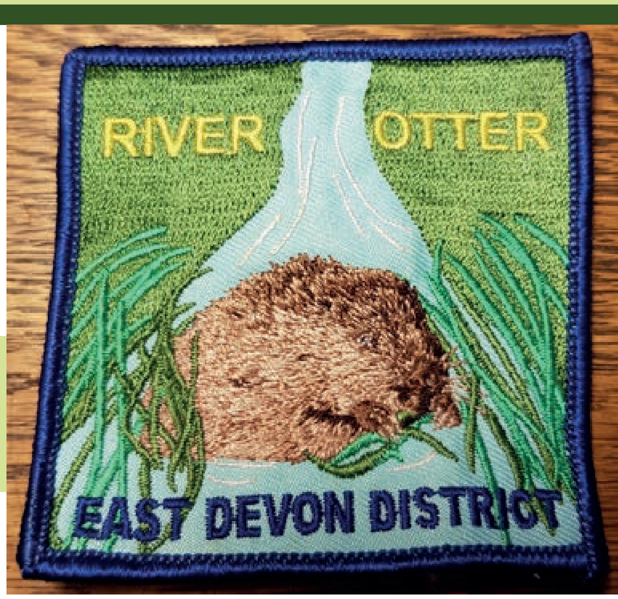
→ Since the very beginning of the Trial, there has been huge interest in the beavers and the work of the Trial. This has manifested itself in requests for talks and guided walks by members of the public, special interest groups, key stakeholders and partner organisations.



→ **Figure 4.13** In the first 4½ years of the Trial a total of 384 events were hosted or attended, at which an estimated 18,000 people were engaged directly with information about the beavers.



↑ **Figure 4.14** Patterns of shift in attitude score between each pair of opposing statements. In these figures, each n refers to the number of people who demonstrated each shift pattern, and the area in grey indicates shift patterns exhibited in <1% of the respondent pool.



→ A Beaver Scouts badge made in honour of the River Otter beavers

Additional perspectives

Ecological politics of beaver reintroduction

During the period prior to the start of the Trial, PhD researcher Sarah Crowley studied the attitudes of stakeholders involved in the discussions about the future of the beavers found to be living and breeding on the river. The research examined the political processes, negotiations and outcomes of the 'unauthorised' reintroduction of beavers to Devon prior to licence to release beavers being granted to DWT and partners[5]. The relevant publication by Crowley, et al. (2017)[5] is provided in Appendix 4.

Interviews were conducted with key informants, alongside documentary analysis (including consultation responses) and field observations. The research identified that the Government's initial response constituted an effort to reassert political and ecological order. From the Government's perspective, the unauthorised reintroduction of the Devon beavers represented both an unwelcome precedent and a potential public health risk. The beavers were therefore framed as both unnatural and illegitimate, and the government planned to secure the situation by capturing them.

This decision was strongly opposed by a diverse collective of British citizens who were united and made powerful by a common goal: protecting the beavers. This collective included East Devon residents, environmentalists, and conservation and animal protection organisations, who expressed varied opinions and arguments, but shared the aim of stopping Government action. While there were organisations and individuals in support of the beavers' removal, the pro-beaver voice became large and powerful enough to sustain a high level of pressure on the Government.

The development of the River Otter Beaver Trial provided an alternative option that, by monitoring and regulating the beavers' presence, allowed governing authorities to regain some control of the situation. The Trial was compared to a citizenship test for beavers, through which they have the opportunity to demonstrate their ability to (re)integrate successfully into British social and ecological landscapes. There are risks with this approach: particularly, the unorthodox events which led to Trial establishment have created tensions between stakeholders that could create challenges in the future. Nevertheless, it was proposed that the Trial provided opportunities to (a) develop methods for, and gain experience in, managing beaver impacts, and (b) find ways to constructively include affected and interested people in future negotiations.

The conservationists' approach to the River Otter Beaver Trial

In May and July 2019 anthropology student, Charlotte Zealley, conducted ethnographic fieldwork focusing on the conservationists involved in the management of the Trial[6]. It took the form of semi-structured interviews and participant observation of day-to-day work.

Charlotte found that, for conservationists, the most significant element of the Trial is its introduction of a powerful nonhuman 'natural process' to the landscape. As such, conservationists distinguish between human and nonhuman processes. Compared to many wildlife reserves in England where species are carefully managed, the Trial is more focused on managing relationships with affected stakeholders. The reintroduction of beavers to the river is distinctive in terms of English conservation because it does not involve the intensive management of a targeted site; the Trial aims not to exclude people from shaping the landscape, rather it seeks to facilitate the integration and co-existence of beavers, their impacts and human activity in one shared landscape.

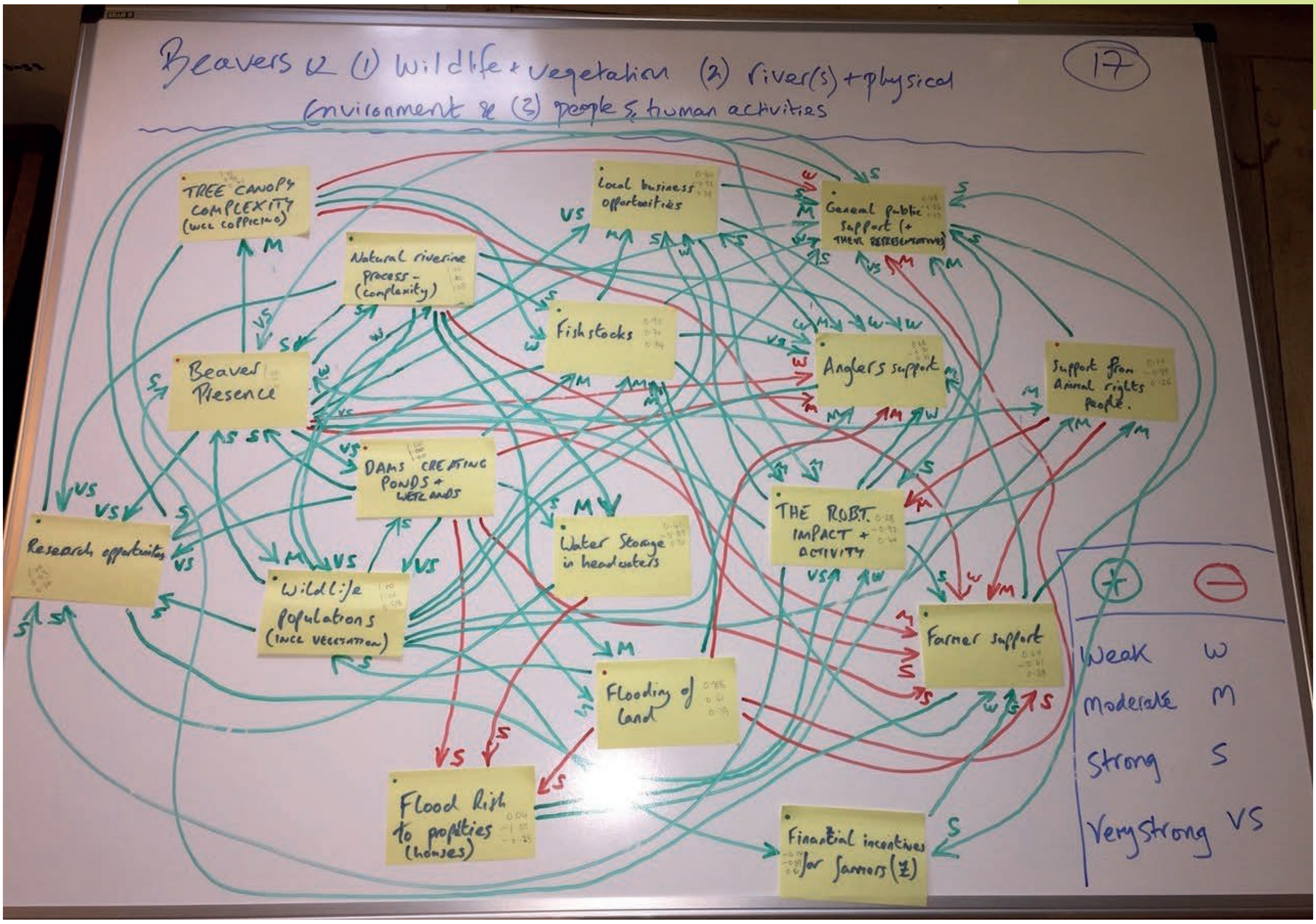
This research highlights the often-conflicting challenge of addressing nature/culture focused perspectives or interests, and that doing so remains pertinent to the perception of the English landscape.

Mental models and emotion; understanding the ROBT as an example of human-wildlife conservation interaction

A PhD research project led by Andrew Blewett (Wageningen University, Netherlands) is investigating the unique circumstances of the River Otter Beaver Trial reintroduction. This study draws on detailed perceptions, understanding and feelings of 48 interviewees including: farmers, land-owners and managers, anglers, conservationists, environmental regulators, utility providers and members of the public. The resulting stakeholder mental models (see Figure 4.15), show concepts and linkages weighted by the perceived importance by the participant. Furthering this research will develop an understanding of the relationship between beaver reintroduction and land-use objectives preferred by stakeholders and policy-makers.

Additionally, during interviews he included a layer of emotion ratings attached to concepts. It is known that emotion plays an important role in decision-making (notably under stress), crucial to wildlife and ecological restoration project outcomes, especially in multi-use landscapes. It is hoped to infer conclusions drawing on the empirical data and decision-making theory, relevant to natural-resource management as it increases further in strategic importance.

↓ **Figure 4.15** An example of a raw mental map collected as part of the stakeholder interview process (with permission).



Key documents in Appendix 4

- Engagement Events and Attitudinal Change (November 2019)
- Nonhuman Citizens on Trial: Eco Politics of Beaver Reintroduction (2017)
- Respondent Reasons for 2017 Nationwide Survey Answers (November 2019)

The appendices are available to view at https://www.exeter.ac.uk/creww/research/beavertrial/appendix4/

NB. These appendices will be updated with other relevant supporting documents, not necessarily listed here.

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CHAPTER 5:
Beaver health and population

The pink-tagged female feeding one of her kits in July 2017

Photo: Nick Upton

The importance of disease risk analysis for beaver reintroduction

Animal health and welfare in conservation programmes is of critical importance. The success of any reintroduction programme can be significantly affected by disease – both directly (the animals subject to reintroduction) and indirectly through disease that may be transmitted, or new conditions created which establish new vectors. The International Union for the Conservation of Nature (IUCN) Reintroduction Guidelines state *'the level of attention to disease and parasite issues around translocated organisms and their destination communities should be proportional to the potential risks and benefits identified in each translocation situation'*[1].

A detailed assessment of any health risks posed by beavers can be found in *'Reintroducing Beavers Castor fiber to Britain: a disease risk analysis'*[2] and in the *'ROBT Final Beaver Trapping and Health Screening Report'*[3] (Appendix 5).

Assessment of beaver health at start of Trial in 2015

When the wild beavers were confirmed to be breeding on the River Otter in 2013, one of the primary concerns expressed by Defra was that the beavers could be carrying infectious diseases, and specifically *Echinococcus multilocularis*, a taeniid tapeworm not currently found in the UK[4]. This is primarily a disease of canids (e.g. red foxes) where rodents are an intermediate host. If a rodent such as a beaver ingests eggs from the environment, they develop in the liver and other major organs, and if the animal dies and is scavenged by a fox, the life cycle is completed as the parasite develops in the intestinal tract – the fox then excreting the eggs[5]. As intermediate hosts, the disease cannot be passed directly from an infected beaver to an uninfected beaver[2]. Because the origin of the original beavers was uncertain, they needed to be tested for the *E. multilocularis* parasite.

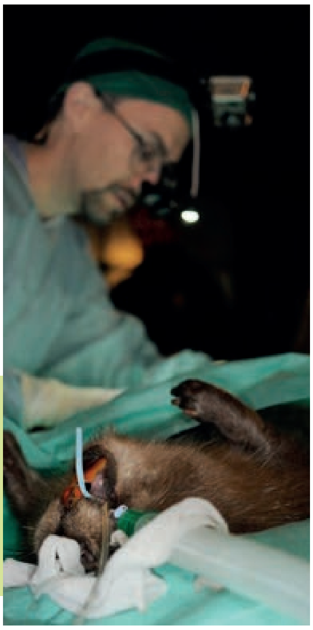
There was also a need to clarify that the species was Eurasian beaver and not the North American species (*Castor canadensis*).

Initial survey and trapping of wild beaver population

In February 2015, following the issuing of the ROBT licence, ecologists from the Animal and Plant Health Agency (APHA) began surveying and trapping. Trapping focused on those mature adults that represented a potential risk of carrying the *E. multilocularis* tapeworm.

Sites of beaver activity were identified, and remote cameras were used to confirm beaver presence, identify individuals and determine family groups, as well as to guide the placement of traps. A total of 11 traps were then located within four separate trapping areas along the river.

Records from remote cameras indicated a total of nine individual beavers (animals were identified and separated by simultaneous sightings, body size and individual tail-markings) in two different social groups (estimated at six and three individuals respectively). All four known adults and one juvenile were captured during 12 nights of trapping in February and early-March 2015. These were transported to Derek Gow Consultancy premises where they were held in purpose-built indoor beaver quarantine pens where the health screening took place on 9th March 2015.



↑→ The captured beavers were placed under anaesthetic enabling detailed health screening to be conducted, including a lung wash for *Mycobacterium bovis* (bTB).

Photos: Nick Upton

↑ When the ROBT licence was issued in February 2015, a team of ecologists from the Animal and Plant Health Agency (APHA) began trapping the wild beavers. Bavarian traps, specifically designed for the capture of Eurasian beaver, were sited so that they were aligned on natural beaver egress points from the river. Traps were locked open initially, baited with apples and monitored with remote cameras. Between 14th February and 4th March 2015, traps were set resulting in four adult beavers and one of the kits being caught. These were then transported to a holding facility nearby.

← A laparoscopic examination of the external surfaces of the internal organs, and ultrasound looking at the interior of organs focusing of the liver was conducted, searching for signs of the *E. multilocularis* cysts. This internal examination also revealed that both adult female beavers were pregnant at this time (mid-March 2015).

Photo: Nick Upton

Health screening methods

A team from the Royal Zoological Society for Scotland including Dr Romain Pizzi and Dr Roisin Campbell-Palmer conducted the health screening assessments in 2015. Blood samples were taken, and haematology and serum biochemistry were performed as a general assessment of each beaver's general state of health (SAC Consulting Veterinary Services, Scotland's Rural College). Further specific serological testing was performed as follows (see Appendix 5):

- European *Leptospira serovars* (pools 1-6) using the microscopic agglutination test (MAT) (APHA, Weybridge);
- *E. multilocularis* by means of two different enzyme-linked immunosorbent assays (ELISAs) targeted against the EM 18 and EM 2 antigens, used for human EM diagnosis, as well as a recently developed immunoblot. A specific anti-beaver IgG conjugate was used for testing at University of Bern, Switzerland.
- Polymerase Chain Reaction (PCR) testing was also carried out for tularaemia on serum (National Veterinary Institute, Norway).

Faeces and rectal microbiology swabs were taken. Faecal samples underwent flotation with saturated salt solution for nematodes and sedimentation for trematodes, as well as microscopy for coccidia, *Cryptosporidium* spp., and *Giardia* spp. and acid-fast staining for *Mycobacterium avium* subsp. *paratuberculosis* (Johne's disease). Standard microbiological culture for bacterial enteric pathogens, including enriched media for *Salmonella* was performed (SAC Consulting Veterinary Services, Scotland's Rural College).

Although bovine tuberculosis has never been detected in beavers, with the animals under anaesthetic, the opportunity was taken to carry out a bronchoalveolar lavage (lung wash).

In addition, lavage fluid was submitted for standard mycobacterial culture and examined cytologically, including acid-fast staining for acid fast/mycobacterial organisms (Veterinary Pathology, RDSVS, University of Edinburgh).

↓ Whilst beavers were anaesthetised, they were sampled by local Coleopterist (beetle specialist) Clive Turner looking for evidence of the host-specific parasitic beaver beetle *Platypsyllus castoris*. No evidence was found.

Photo: Nick Upton

Results of health screening at start of Trial

A detailed summary report of the health and genetic status of the beavers at the start of the Trial was published by Dr Simon Girling and the team from RZSS, and is included in Appendix 5. Full health screening of the original founder beavers did not demonstrate any evidence of significant zoonotic disease, including *Giardia* spp., *Salmonella* spp., *Campylobacter* spp., *Yersinia* spp., *Cryptosporidium parvum, Echinococcus multilocularis, Francisella tularensis* and *Mycobacterium* spp.

One beaver tested positive for Leptospirosis[24] *L. javanica*. Fluke eggs were detected in one beaver in which atypical eggs were seen, which are most likely to be *Strichorchis subtriquetrus* (beaver intestinal fluke), with no fluke eggs detected in any of the remaining individuals.

All individuals were passed fit for re-release, presenting no health concern to humans, livestock or other wildlife.

DNA analysis of the River Otter beavers

Genetic analysis of surplus blood samples collected during this health examination was undertaken by Dr Helen Senn of the WildGenes Laboratory at the Royal Zoological Society of Scotland to confirm their species, and to establish the degree of relatedness and genetic diversity.

All five beavers screened were genetically determined as being Eurasian beaver *Castor fiber*. All animals assigned with high probability to either Bavarian or Baden-Württemberg populations. These are German populations of mixed reintroduced origin.

Examination of genetic relatedness revealed that all beavers were closely related, consistent to belonging to a single family group. It was not possible to be certain of the exact pattern of relatedness between the animals because they were all so closely related. Appendix 5 contains a diagram of the most likely configuration of a family tree based on age and genotype of beavers.

This identifies the yellow tagged female (F0815) as the female parent of three of the other animals present, and highlights that the male parent of these three beavers is absent.

The licence issued by Natural England allowed up to five additional beavers to be released into the river to enhance the genetic diversity of the population.

← Digestion of woody material is increased through the practice of caecotrophy where the pellets are ingested for a second time.

Photo: David White

Ongoing monitoring of beaver health during Trial period

Methods for monitoring beaver health

Throughout the Trial period, beavers were trapped in order to identify and tag kits born on the River Otter and to monitor the ongoing health of the population. Trapping work led by Dr Roisin Campbell-Palmer was carried out during the winter months, between October and March to avoid unnecessary stress to heavily pregnant females, or when there may be dependent kits present.

The selection of trapping sites was based on where breeding was thought to have taken place the previous season in order to identify young animals. Pre-baiting with carrots and apples, combined with the use of camera traps, was conducted before traps were deployed. These traps were not set initially and baited to encourage and monitor beaver activity. Once established, they were then set in the evening and checked the following morning. Any beavers trapped were identified using a combination of ear tags and Passive Integrated Transponder (PIT) tags – commonly used for cat and dog identification purposes. They were then given an external physical examination for general body condition and new young animals were sexed and then fitted with ear and PIT tags. They were then released immediately at the point of capture.

↓Trapping and health screening work on the River Otter was led by Dr Roisin Campbell-Palmer, supported by a small team of individuals including Ed Lagdon and Jake Chant.

Pictures: Francisco Teles

Number of beavers trapped and released:

- 2015 - five individuals (original trapped animals)
- 2016 - three individuals
- 2017 - six individuals
- 2018 - 17 individuals
- 2019 - 12 individuals

NB – Some individuals were trapped on multiple occasions.

▶ **Live trapping beavers**

End of Trial health status

The IUCN guidelines for reintroductions[1] stress the importance of post-release monitoring as a significant component in evaluating any reintroduction process. One important method of health assessment of any animal is to assess haematological and biochemical parameters[6] along with general parasitology and bacteriology assessments. This provides a means to evaluate both the level to which the released animals and their offspring are coping in their habitat, and the suitability of a release location.

During the course of the Trial, and particularly in the final year, additional samples were collected in some cases to enable more detailed health screening to be conducted, and the Final Beaver Trapping and Health Screening Report[3] was compiled by Dr Simon Girling and Dr Roisin Campbell-Palmer and is presented in Appendix 5.

The health of the beavers on the River Otter has been consistently good throughout the five years of the study. No evidence of significant zoonotic disease has been apparent, and beavers have shown good body condition throughout with successful reproductive rates and evidence of high kit survival.

In addition to the exposure and seroconversion to *Leptospira* spp, that was evident in one of the founder beavers, it was also detected in three others over the 5-year trial[24]. (Leptospirosis, also called Weil's disease, is commonly associated with the urine of infected rats and mice). Subsequent testing showed waning of the antibody response with no clinical disease being evident, suggesting these animals were not persistently infected.

From a health and biosecurity perspective, beavers are currently considered to present no significant risk to human, livestock, or other wildlife health.

Mortalities during Trial period

Throughout the Trial, a total of three beaver mortalities were confirmed.

In March 2018 a dead beaver was reported by a member of the public on the side of the road where the river passes under the Langford Road near Honiton. The body was recovered and given a post-mortem examination by New Street Veterinary practice. The PIT tag identified it as a 4-year-old female (F9857) born in the catchment in 2014. She had been trapped and re-released at the start of the River Otter Beaver Trial in 2015. The female was in good body condition and was pregnant at the time of death. The road traffic accident had caused significant damage to the head, broken the right rear leg and caused significant internal injuries. This death coincided with high river flows. Otters are known to be more vulnerable to RTAs when high flows make swimming under bridges more difficult, and this death suggests the same may apply to beavers, with a weir at this location providing an additional barrier to pass.

In February 2019, the remains of a beaver were recovered at the eastern end of Chesil beach in Dorset. The remains were given a basic post-mortem examination by New Street Vets; no PIT tag was detected and there was not enough of the animal left to gain much useful information. However, the ear tag was confirmed as a ROBT tag, and from this it was possible to narrow it down to one of five beavers. The width of the tail (125mm) is consistent with a young animal, probably a 2-year-old. Whether the animal swam out of the mouth of the river in an attempt to disperse, or died in the river and was washed out during high flows, is impossible to determine.

In April 2019 a recently released beaver was found dead near the mouth of the River Otter. This animal had recently been health screened and been shown to be healthy, and there were no external signs of injury. The movement and release of beavers into an unfamiliar river has associated risks as outlined below.

Impacts of high flows on beavers

The River Otter water levels can rise rapidly after heavy rain, and high summer flows are not uncommon which may represent an increased risk to beaver kits. Adult beavers have occasionally been witnessed moving kits before they are independent swimmers.

▶ **Female moving kit (Tom Buckley)**

Beaver releases

Consideration of release techniques

Over the course of the Trial period, 10 beavers have been released into the river. These are in addition to those beavers trapped for tagging and health screening which are released immediately at the point of capture. With expert advice and experience gained on other projects, a number of different techniques have been used.

The mobile and territorial behaviour of beavers are important considerations when planning new releases and there are significant risks associated with moving beavers into new areas. The objectives of introducing genetic diversity into an established population means that some disruption of existing pairs and territories may be desirable. However this comes with the risk of conflicts and sometimes injuries resulting from aggressive territorial behaviour. Some mortality has been experienced elsewhere as a result of territorial aggression. With an understanding of beaver ecology and behaviour, the risks can be managed to acceptable levels.

When first released into an unfamiliar area, beavers will be vulnerable to territorial behaviour by any beavers in the vicinity, and a common response on release is 'flight.' Surveying the release location for signs of occupation is vital, and the Trial has had to revise one planned release because of the discovery of fresh beaver signs in the vicinity of a release site.

The presence of some deep water at the release location is crucial to provide immediate safety and is likely to encourage beavers to settle. An offline pond adjacent to the river provides the ideal situation. This gives beavers shelter from flow, and from any perceived threat from any adjacent beaver territories. The provision of an artificial lodge or the use of temporary electric fencing provides 'soft release' conditions which will encourage animals to stay in the immediate term.

↓ Beavers are transported to the release location in a carrying crate.

Photo: Mike Symes

Another critical consideration is the attitude of landowners. Clearly the landowner must also be agreeable to a release and be fully appraised of their likely impacts. Landowners have expressed concern that releases will attract large numbers of beaver watchers, potentially trespassing to catch a glimpse of the animals. Strict confidentiality has been maintained around releases.

As beavers have colonised this relatively small catchment over the course of the Trial, finding this combination of favourable conditions has become increasingly difficult.

Beavers released

- On 23rd March 2015, the adult yellow-tagged female (F0815), the adult red tagged male (M9847) and their single female kit were all released together into an oxbow lake immediately upstream of their existing lodge and the area where they has been trapped a few weeks previously.

- On 24th March 2015, the adult pink tagged female (F9848) and adult green tagged male (F9846) were released into the main river immediately opposite their existing lodge, into which they swam shortly after.

Management of genetic diversity

The licence issued to Devon Wildlife Trust made provision for five additional beavers to be released into the catchment to enhance the genetic diversity of the population. In May 2016 a pair of beavers were released together into a riverside pond in one of the tributaries. These animals remained in the vicinity of the release location and successfully raised kits between 2017 and 2019. In April 2019 an additional two beavers were released separately, although one of these subsequently died.

- On 23rd May 2016, an additional pair of 2-3 year old beavers were released into an offline pond in an area of semi-natural wetland habitat <50m from the River Tale. They were both captive bred animals from enclosures in Devon and were released into two artificial lodges constructed on the edge of the release pond. They settled well and soon constructed their own lodge on an island in the pond, only returning to the artificial lodges to collect bedding that had been provided for them.

▶ **Two new beavers released in 2016**

▶ **After their release**

▶ **Beaver kit with adult female**

▶ **Beaver kits**

↑ Providing some shelter such as an artificial lodge may help animals settle into the release location. Animals can either be released into the lodge, or nearby, and moving their bedding from the holding facility or carrying crate is sometimes used as a technique to encourage settlement.

Photo: Nick Upton

- On 10th April 2019, a young male animal was translocated from a conflict site on the River Tay in Scotland and released into the middle reaches of the main River Otter at dusk, in an area upstream of adjacent territories. No lodge was provided, and the animal slowly worked its way upstream after release. This animal was later discovered to have settled in a pond in an adjacent catchment, and in October was relocated to a pond, offline from the main River Otter. This animal was enclosed within an electric fence to encourage it to remain in this pond for a period, and on 9th November 2019, a young female animal from Scotland was also released into this pond.

- On 21st April 2019, a young female was released into the lower reaches of the River Otter at dusk into an unoccupied space between territories with plentiful undisturbed habitats. Following release, she slowly moved downstream. The body of a dead beaver recovered from near the estuary three days later was confirmed to be the released animal. There were no obvious external injuries suggesting that cause of death was not directly due to conflicts with other beavers.

The population dynamics of beavers on the River Otter

Historical beaver population and colonisation of the catchment

↓ In 2012 staff at C.Plant at Fenny Bridges became aware of beaver activity in the main river directly adjacent to their site. A lodge was constructed at the base of the riverbank and fruit trees in an adjacent orchard were being felled.

Photo: C.Plant

▶ **Young beavers in River Otter in 2014**

← In July 2008, a willow stump clearly coppiced by a beaver was photographed by Mervyn Newman in the vicinity of Deer Park Hotel near Honiton. The regrowth suggests that it had been felled by a beaver the previous winter.

↑ On 25th April 2012, staff at C.Plant discovered a beaver in the ditch adjacent to their property. It appeared to be unwell, and it clambered up the bank in daylight, with the river still in flood conditions. The beaver was collected and died before it reached the vet. A post-mortem examination was conducted by Dr. Alex Barlow at APHA which identified acute focal pneumonia consistent with inhalation of water.

Monitoring of beaver family groups

It would be very useful to be able to monitor the location of individual beavers within the wider catchment over longer periods to further understand their migration, dispersal, and their use of resources and interactions with other beavers. The value of such research would be greatest during the initial phases of reintroduction to, for example, record territorial behaviour and mortality rates. Scientists elsewhere have carried out radio-tracking research for short periods of intensive study by fitting transmitters to beavers[7]. Their nocturnal nature, and the fact that they spend much of their time underground or underwater, squeezing between roots and other constrained spaces, creates many practical challenges and risks to welfare[8]. The tiny transmitters fitted to birds do not have the accuracy that would indicate which part of the catchment the beavers were in. Working with electronics expert, Dr Mark Neal, we explored fitting a transmitter onto an ear tag but were unable to reduce its size sufficiently to ensure successful attachment to a beaver's ear.

Beavers are very difficult to differentiate from one another, and whilst ear tags can assist in daylight and allow some monitoring of the behaviour of certain individuals, they are not particularly useful after dark, as infra-red cameras do not show colour. However, they have revealed that a relatively small proportion of the population comprise the majority of sightings.

The role of a small number of high-quality naturalists and photographers has been vital in understanding the dynamics and breeding success of some of the family groups. The many hours spent beaver watching, analysing camera trap and fixed camera footage have proved key to understanding breeding successes and territorial movements that are otherwise very difficult to obtain through other less intensive means. The analysis of tail scars and unique markings has been shown by one naturalist, Tom Buckley, to be very valuable for monitoring animals. The Trial is extremely grateful for their dedication and willingness to share this information.

← The **yellow tagged female (F0815)** has been monitored in the vicinity of Ottery St Mary since 2013. DNA analysis conducted in 2015 revealed her to be the original founder female for the whole population. She was filmed again by an angler in July 2019 so, assuming she was an adult in 2007, she would now be at least 14 years old. It is unclear which male she is now paired with as the red-tagged male that she was caught and released with, in 2015, has subsequently established a new pairing with a different female.

Photo: Nick Upton

▶ **Yellow tagged female (Tom Buckley)**

How vulnerable are beavers to disturbance?

This is a difficult question to answer conclusively. It appears that some beavers are more timid, and sensitive to disturbance than others. Some are never reported or seen by local beaver watchers or the ROBT team. Others have been more tolerant of people, and have been much easier to watch, at least for some periods of the Trial. The two female beavers with the highest number of reported sightings are those that were captured by APHA and spent some time in captivity in early 2015.

In the summer of 2015, following the start of the Trial, the yellow tagged female was the subject of intense public interest and visitor pressure and many beaver watchers had rewarding experiences. In the late summer of that year, she moved upstream into a new lodge away from the public footpath, sparking the headlines 'Devon Beavers have disappeared.'

In 2016 and 2017, the pink tagged female was living in a lodge in a high profile location, directly opposite a busy public footpath. In some summer evenings in excess of 30 people were counted standing watching her with her young kits. Many of the photographs taken of the beavers were during this period. However, in 2018 she gave birth in a lodge in an area with no public access, but in 2019 returned to a publicly accessible area, albeit much further downstream, than the original well-known lodge.

It is likely that dogs are a source of disturbance and will be seen as a threat, particularly when in the water, and during the period when kits are young and vulnerable. Both of these females have been involved with at least one incident with dogs and have moved burrows shortly afterwards. There are, however, many other possible push/pull factors so it is impossible to draw any firm conclusions from this.

If the family tree in Appendix 5 is correct, this **pink tagged female (F9848)** is an offspring of the yellow tagged female, and is paired with one of her siblings. She was trapped and released in 2015 alongside the green tagged male (M9846), and they were living in the same lodge in 2019.

This female has used many different burrows within a long territory around Otterton village during the Trial period. Between 2015 and 2019, she has given birth to kits in four different locations along the main river.

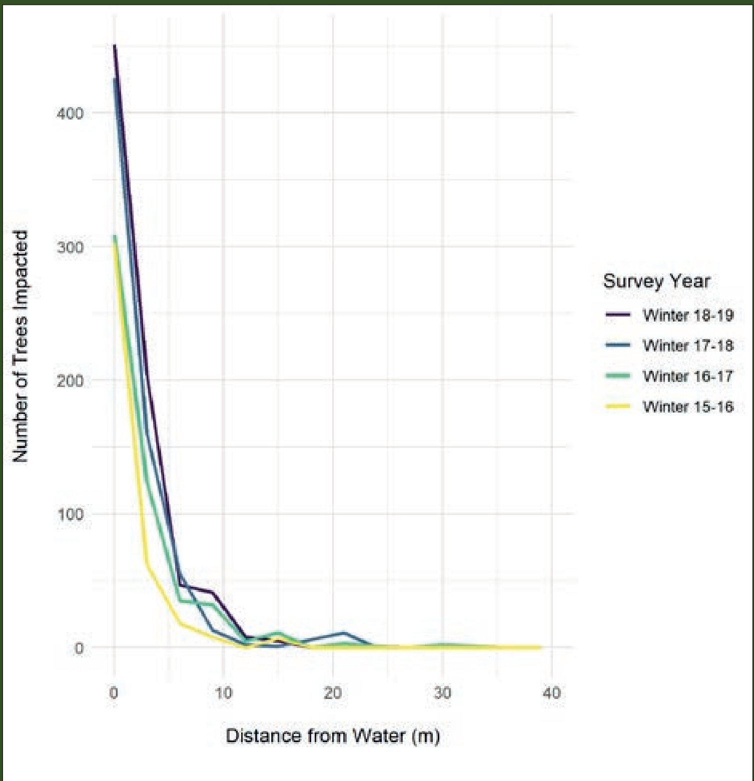
Sightings of this female have been recorded throughout a length of 4.5km of the main River Otter between White Bridge in the estuary and north of Colaton Raleigh. This female has been extremely productive with five kits confirmed in 2016 and four in 2017, and breeding confirmed every year since.

Photo: Nick Upton

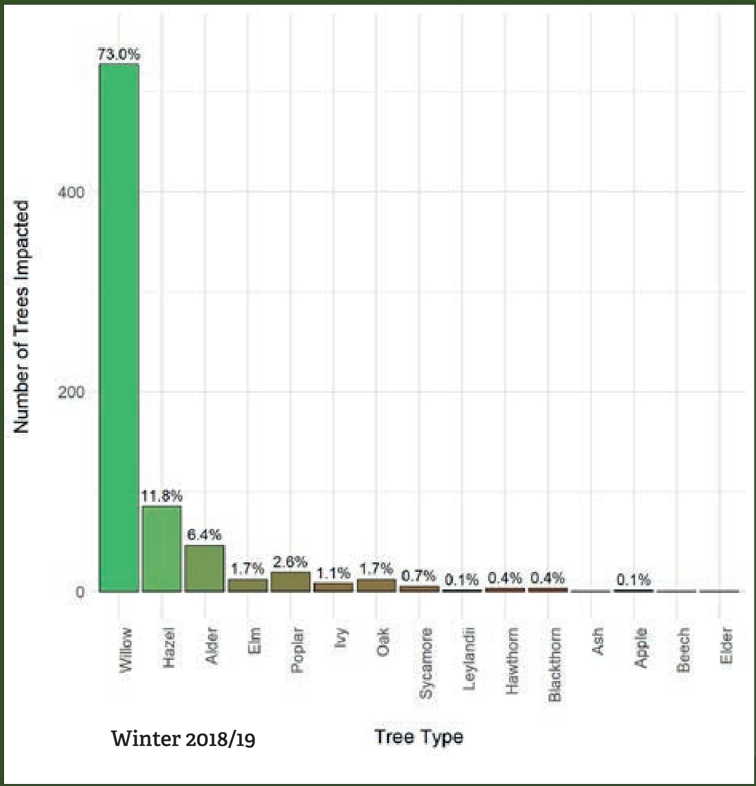
▶ **Pink tagged female and kits (Sylvia Meller)**

Browsing on woody species

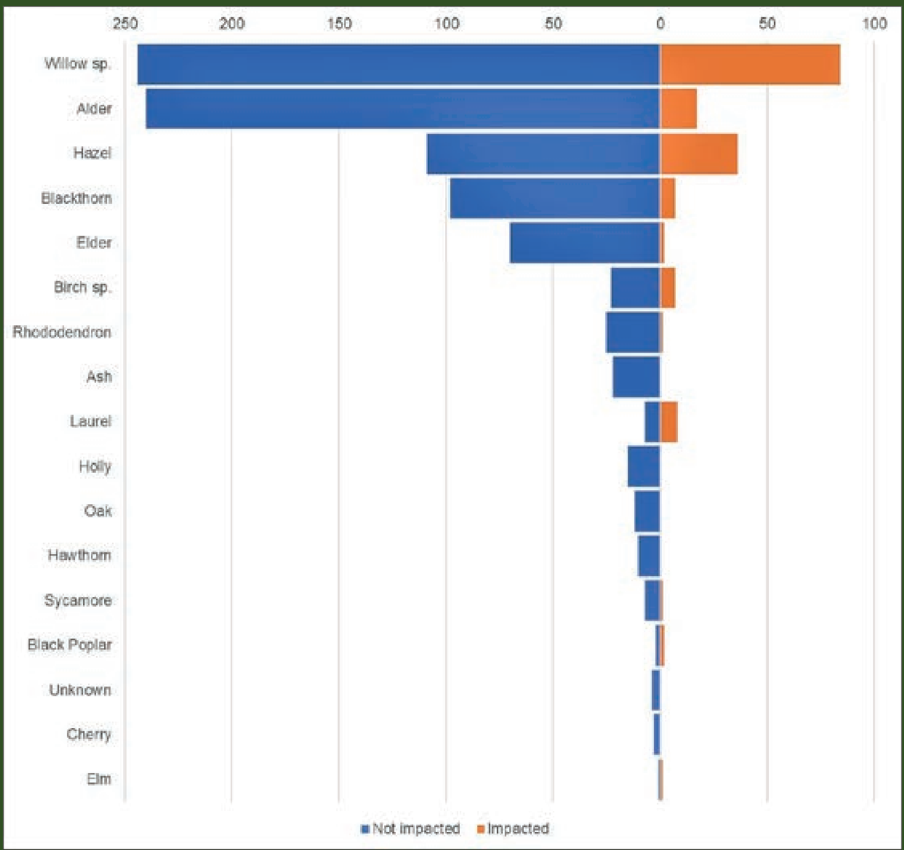
The annual systematic surveys of the catchment have provided a dataset of 2,356 trees that have been fed on since the first surveys were conducted in 2015. These clearly show how the majority of feeding is very close to, or within water (Figure 5.1) and that winter browsing in the River Otter catchment is predominantly on willow, although a wide variety of species are occasionally used (Figure 5.2).



↑ **Figure 5.1** Winter browsing on woody species is mostly on trees close to the water's edge. Here those trees that are fed on from within the water are included in the figure for 0m.



↑ **Figure 5.2** Tree species impacted by beaver activity surveyed in winter 2018-19 showing the importance of willow browsing to the beavers in the River Otter catchment.



Food resources within the catchment

↑ **Figure 5.3** In early 2019 a survey was undertaken to assess whether selection of winter foraging was related to the proportion of tree species found within four of the beaver territories. This indicated an overwhelming preference for willow. Data collected by Fiona Coope.

NB. for the purpose of this work, willow and birch have not been further separated into different species.

Beaver Habitat Index (BHI)

The empirical results from field surveys reveal that beavers preferentially forage on particular vegetation types. This information has been used to inform the development of a method to predict beaver foraging habitat over large (national) areas. Therefore, nationally available data were required for this purpose.

No single dataset contained the detail required to depict all key vegetation types, relevant to beaver foraging. Therefore, a composite dataset was created from: OS VectorMap Local data[9], The Centre for Ecology and Hydrology (CEH) 2015 Land Cover Map (LCM)[10], Copernicus 2015 20 m Tree Cover Density[11] and the CEH woody linear features framework[12].

Vegetation datasets were assigned suitability values (zero to five), at a resolution of 5 m. Zero values were assigned to areas of no vegetation e.g. buildings, and values of five were assigned to favourable habitat e.g. deciduous woodland. Values were assigned based on a review of relevant literature[13,14], field observation and qualitative comparison with satellite imagery.

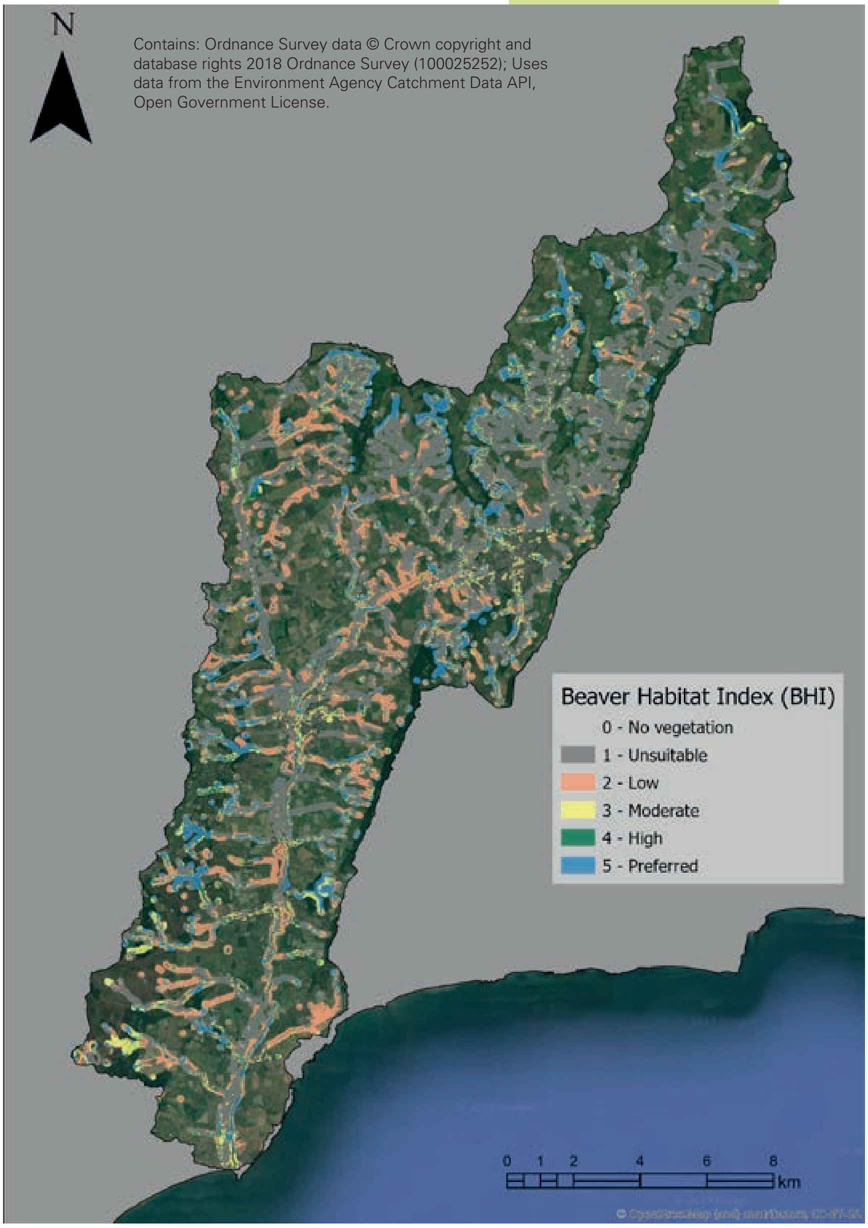
Typically, beavers rarely forage more than 30-40 m from water[13] and spend the majority of time either in water or bankside locations. However, in some instances they may forage up to 100 m from a watercourse[15]. Therefore, we have excluded all areas >100 m from a river or lake from the model and classified the area as unsuitable for foraging.

To validate this model, additional field surveys following the methods outlined in Chapter 1, were carried out in two additional locations: (i) River Tay catchment, Perthshire - currently the largest population of beavers in Britain[16,17], containing approximately 400 individuals over an area of ca. 5000 km^2. (ii) River Carey, Devon – a sub-catchment of the River Tamar which contains at least two beaver family groups and covers an area of 2.4 km^2.

Model validation across the Otter, Tayside and the River Carey revealed that reaches with higher average BHI scores are more likely to be occupied than lower scoring reaches and this is therefore a valuable predictor of occupancy. For example, those reaches with the highest scoring BHI scores were between 25 - 40 times more likely to be occupied than those with the lowest scores.

The BHI provides crucial information for community and stakeholder engagement, pre-emptive management of beaver impacts, release site identification, the prediction of viable territories, dam capacity and likelihood of dam construction.

↓ **Figure 5.4** Beaver Habitat Index for River Otter catchment



Beaver Dam Capacity Modelling

Being able to predict where beavers are more likely to construct dams and in what densities dams are likely to occur is extremely valuable for targetting the management and mitigation of beaver impacts on infrastructure and farmland, and the prediction of their likely positive impacts on hydrology and ecology.

The ROBT has developed a Beaver Dam Capacity (BDC) model which uses the framework outlined by Macfarlane, et al. (2015)[15] to determine the capacity for damming on the River Otter. This approach could similarly be carried out in any river system in Great Britain.

The method evaluates the following variables at the reach scale (122 m ±47 m): vegetation quality within 10 m and 40 m of the riverbank (based on BHI model), bankfull width, channel slope, stream order, low and high flow stream power and contributing catchment area. These variables are evaluated in a sequence of calculations to determine BDC.

Dam capacity describes the maximum number of dams that may be built in a given reach. BDC will never be reached in a river system as beaver territory boundaries would inhibit the development of extended sections of dammed watercourse in close proximity. However, short sections of channel will frequently reach capacity. Critically, dam capacity is an excellent predictor of preference towards dam construction.

Model validation across the Rivers Otter and Tay, and the River Carey sub-catchment revealed that reaches classified as ‘pervasive’ (the highest dam capacity category) were 170 times more likely to be dammed than reaches predicted to have no capacity for dams, and 3.4 times more likely to be dammed than reaches where damming was predicted to be ‘rare’.

Based on observed dam densities across the validation catchments, regression analysis was used to predict the number of dams that could occur in the event that beavers were active in all reaches of the River Otter. Under this scenario, it is predicted that the number of dams that may be constructed throughout the River Otter catchment is between 262 – 814. This equates to a dam density of between 0.4 - 1.4 dams/km, though densities will be much higher in small streams and much lower in large channels.

Two beavers dam building

This work has been submitted for publication in the Journal of Wildlife Management and is going through the peer review process.[23]

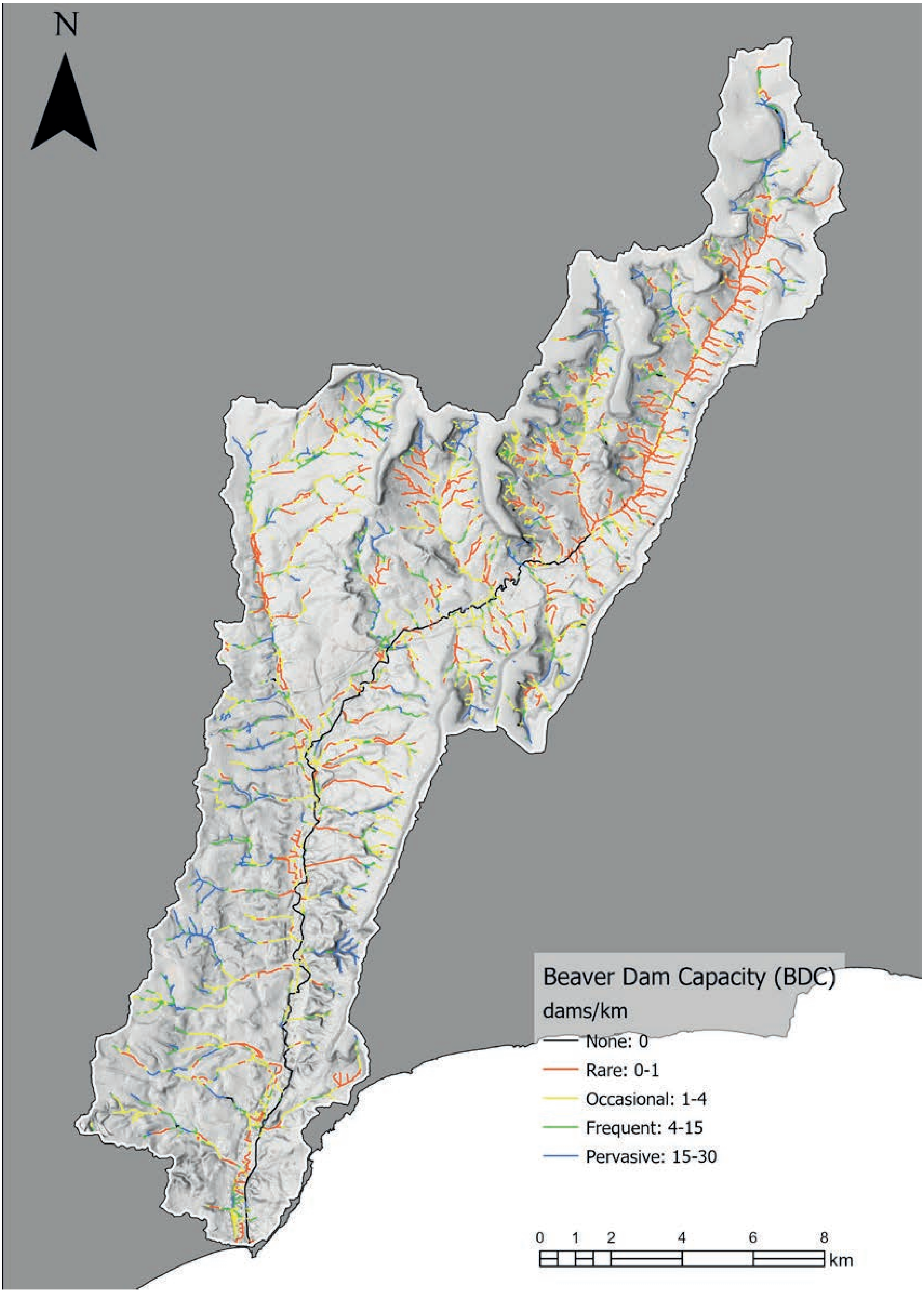


Figure 5.5 Beaver Dam Capacity model results for the River Otter catchment.

Beaver population carrying capacity of River Otter catchment

The maximum population of beavers that a catchment can sustain is the ecological carrying capacity. However estimating it in advance is challenging. There are no reported estimates of beaver population carrying capacity within Europe. The challenge is increased by the lack of catchments within Europe, or indeed worldwide, which are at carrying capacity. Where beaver populations become large and their activities result in frequent conflict with other land uses, they are often managed via relocation or lethal control, thus artificially limiting the population of a catchment. It could therefore be inferred that there is a maximum socially-acceptable carrying capacity which may be considerably lower than a landscape's ecological carrying capacity.

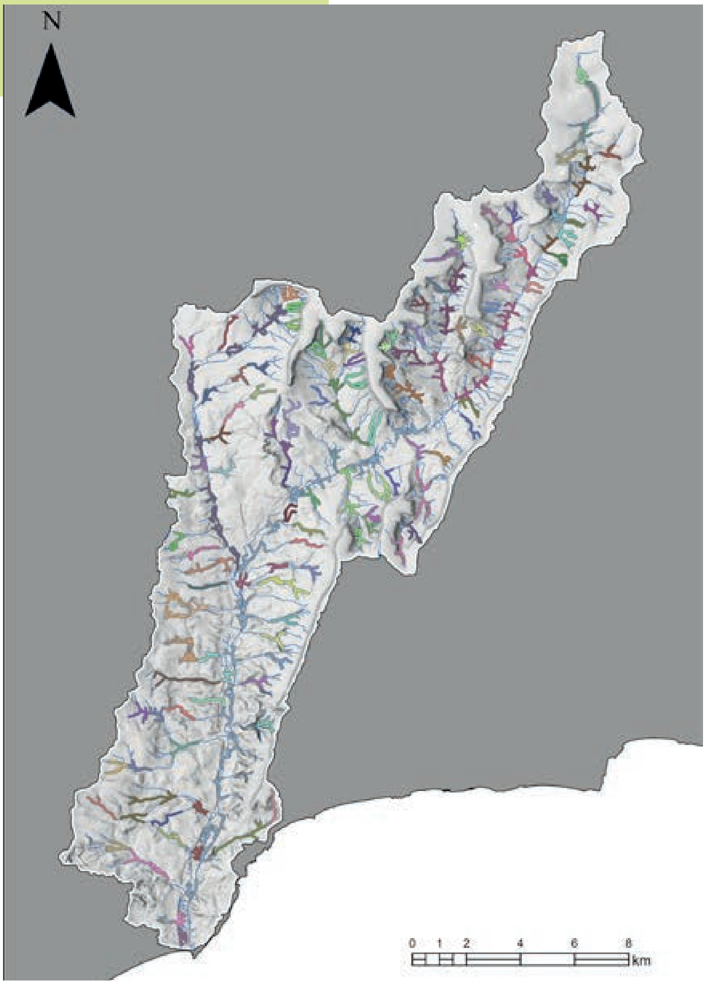
Given these complexities, we have attempted to estimate the maximum population carrying capacity of the River Otter catchment using a simple rules-based system. These rules are as follows:

- Beavers require a minimum amount of viable food resource.
- In streams ≤4th order beavers can only reside where they are able to construct dams (based on BDC model).
- The average channel length in a given beaver territory is 3.3 km ±0.2 km (based on published average channel lengths per territory[7,18–22].
- Beavers are a territorial species and territories do not significantly overlap.

Additionally, we do not attempt to estimate the number of individual animals, rather the number of territories that may be occupied. Therefore, our approach is referred to, as a Territory Capacity Model (TCM).

Figure 5.6 The maximum number of territories, shown as unique colour zones along the stream network, that the TCM predicts is between 147 and 179. This area of research requires further validation and should be a key area of focus for future research as populations expand.

Contains: Ordnance Survey data © Crown copyright and database rights 2018 Ordnance Survey (100025252); Uses data from the Environment Agency Catchment Data API, Open Government License.



The TCM requires the output river network produced in the BDC/BHI modelling work and functions as follows: starting with the highest order streams, every reach (ca. 150 m) is buffered to a size so that the total stream length in each buffer is 3.3 km ±0.2 km. Overlapping zones are then compared and the zone with the highest quality of vegetation (derived from the BHI) is selected as a final territory. The process is repeated for each level of stream order until all available space between territories is filled.

The purpose of the model is not to predict the location of territories, rather to determine the maximum number of territories which could occupy a catchment. Beavers are unlikely to conform to the modelled arrangement of territories which would therefore limit the maximum number that fit in a catchment. Additionally, the model assumes that animals cannot exit the catchment. These assumptions mean that the predicted territory capacity derived from this model should be considered as an absolute maximum and we would expect the observed capacity (if this were allowed to be reached) to be considerably lower.

Once the population reaches a certain level, territorial conflicts between beavers become more frequent. Injuries to tails are frequent, and serious and even lethal injuries can be inflicted as wounds often become infected. It would be expected that the level of mortality would increase as the population approached carrying capacity.

Dispersal into adjacent catchments

As the population within the River Otter catchment grows, dispersal events into adjacent catchments become more likely. However, beavers' tendency to stay in watercourses makes crossing over catchment boundaries more difficult where headwater streams between catchments are a long distance apart. One wetland habitat that spanned the catchment boundary was identified as a potential crossing point and was routinely monitored.

↑ The dispersing beaver is likely to have followed the River Otter to the source. The last 2 km of the River Otter borders the edge of intensively managed permanent pasture, temporary grass ley and arable fields.

All reported 'beaver' sightings in adjacent catchments have been followed up. Detailed surveys have concluded they were inaccurate sightings; with many assumed to be otter and one hoax.

The only exception to this was in August 2019 when a recently released beaver had settled in the headwaters of the Culm, just north of Otterhead. The exact route that the dispersing beaver took to the headwaters of the Culm is unclear. The most obvious route would be from the very upper limit of the river above Otterhead. From the source of the River Otter the beaver could have travelled 1 km across three flat, intensively managed grassland fields and a small country lane before finding sloping ground that led to the headwaters of the River Culm.

← Land use close to where the beaver settled is permanent pasture with wet, rush dominated areas. Following the wetter areas of these fields would have led the beaver to the headwaters of the River Culm.

Key documents in Appendix 5

- Beaver health and genetic screening report – RZSS 2015
- Final trapping and health screening report for the ROBT – RZSS 2019
- Beaver mortality reports and post-mortems (various)
- Reports for seasonal beaver health monitoring (various)

The appendices are available to view at www.exeter.ac.uk/creww/research/beavertrial/appendix5/

NB. These appendices will be updated with other relevant supporting documents, not necessarily listed here.

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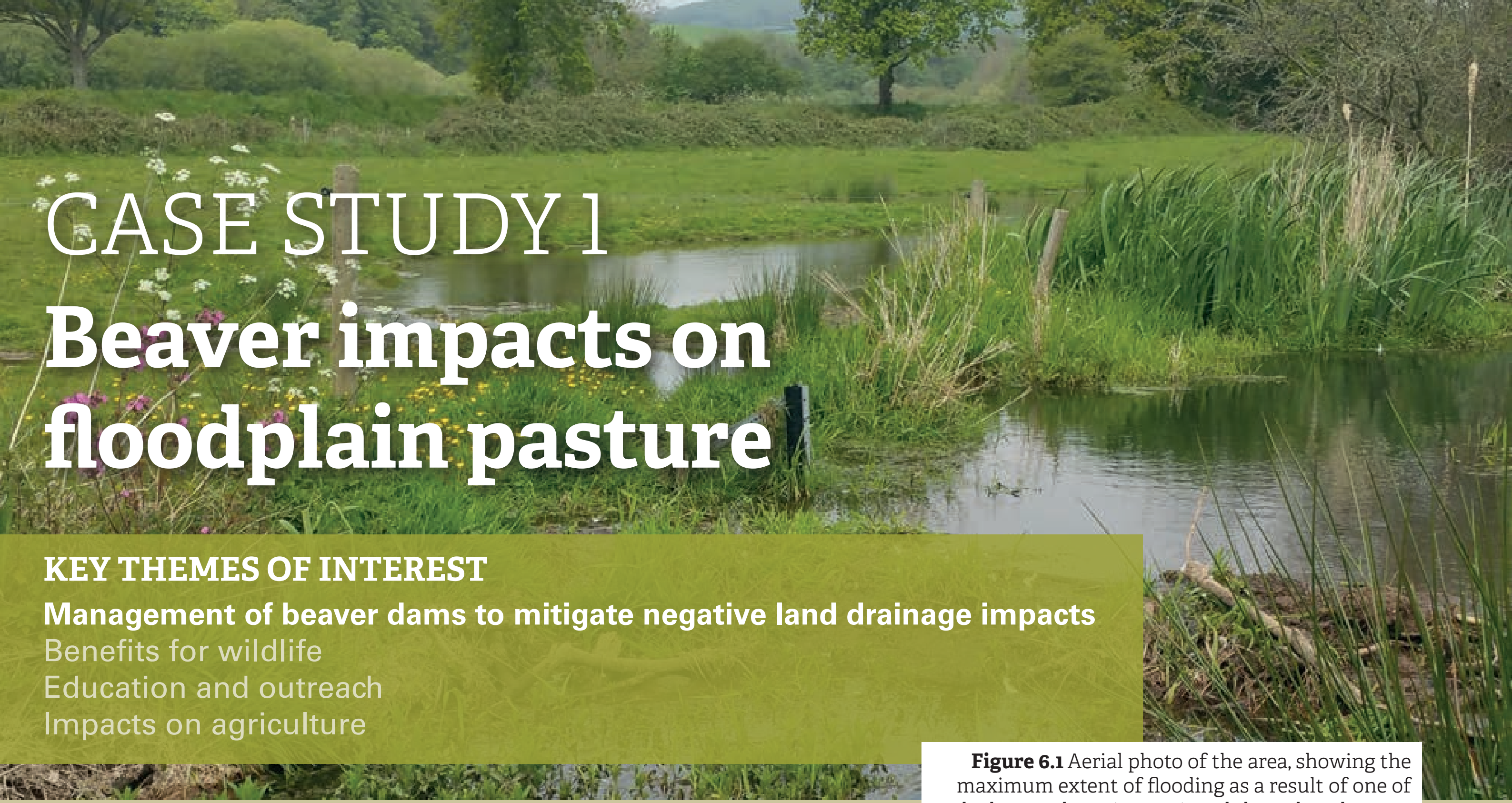
CASE STUDIES



CASE STUDY 1

Beaver impacts on floodplain pasture

KEY THEMES OF INTEREST

Management of beaver dams to mitigate negative land drainage impacts

Benefits for wildlife

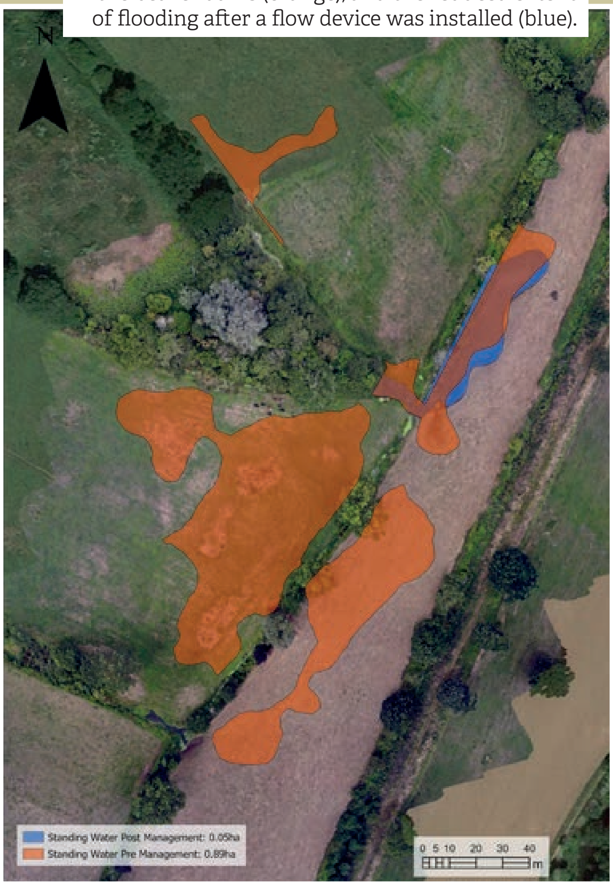
Education and outreach

Impacts on agriculture

Overview of site and beaver behaviour

- This pastoral site, in the lower floodplain of the River Otter, supports a dairy farm linked with an agricultural college.The intensively managed pastures lie over heavy, clay soils which are drained via a network of ditches and field drains.
- In September 2016 beavers were first noticed by college staff when a dam was constructed in a drainage ditch.
- The flooding of 0.57 ha of low-lying farmland was deemed acceptable for the first part of the winter but the college required all available grazing land the following spring.
- ROBT staff installed England's first beaver flow device in this location, returning the water levels back into the ditch network, and facilitating grazing whilst retaining the beaver territory.

Figure 6.1 Aerial photo of the area, showing the maximum extent of flooding as a result of one of the beaver dams (orange), and the reduced extent of flooding after a flow device was installed (blue).



Beaver population

First signs of beavers were detected in September 2016. A young pair were confirmed by trapping and tagging in January 2017. Beavers are still present and assumed to have bred subsequently but this is not confirmed.

This is one of the few locations where beaver scent mounds have been found. These are piles of mud and vegetation covered with castoreum that are used as territorial markers.

Photo: David White

Initially 'notching' of the dam was used to reduce the water levels. Beavers were persistent in rebuilding, and it became clear this was not a sustainable solution at this location.

In December 2016 a flow device was installed to reduce water levels

Flow devices (aka 'beaver deceivers')

- This intervention is used to reduce water height behind beaver dams whilst maintaining beaver presence.
- The structure comprises a pipe that allows water to bypass or flow through the beaver dam. The pipe inflow is situated in a submerged cage to prevent beavers detecting the source of the leak and blocking the pipe.
- This flow device was installed at a cost of £500. Due to the design and location of this device, consent from Local Authority was not required.

Following the installation of the flow device, the beaver activity at this location declined significantly. It is thought that the beavers moved and began damming in another location 200 m downstream, possibly in response to the installation of the device. They remained active throughout the territory, with no further agricultural impacts noticed throughout 2017.

In Autumn 2018, a new dam was constructed 20 m downstream of the piped dam. At this point staff at the college were content to retain the beavers, and this allowed the wetland habitat to become extensive, with 0.57 ha of open water created and ca. 0.5 ha of wet grassland habitats.

When the device was installed, the water levels dropped significantly, reducing the extent of flooding in the adjacent fields.

Benefits for Wildlife

The speed with which wildlife-rich wetland habitats can be created by beavers in such a flat landscape was demonstrated very clearly at this site. Table 6.1 shows the return of snipe and teal and other wildfowl using the beaver ponds in the winter months. Due to the lack of standing surface water prior to beaver damming, such birds were absent from this farmed landscape.

Bird species	Numbers
Snipe - *Gallinago gallinago*	6
Teal - *Anas crecca*	28
Mute swan - *Cygnus olor*	4
Mallard - *Anas platyrhynchos*	10
Little egret - *Egretta garzetta*	2
Heron - *Ardea cinerea*	1

Table 6.1 Wetland wildfowl observed using the beaver ponds, 27th February 2019.

28 teal have been counted on this site on one occasion. Photo: David White

Camera trap and video footage shows a grey heron feeding on trout, eels, and brook lamprey around the dams whist in spate.

Heron catching elver

Education and outreach

The location of this beaver territory within the grounds of an agricultural college has provided a valued educational resource. College students from a diverse range of courses have received informal and formal information and training regarding the behaviour and effects of beavers on the agricultural systems since 2016.

Impacts on agriculture

In 2016 0.89 ha of floodplain pastures were inundated by surface water due to beaver damming. One management solution would be to fence off this area and accept the loss of pasture as grazing land. There are financial implications of this approach, both in terms of the value of the land to the business and in terms of secondary impacts such as movement of cattle between different fields. The John Nix pocketbook[1] estimates the financial impact of the loss of this land to be £1,566 per year. Now the flow device is installed and the area of land under water is 0.054 ha, the estimated financial impact is £95 per year.

Additional secondary costs would need to be estimated on a site-specific basis.

The opportunity cost is the loss of the wealth of ecosystem services that the wetland could provide. Future Environmental Land Management Schemes (ELMS) could involve payments to farmers to make space for water, helping to mitigate conflicts in future and rewarding farmers for providing a diverse array of ecosystem services.

Landowner perspective

"From my point of view, trying to balance the overall college view as well as the need for a commercially operating farm and talking with Devon Wildlife Trust, we were really trying to find a way forward that meant the farm could continue to operate as a commercial business but in a way that was allowing the beavers to create a habitat."

[On lessons for the future] *"The sooner that the conversations could be had between the different parties, the better. And regular communication is critical so that no party really suddenly gets a nasty surprise about something that's going on. [...] communication always is critical."*

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CASE STUDY 2

Beaver wetland in farmland upstream of a flood-prone village

KEY THEMES OF INTEREST

Cost versus benefits of Flood Alleviation
Flood attenuation and slowing the flow
Impacts on agriculture
Management of dam to limit impacts on highway
Large tree felling management

Overview of site and beaver behaviour

- Beavers established a territory in a tall herb fen habitat, adjacent to a mixed organic farm. The farm comprises some Grade 1 arable land, improved pasture and lower grade grasslands, upstream of a village at risk of flooding.
- The site supports six dams including the main channel dam which now extends to 60 m in width across the floodplain. >1000 m^2 of standing water has been created with complex wetland and multi-thread channels exposing former river-channel gravel beds throughout the floodplain (0.08 ha).
- This site represents a unique opportunity to study both the costs and benefits of beaver activity due to the negative impacts on productive farmland and flood risk benefits to a downstream settlement.

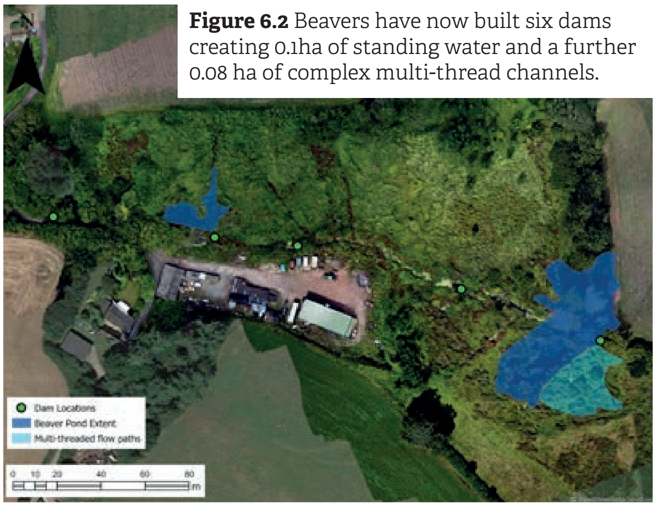


Figure 6.2 Beavers have now built six dams creating 0.1ha of standing water and a further 0.08 ha of complex multi-thread channels.

Beaver population

Beaver activity was first noticed here in 2016 by the grazier and trapping confirmed the presence of a single young female beaver in March 2017. A male beaver was subsequently trapped in February 2018. The following January a yearling was trapped, confirming successful breeding in 2018.

Beavers reached this site after travelling up a 300 m long, open, concrete aqueduct, demonstrating that beavers are able to navigate throughout a watercourse network, even if the watercourse appears to be inhospitable.

Cost versus benefits of flood alleviation

Benefits - flood attenuation

The beaver dam complex is 300 m upstream of a flood-prone village which has been monitored by the Environment Agency since 2009. This time series dataset has established a comprehensive understanding of flood risk over seven years before beaver colonisation. 52 properties in the village are at risk of flooding from the brook and other surface water sources, including both pluvial (rainfall/surface water) and fluvial (stream) flooding.

Since 2000 there have been four flood events in the village

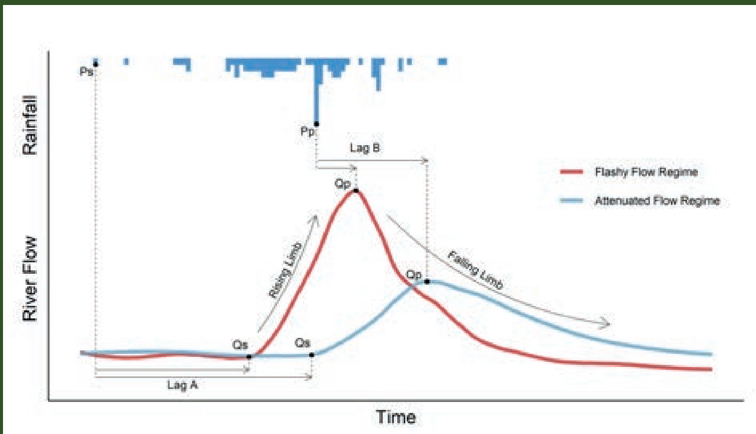


Figure 6.3 A schematic hydrograph showing the different elements of an attenuated flood hydrograph.

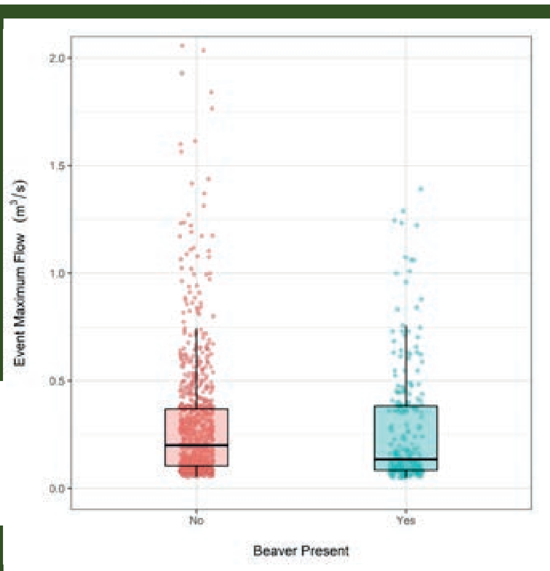


Figure 6.5 Peak flows before (red) and after (blue) beavers impacted the hydrology.

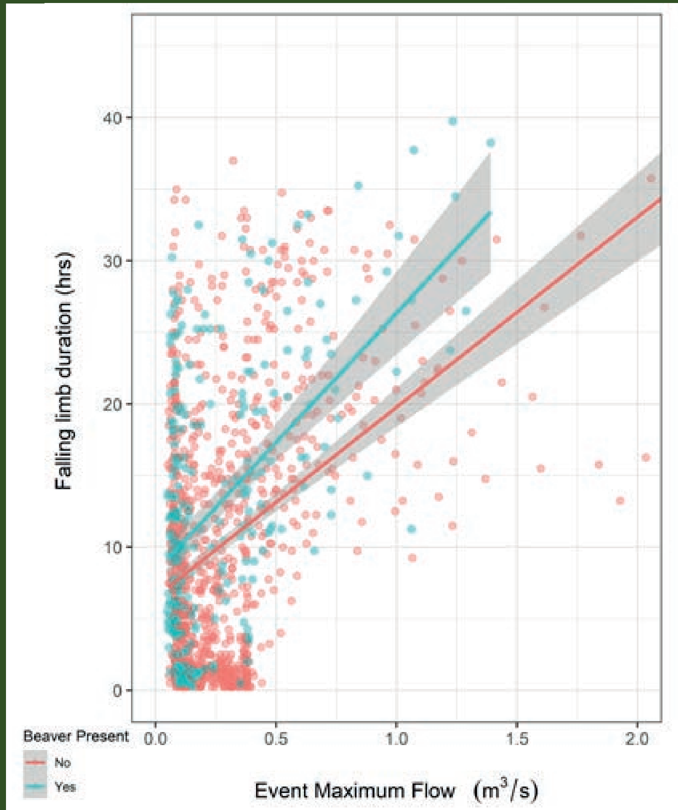


Figure 6.6 Relationship between maximum flow and the time taken for flows to return to a normal (base) flow for hydrological events before (red) and after (blue) beaver dams were constructed. After beavers constructed dams, the time taken for river flows to fall from their peak to base flow was, on average, greater than before dams were constructed. This indicates that water is being released from the beaver ponds more slowly, attenuating downstream flow.

which affected between two and five properties. According to publicly available data held by the Environment Agency, the River Otter area more broadly was subject to 166 flood alerts and warnings between January 2006 and December 2018[1].

The six beaver dams alter the hydrology locally by impounding water upstream and pushing water out onto the floodplain that was previously disconnected from the channel, due to historical deepening and straightening of the stream. The ponds cover 1000 m^2, with an average depth of approximately 0.7 m. Thus, the beaver dams hold water on the floodplain, pushing it sideways and releasing the water slowly, rewetting surrounding areas and creating a complex wetland environment.

In addition, the time that the water takes to flow into the site following rainfall and furthermore, the time that it takes to leave has also altered. Falling limb recession (the time it takes water to subside or leave the site) is longer, demonstrating that the flood hydrograph is attenuated (or flattened) by the presence of the beaver dams.

When compared with the detailed records of flood flows before beaver damming, more recent floods have been attenuated, taking longer to move through the site and demonstrating lower peak flow levels. The data show this effect persists even after large rainfall events and following periods of prolonged wet weather. This is because beavers have created a huge storage area within the floodplain above the village, routing water via complex flow-paths and increasing the roughness of the flow surface. Before beaver damming, water flowed at speed through the straightened and deepened channel.

The East Devon Catchment Flood Management Plan (CFMP)[2] for this area recommends "more natural river processes, creation of wetland habitats, and the reconnection of rivers with their floodplains" to mitigate flooding. The possible costs avoided have been assessed under ten hypothetical scenarios using the funding calculator for flood and coastal erosion risk management grant-in-aid allocation, a tool which is used in Environment Agency assessments and is openly available on the UK Gov website[3].

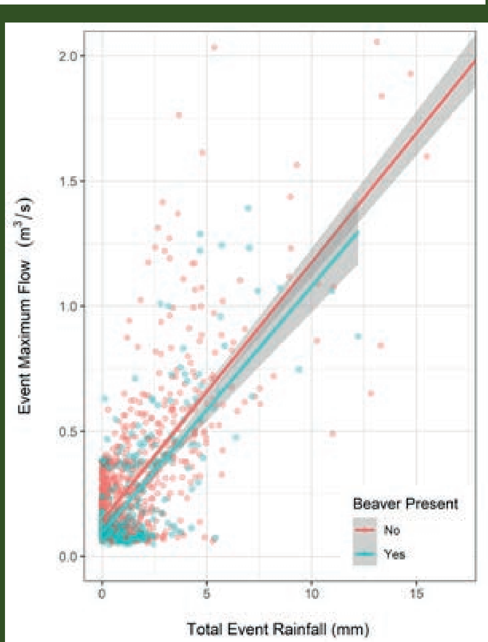


Figure 6.4 Relationship between total rainfall and maximum flow for hydrological events before (red) and after (blue) beaver dams were constructed. After beavers constructed dams, downstream flows were more likely to be lower for a given amount of rainfall.

Scenario	Details	Moderate Risk	High Risk	Very High Risk	Pre-Inflation			Post-Inflation		
					Benefit Per Year	**5 Year Benefit**	10 Year Benefit	Benefit Per Year	**5 Year Benefit**	10 Year Benefit
Properties Currently At Risk		*7*	*38*	*5*						
1	One moderate risk property downgraded to low risk	6	38	5	£150	£750	£1,500	£163	£815	£1,631
2	One high risk property downgraded to moderate risk	8	37	5	£450	£2,250	£4,500	£489	£2,446	£4,892
3	One very high risk property downgraded to high risk	7	39	4	£750	£3,750	£7,500	£815	£4,076	£8,153
4	All moderate risk properties downgraded to low risk	0	38	5	£1,050	£5,250	£10,500	£1,141	£5,707	£11,414
5	All high risk properties downgraded to moderate risk	45	0	5	£17,100	£85,500	£171,000	£18,588	£92,939	£185,877
6	All very high risk properties downgraded to high risk	7	43	0	£3,750	£18,750	£37,500	£4,076	£20,381	£40,763
7	All moderate and high risk categories downgraded one risk category	38	0	5	£18,150	£90,750	£181,500	£19,729	£98,645	£197,291
8	All high and very high risk categories downgraded one risk category	45	5	0	£20,850	£104,250	£208,500	£22,664	£113,320	£226,640
9	All properties downgraded one risk category	38	5	0	£21,900	£109,500	£219,000	£23,805	£119,027	£238,053
10	All properties downgraded to low risk	0	0	0	£30,600	£153,000	£306,000	£33,262	£166,311	£332,622

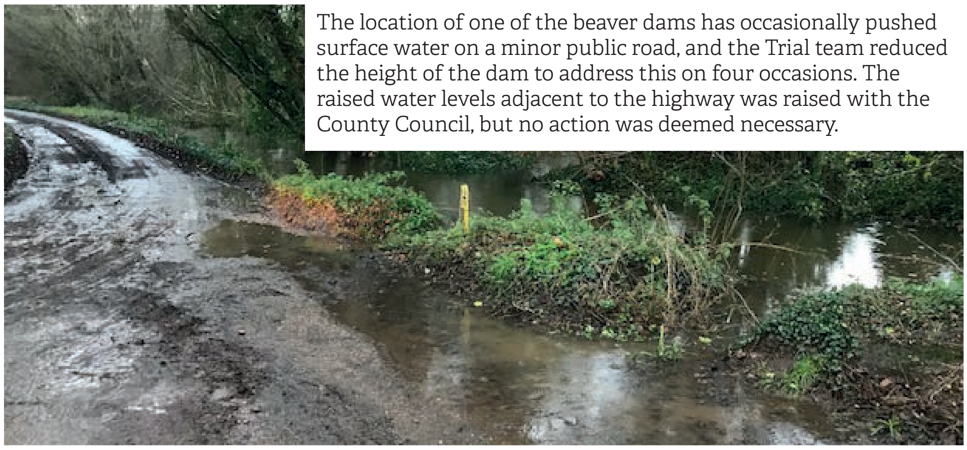
Table 6.2 – Potential weighted annual average damage costs avoided by the reduction of flooding by beavers under hypothetical scenarios[4]. As there are other surface water flows which contribute to flooding, it is thought that Scenarios 1 to 6 are more likely as a result of beaver impact.

Costs - Impacts on agriculture

One impact of this additional water storage on the land was elevated water levels in the corner of a Grade 1, organic potato field, preventing the planting of 0.4 ha of first early seed potatoes (a high value crop) under a 5-year rotation. The costs of this waterlogging were £1,495 (profit foregone) and £600 for seed potatoes unplanted (used for cattle fodder)[5]. If the same area of field was affected the following year, this would impact upon a cash crop of spring barley leading to an estimated £227 gross margin loss[5]. For future avoidance of such costs, removal of 0.4 ha of the field from agriculture has been recommended.

Additionally, the corner of a pasture field and a ford became submerged / waterlogged making them practically impassable to machinery and livestock. This ford was moved to a different location to reconnect access between the two sides of the valley at a one-off cost of £900.

The landowner allowed the beavers to fell five poplar trees (one of which fell onto the farmer's fence), at a removal cost of £200.



The location of one of the beaver dams has occasionally pushed surface water on a minor public road, and the Trial team reduced the height of the dam to address this on four occasions. The raised water levels adjacent to the highway was raised with the County Council, but no action was deemed necessary.

Water flowing around the original beaver dam and across the floodplain, came back into the stream through an important gateway used for farm access. Rather than interfere with the flows, the decision was made with the farmer to move the gateway further downstream.

Due to raised water levels, 0.4 ha of Grade 1 agricultural land was impacted, preventing access by heavy machinery used to grow organic potatoes.

Large tree felling management

Prior to the arrival of the beavers, the majority of the failing poplar plantation that covered the wetland was proactively felled to prevent trees falling on an overhead powerline. However, approximately 10 large poplar trees were retained, and one of these has been felled by beavers onto the perimeter stock fencing. This is one of the few sites in the Trial where large trees are being felled, and on this site, the management response has been to allow the beavers to fell trees unrestricted. Protection measures can be used to prevent beavers gnawing trees, or trees can be proactively felled in a desired direction to prevent potential damage.

Flood Alleviation Cost-Benefit Analysis

As the potato field is in a 5-year cropping rotation with two high value crops, we have assessed the costs over five years against the benefit of the potential 5-year weighted annual average damage cost avoided. We used figures which account for inflation until 2018.

The estimated total potential gross margin loss from the two cash crops in the waterlogged field (organic first early potatoes and organic spring barley) was £1722. If just one property at high flood risk is downgraded to moderate risk as a result of the beavers' activity, the estimated benefit is £2446 over five years[4], thus there would be an estimated net gain of £724 over five years. If one property at very high risk is downgraded to high risk as a result of beavers, the estimated benefit is £4076, thus the net benefit in this instance is estimated to be £2304 over five years.

With the additional one-off costs at the site included (potato seed unplanted, ford relocation and felled poplar removal) the estimated economic cost is raised to £3422. This is below the estimated benefit for one very high-risk property being downgraded to high risk[4], with a net benefit of £654 over five years.

Therefore, if at least one very high-risk property has been downgraded by one flood risk category as a result of beaver activity, the economic benefits of reduced flood risk have outweighed the economic costs at this site. The benefit margin would increase if and where the number of properties where flood risk category has been reduced increases (see Table 6.2).

NB. It is important to note that it is crucial to develop innovative mechanisms to address the imbalance between those who derive benefit from the presence of beavers (e.g. local residents at risk of flooding and insurance companies) and incur no costs and those who are exposed to ongoing costs and derive little or no benefit.

Farmer perspectives

"Population is growing, demand on food is growing, world population is growing, diminishing natural resources out there, are all absolute facts of life. You can't deny any of that. So we do have to be mindful that food production has to be protected and kept going, but obviously it is important that we have a balanced view of that with not only protecting our natural habitat but also enhancing it as well. So I think having the two together is really good."

Public perceptions

An exploratory study was conducted via an online questionnaire. In the community downstream of the beavers 303 properties were invited to participate, 15 of whom did so (4.95% return rate). Comments received included the following:

"It appears to be a means of using nature to solve the problem of flood risk and may well reduce the need to use more expensive and perhaps more environmentally damaging engineered solutions."

"I would have thought that flood reduction by beavers would be minimal, and unreliable – to say the least."

"I believe this could be a fantastic opportunity to increase animal biodiversity in the area and is a positive measure that is environmentally friendly that can reduce flood risk."

"If it reduces flooding downstream, does that mean there may be flooding elsewhere?"

1. Environment Agency. Historic Flood Warnings. https://data.gov.uk/dataset/d4fb2591-f4dd-4e7f-9aaf-49af94437b36/historic-flood-warnings (2019).
2. Environment Agency. *East Devon Catchment Flood Management Plan.* (2008).
3. Environment Agency. Funding calculator for flood and coastal erosion risk management grant-in-aid allocation. https://www.gov.uk/government/publications/fcrm-partnership-funding-calculator (2014).
4. Penning-Rowsell, E. *et al. Flood and Coastal Erosion Risk Management I A Manual for Economic Appraisal.* (Taylor & Francis Group, 2014).
5. Lampkin, N., Measures, M. & Padel, S. 2017 *Organic Farm Management Handbook.* (Organic Research Centre, 2017).

CASE STUDY 3

High profile beaver territory with extensive public access

KEY THEMES OF INTEREST

Socio-economics effects of visitors around Otterton village
Conflicts between river users
Incident with dog
Managing impacts on trees

Overview of site and beaver behaviour

The village of Otterton has been a focal point of beaver tourism since 2016 when a family of beavers living on the main river became very easy to watch from nearby public rights of way. This coincided with the beaver family group near Ottery St Mary moving upstream and away from public access. Local people were the first to enjoy the views offered by a pink tagged female feeding her kits. Word soon spread through the media, resulting in wildlife tourists visiting Otterton from much further afield.

The main river at this location is approximately 10m wide and flows into the tidal reaches of the estuary just south of the village. Public footpaths run along the west side of the river to the village of Colaton Raleigh and south to Budleigh Salterton and are some of the busiest footpaths in Devon.

The small picturesque village has a pub (the Kings Arms) and a busy riverside café and bakery (Otterton Mill) as well as a community shop. Parking in the village is limited and the village becomes very busy during the tourist season.

Beaver population

The original pair living here from ca. 2014 are thought to have successfully raised kits every year since 2015. In 2017 they had five kits, and in 2018 a further four, suggesting a thriving pair with ample food and habitat resources.

Photo: Nick Upton / naturepl.com

Five kits were born in 2017, which is well above the average litter size, suggesting healthy animals living in a suitable environment

Socio-economic effects of visitors around Otterton village

A resident's questionnaire was circulated in 2018, asking whether local people perceived a change in visitor numbers to the area. Of the 65 respondents who answered the question, 69% answered that there *had* been a change in the number of visitors, 9/10 of these stating that it was an increase. The change was directly attributed to the presence of beavers by 31%, with 56% partly attributing the change to beavers and 13% suggested other factors.

The impacts that businesses reported were largely positive and included: an increase in visitors leading to an increase in custom; beaver-related products and merchandise (such as postcards, bronze beavers and "Beaver Bitter"); holding beaver-related event days at local businesses; the use of beavers in their business marketing; the potential for future beaver-related initiatives (such as guided walks or interpretation).

Figure 6.7 This 'word frequency' analysis reveals how respondents from the resident's questionnaire felt upon seeing beavers or signs of their activity.

'Beaver-watching' willingness-to-pay value estimates

The residents' questionnaire asked what they would be willing-to-pay for a 'typical' beaver-watching experience on the river near to their village. From those who provided an answer to the question, the average value obtained per respondent was £7.74 (£5.78 to £9.70). These willingness-to-pay values have been obtained from residents; it is unknown whether this value would differ for visitors to the area which may include higher travel or accommodation costs.

Local business perspectives

The following quotes were from managers of businesses in the village.

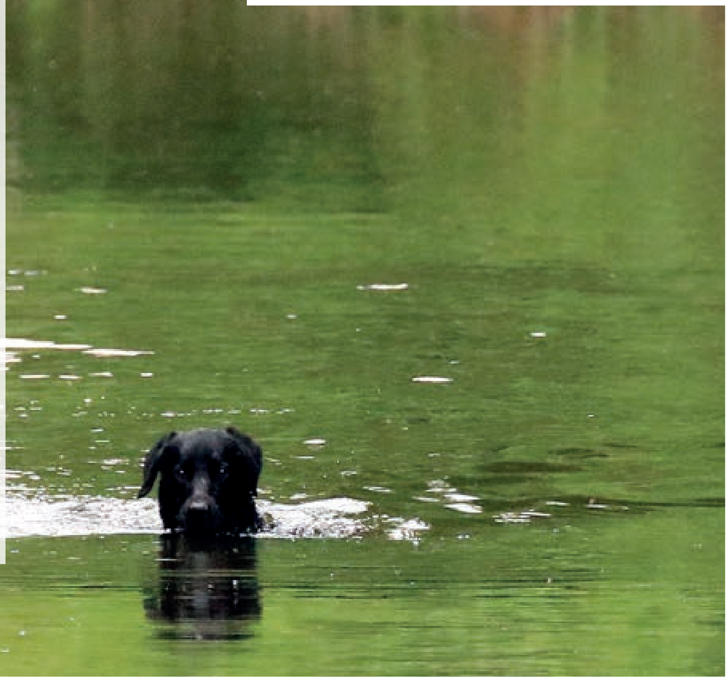
"I think any opportunity that affords itself to us and promotes the business we could potentially use that as a vehicle to do that. With the wildlife, whether that be beavers or otters, then we would seize that opportunity. So as far as we're concerned, wildlife tourism is a growing market and fundamentally if the river and the environment here promotes something along those lines then that suits us."

"You do get a lot of people coming to see them and there's a few people as well that check in not realising there's beavers there as well so they will take the time to go and have a look."

Incident with a dog

On 26th June 2017 an incident was reported regarding a beaver/dog conflict that had occurred in a pool not far from Otterton. The dog (a spaniel cross) was bitten by a beaver and was receiving veterinary treatment for an infected bite wound. The last week of June and first week of July are when kits are first seen emerging from the lodge, and it is surmised that the adult beavers were behaving particularly defensively during this period towards any perceived threats in the water.

The owner of the dog was keen to ensure that other dog owners were informed of the presence of beaver lodges. The existing signage was revised and upgraded, asking people to avoid allowing their dogs to enter the water, especially in these locations, in line with the Countryside Code which asks dog owners to 'keep dogs under effective control'.



This stretch of footpath is widely used by dog walkers who commonly allow their dogs to enter the water.

Photo: David White

Signage is controversial, and the new signs have subsequently been vandalised on at least two occasions. There is also a balance that needs to be struck between the need to inform dog owners of a risk in an exact location, with a high visibility sign (as is used occasionally in mainland Europe), with the risk of increased disturbance of the beavers by beaver watchers.

Conflicts between river users

Up to 50 people were counted beaver watching on summer evenings in 2016 and 2017, and the riverside path leading north from the village to the lodge site was busier than normal in the evenings with beaver watchers from the village and further afield. Local dog walkers, runners and anglers continued to use the path and there were occasional conflicts reported between the different users. In particular, anglers (fly fishing) using one of the pools near the beaver lodge found themselves the focus of negative comments from a small number of the beaver watchers who were concerned that the anglers were causing disturbance. However, generally the atmosphere was positive and was largely 'self-policing' when it came to noise and disturbance.

Managing impacts on trees

In the Otterton area a number of trees have been impacted by beavers, especially willow trees which are a prime source of food, as well as leylandii and apple trees. In all cases, advice and support was provided to landowners who requested it, leading to the protection of vulnerable or important trees. In one case a tree with high sentimental value was felled by beavers.

Proactive protection of riverside apple trees around the village was necessary to avoid impacts. Apple trees (and windfall apples) are particularly desirable for beavers. In this case the existing sheep fencing around some of the trees was deterring the beavers from feeding on them.

Leylandii trees were the subject of beaver feeding in one garden in 2015.

A few of the trees in gardens backing onto the river have been impacted by beavers, and in one case the land owner expressed their concern about the beaver trial by putting up this poster. When asked about it, the owner explained *"It was just a spindly little thing so we staked it and looked after it, but obviously there weren't any beavers in those days so we never thought of putting a cage round it."*

CASE STUDY 4

Beavers living in and around a water-supply reservoir

KEY THEMES OF INTEREST

Water supply infrastructure

Use of volunteers/management

Overview of site and beaver behaviour

- At the source of the main River Otter, Otterhead Lakes are situated within the grounds of an old Victorian estate and former landscaped garden. The site is dominated by two extant lakes and includes a range of semi-natural habitats. The site is now a water supply reservoir and a Local Nature Reserve.
- A young pair of beavers established a territory in the upper lake in 2017 and have now constructed 11 dams, transforming the area above the upper lake into a complex wetland with 0.52 ha of new open water. As well as the ecological benefits of beaver presence, this was identified as a suitable site to monitor the impacts of beaver dams on hydrological function and water quality.

Extent of open water created by beavers as a result of damming upstream of Otterhead Lakes.

Beaver population

Signs of beaver activity were first confirmed in March 2016, although initially it was sporadic. Video confirmation was obtained of a 1-year-old female beaver making its way to the site in early summer 2017 where it paired up with a young male and bred successfully in 2018 and 2019.

Ear tags were able to demonstrate that a kit born near Otterton in 2016 and given orange ear tags in March 2017 made the 50 km journey to Otterhead lakes as a 1-year-old, where it paired up and gave birth to a single kit in 2018.

Water supply infrastructure

The beavers are living in an engineered lake with a dam and stepped spillway with a second discharge point via a wooden drop-board sluice and culvert. The activity of the beavers on these structures is carefully monitored and managed, to avoid issues with water management.

A number of beaver dams have been built upstream of the reservoirs, storing water and trapping sediment.

Adult feeding at Otterhead (Nick Upton)

The beavers are feeding extensively on the vegetation growing in the shallow water in the lake, and are dredging canals and pools in it, creating areas of open water in amongst the silt and emergent vegetation.

This site represented the perfect opportunity to understand the potential benefits of beaver dams upstream of a fresh water supply reservoir. With funding from the Environment Agency and Wessex Water, in-stream monitoring stations above and below the area of beaver activity and downstream of the abstraction point have been established. Monitoring stations continuously record the rate and amount of water travelling through the site, to investigate whether beaver activity has an attenuating impact upon flow regimes. Additionally, turbidity sensors monitor whether beaver dams are trapping sediment resulting in cleaner water downstream.

Conflict management / support from volunteers

The beavers are having a regular impact at the crest of the main spillway where shallow water passes through a wide culvert. Here beavers are regularly adding material to dam the spillway. In order to retain the design level of water in the reservoir, it was deemed necessary to keep this spillway clear, via regular removal of beaver sticks.

The site is also used by a local Forest School, who were keen to assist with monitoring the beavers and removing the debris from the spillway. With training and supervision this was seen as a very effective solution, although options for installing an engineered structure could be investigated in future if necessary.

The crest of a spillway within a culvert has been the focus of damming activity by beavers. The ROBT was supported by local volunteers who inspect and remove the build-up of beaver sticks.

The sound of flowing water is one of the triggers for beavers to build dams and raise water levels. The two outflow points from the reservoir attracted the attention of the beavers. Initially the wooden drop-boards were chewed and sticks were used by beavers in an attempt to stop flows at this point. This was not a recurrent issue however.

Where beaver dams have washed through, clean gravels are left behind.

In order to deter burrowing of beavers and effectively monitor the integrity of the dam, the landowners removed the non-native laurel and rhododendron that was growing along much of its length.

Initial results

Time series data illustrate the fast response times of flow into the site, above the beaver dams and upper reservoir. Monitoring will continue to quantify whether beaver dams attenuate flow through this drinking water reservoir system and also to establish what level of sediment retention beaver dams may (or may not) deliver. Reducing sediment loading on drinking water reservoirs is a priority, and in this example is also desirable to reduce siltation of the reservoir which is stocked by a local fishing syndicate with brown trout.

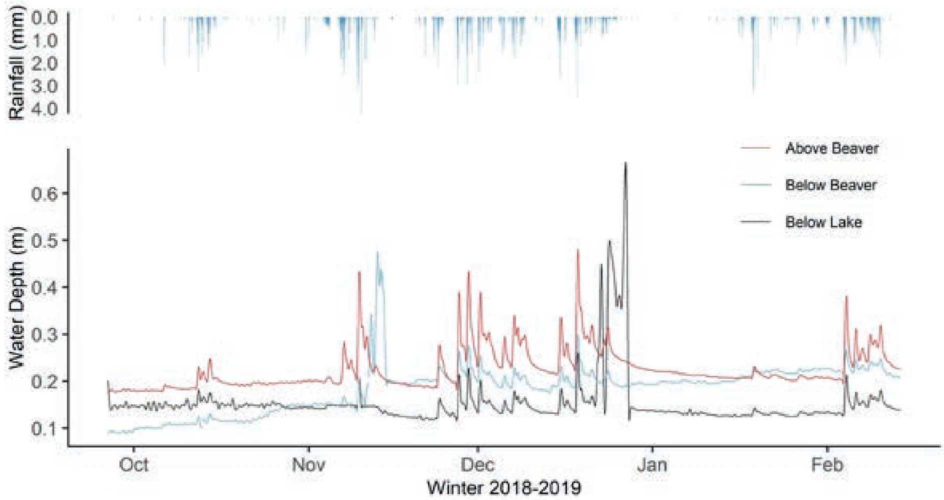


Figure 6.8 An early example of the continuous hydrological (channel depth) data being collected. Monitoring began in September 2018.

CASE STUDY 5

Release of beavers into a County Wildlife Site

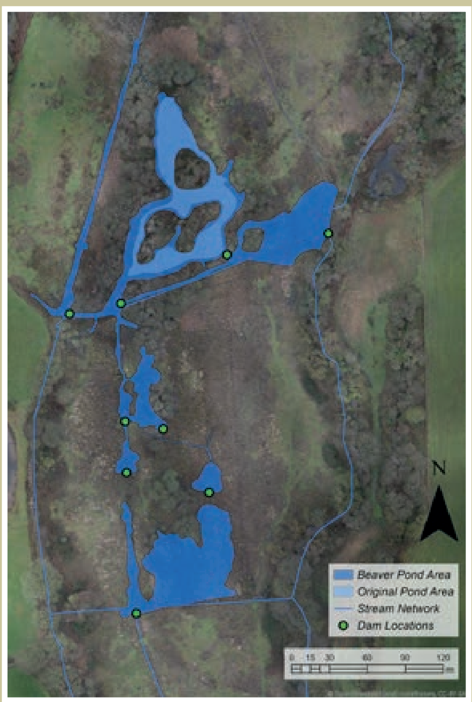
KEY THEMES OF INTEREST

Techniques for release and monitoring of beavers

Restoration of dynamic natural processes

Changes to vegetation structure

Conflict management



Overview of site and beaver behaviour

- The ROBT licence allowed for an additional five beavers to be released to enhance the genetic diversity of the population, and in 2016 a pair of captive bred beavers were identified as being suitable.
- Experience suggested that offline ponds are the ideal locations for introducing beavers into new areas as they provide refuge from high flows and from any beavers already present in the watercourse.
- The 19 ha Clyst William Cross County Wildlife Site is designated for its tall herb fen and wet grassland communities. It was previously managed as a wet meadow and these features were in decline as a result of scrub-encroachment due to lack of grazing management. The presence of one large pond and associated wetland habitat on the floodplain made this site ideal for release of a pair of beavers.
- Ecological impacts arising from the beavers' presence have been dramatic with 6,880 m^2 of open water created, increasing the aquatic value of the site, benefitting wetland species like water voles, and restoring dynamic processes to the watercourse, enhancing habitats for fish.

Beaver population

Occasional beaver feeding signs were detected in this stretch of the River Tale in March 2016, with no sign of an established territory. A pair of young beavers was introduced in May 2016. They have successfully bred in every subsequent year (two kits in 2017, three in 2018, one confirmed in 2019), leading to a large family group now occupying the site.

Four fixed cameras were installed recording 12 hours each night, to capture the behaviour of these nocturnal animals and monitor the success of the release. We are indebted to volunteers led by Michelle Grist who spent many hours analysing camera footage, and the support provided by Wildlife Windows.

Techniques for release and monitoring of beavers

Two artificial lodges were constructed on the edge of the large pond, providing refuge and helping the animals to settle into the release location. The pair of beavers were released separately into the lodges. Transferring their bedding from the holding facility or carrying crate was used as a technique to provide the animals with a familiar scent enabling them to accept their new surroundings. Photos: Nick Upton

Prior to release of beavers into the site it was established that there were no other resident beavers in the vicinity, via feeding sign surveys and intimate knowledge of the site by the landowners.

A crucial consideration is to ensure that landowners understand and support the potential scale of changes that may result from beaver activity. One of the main reasons that this site was so suitable for beaver release is that the landowners were supportive and also actively sought a progressive, sustainable solution to management of the County Wildlife Site.

The beavers settled well and soon constructed their own lodge on an island in the pond, only returning to the artificial lodges to collect bedding that had been provided for them.

Restoration of dynamic natural processes

When the beavers were released, it was not clear if they would build dams in the River Tale itself. Subsequently, many of the dams that have been built in the main channel have not persisted through the winter months. However, the construction and natural erosion of the dams has reintroduced dynamic natural processes that are largely absent from our rivers and streams. Where the channel had been deepened and straightened, the beaver activity is re-meandering and raising the bed levels. Gravels and larger sediments are deposited behind the dams and are redistributed as the dams erode, enhancing gravel structures such as sediment bars and riffles, and encouraging localised areas of erosion and scour. This provides a range of important habitats for fish (such as trout and bullhead) and macroinvertebrates.

The presence of ephemeral beaver dams on the main channel has re-connected the river with the floodplain, creating new flow pathways in times of flood, depositing nutrient-rich silts back onto the floodplain, and improving water quality downstream.

Changes to vegetation structure

As with many wildlife-rich open grassland habitats (which are managed at a seral stage in succession), widespread scrub growth can negatively impact on a site's ecological interest. Scrub is in itself however not a negative feature and a proportion is highly desirable on most sites – it becomes an issue where there are not human driven or natural processes which create an ever-changing mosaic of features. The condition of the County Wildlife Site was previously categorised as 'red,' denoting that its lowland tall herb fen and wet grassland condition was 'declining or lost' due to lack of management.

Beavers are now having a marked impact on the willow scrub, restoring a more dynamic natural mosaic structure, breaking up some of the patches of scrub, creating complex succession stages and creating new areas of open water and marginal vegetation.

It was anticipated that some trees would be felled/coppiced, and under-storey vegetation would respond. Drone photogrammetry and spatial data analysis was used to capture and quantify changes to vegetation structure across the site, resulting from beaver activity. Winter feeding signs surveys recorded that 209 trees were impacted. Photogrammetry has shown beavers have strongly influenced woody vegetation structure - a reduction in canopy heights and an increase in canopy variability, with a greater range of tree shapes/sizes than before beaver reintroduction.

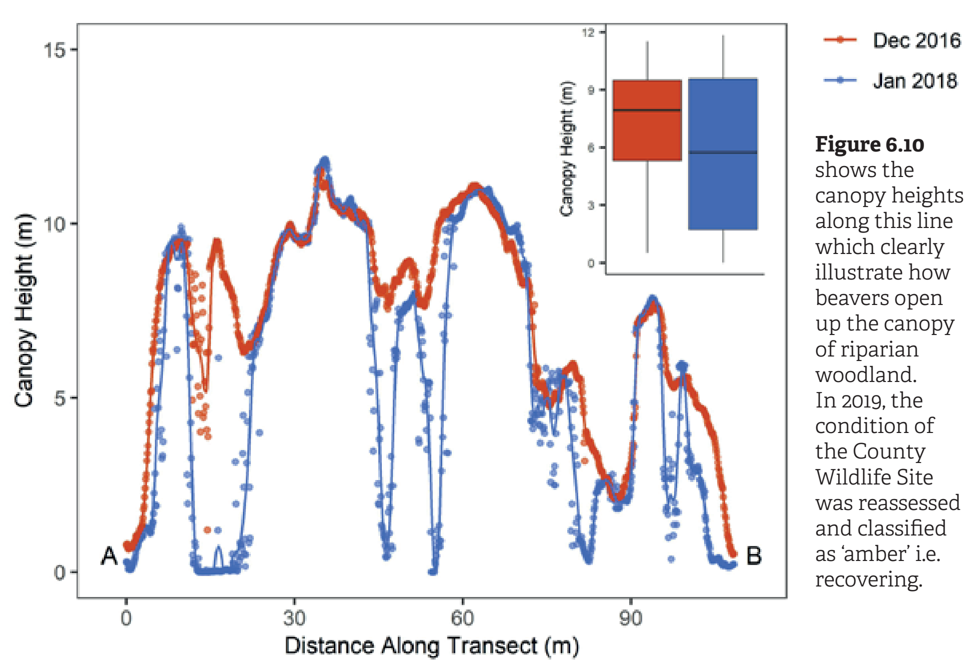


Figure 6.10 shows the canopy heights along this line which clearly illustrate how beavers open up the canopy of riparian woodland. In 2019, the condition of the County Wildlife Site was reassessed and classified as 'amber' i.e. recovering.

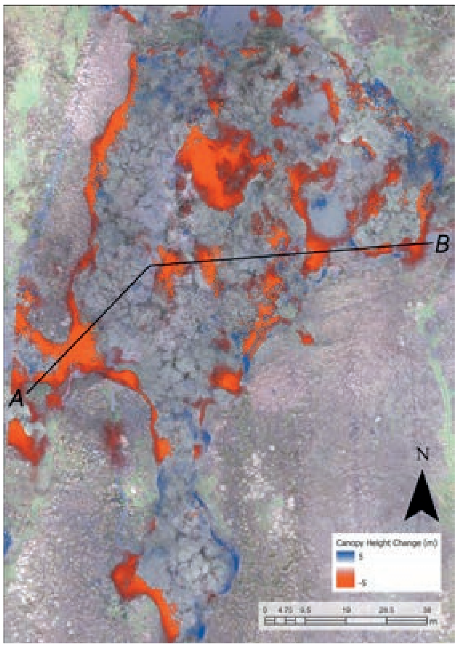


Figure 6.9 Aerial image showing where areas of the canopy have increased in height or been reduced. Numerous areas of canopy have been lowered by beavers, which has increased light penetration and canopy height variability. The cross section indicated on the map, intersects a part of the canopy which has experienced extensive felling.

Beaver engineering of the watercourse has reconnected it with its floodplain enabling significant volumes of water to be stored. This has, however, impeded access across the site on-foot and for light farm machinery. The solution was to build a short section of boardwalk in 2019.

Managing local access due to flooding

Stage-board installed to demonstrate the height that a beaver dam would need to reach to back-up water to the road bridge (red line) and potentially increase risk of flooding upstream.

Figure 6.11 A basic 2D model of flood inundation for the River Tale and how this might be altered by a beaver dam.

Conflict management

Addressing perceptions of flood risk

The landowners historically cleared the main river channel downstream of their property of large woody debris, due to concerns that it increased flood risk. As a result of beaver damming activity a conversation began as to the potential increase in flood risk that might result. The construction of a 2D hydraulic model predicting the extent of flooding allowed a stage-board to be installed to show where water levels had to reach, before flooding of properties occurred. This modelling showed that, in the beaver dam's current location, there is no increased flood risk, unless the dam was built to the height of the red line (see image) i.e. 1.5 m above current bankfull depth. It was also identified that dams in the river reach adjacent to the house should be removed, as these could back-up flow in critical locations, increasing flood-risk to properties.

Presentation and clear communication of this evidence to the landowners (and indeed other audiences) illustrated how common misconceptions of flooding and river management can be addressed. In this case, woody debris is no longer actively removed from the channel, as there is no flood risk reason for doing so.

Local Landowner perspectives

"We have thoroughly enjoyed having the beavers as neighbours and they have been a constant source of delight with the frequent and rapid changes to their local ecosystem. It has been fascinating to watch their engineering projects take shape. We have also enjoyed the steady stream of expert visitors from a very diverse set of backgrounds who we have learnt so much from. The only minor issue has been the need to protect our fruit trees (mainly apple and cobnut) from the beavers' attention. Our initial concerns surrounding issues with flooding, due to the damming of the stream, have proved unfounded with some expert work by Exeter University on flood modelling. We hope that the beavers will become a permanent feature of our landscape and the positive effects of their presence can continue to ripple out."

"How big was the tree that the beavers had then?" "Quite big." "So now I got one sort of that big" [indicates much smaller] [...] *"We might get two apples next year so again by the time we actually make something with an apple off that tree again, we're talking about 10 years' time aren't we at least. That's the problem we've got, as we get older everything takes a lot longer. You're a youngster [...], if you put a tree in now you'll probably get 30, 40 years of apples off of it. So, you know, it's sort of a long-term plan that's been bitten off."*

Tree protection

Riverside orchards are particularly at risk from beaver activity - both from feeding on apples and coppicing of the trees. Apple trees within an orchard adjacent to the CWS were identified and protected prior to the release of the beavers. Since release the beavers have been feeding on windfall apples and have damaged one of the few unprotected trees. All remaining trees have now been protected and discussions are ongoing to reduce the visual impact of the tree guards.

CASE STUDY 6

Conflict between landowners experiencing beaver activity

KEY THEMES OF INTEREST

Impacts of beaver behaviour in an intensively farmed landscape

Beavers and maize crops

Volunteer support for management

Overview of site and beaver behaviour

This case study provides a good example of the impacts of beavers on land located in the middle reaches of the catchment, which is intensively farmed and agriculturally productive. The farms are characterised by deep, fertile, floodplain soils which are extensively under-drained.

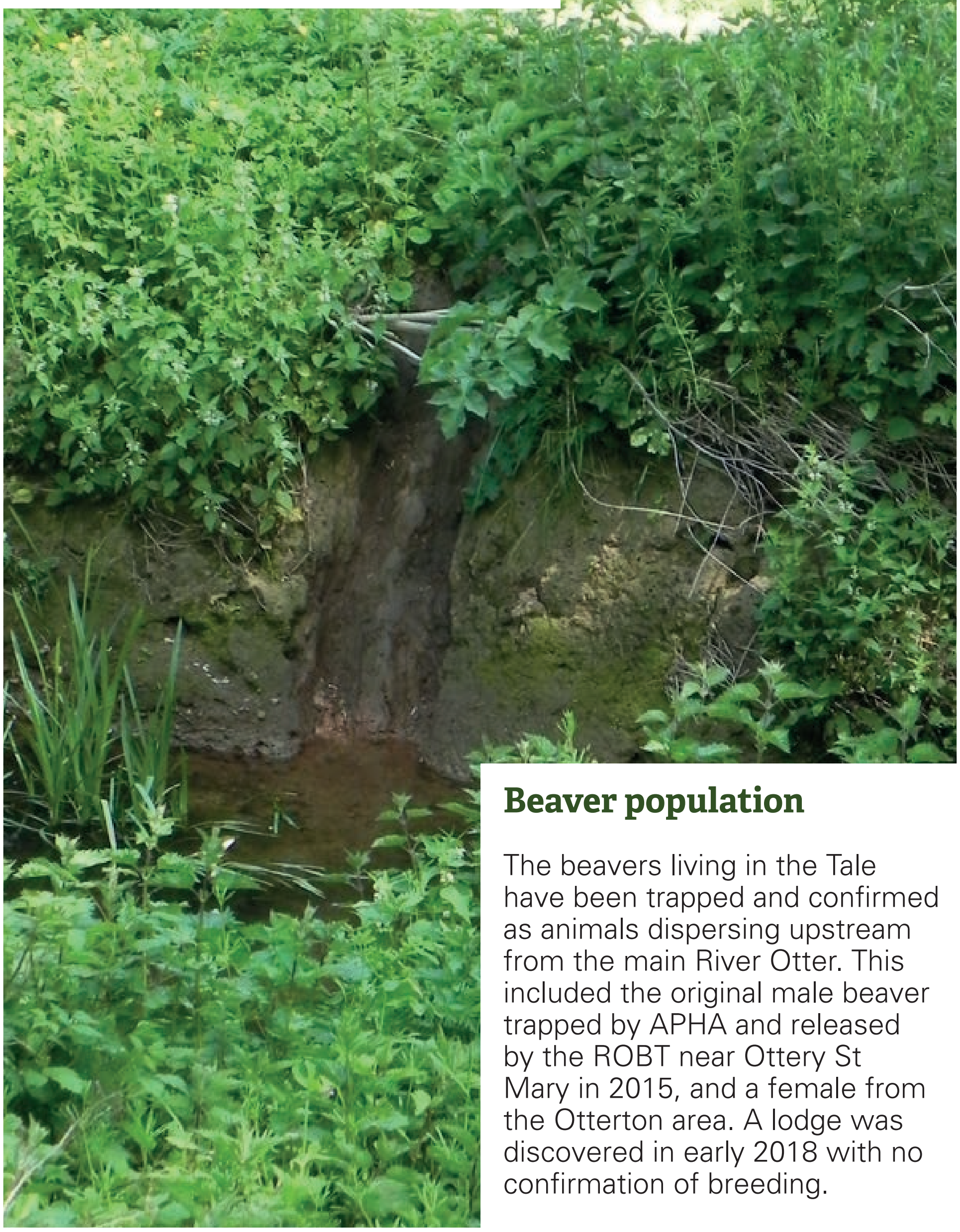
Beaver dams were built in-stream during low summer flows, enabling beavers to access riverside maize crops. This also temporarily raised water levels, impacting on land drainage in low-lying floodplain pasture.

A difference of opinion between neighbouring landowners regarding the activities of the beavers (both for and against) and their impacts led to disagreement about potential solutions.

The ROBT team worked closely with all parties to resolve potential conflicts successfully, highlighting the crucial role of expert advisory support and ongoing solutions-focussed dialogue.

The ROBT removed the beaver dam on a number of occasions until the maize was harvested. Electric fencing was erected by the ROBT which successfully discouraged further feeding.

On this site, beavers have created a slide into the water.



Beaver population

The beavers living in the Tale have been trapped and confirmed as animals dispersing upstream from the main River Otter. This included the original male beaver trapped by APHA and released by the ROBT near Ottery St Mary in 2015, and a female from the Otterton area. A lodge was discovered in early 2018 with no confirmation of breeding.

Impacts of beaver behaviour in an intensively farmed landscape

The ROBT first confirmed the presence of beavers in the mid-reaches of the River Tale in 2015 through routine surveys of feeding activity. In 2017 the Trial confirmed beavers had subsequently established a territory in the area.

Although the owner of the land where the dams had been built was supportive of the beavers' activity, a number of neighbours were concerned about elevated water levels and had initially removed a dam.

Impounded water caused silt to be deposited in a drinking bay that had been constructed to restrict cattle access to the river.

The low-lying floodplain and interconnected nature of the drainage channels meant a range of local residents and farmland owners were concerned about potential impacts arising from beaver activity. There was a risk that differences in opinion, and levels of understanding regarding beaver behaviour, would lead to disagreement and potentially conflict.

Two evening meetings were initiated by the ROBT with a group of neighbouring landowners from the area to ensure clear channels of communication were maintained and concerns were properly understood and documented. The ROBT explained what interventions could be taken to resolve potential beaver conflicts.

Intensive action from the ROBT Field Officer was provided to monitor and manage beaver activity. Volunteers also provided support by regularly walking stretches of riverbank to check for signs of fresh activity and helped protect trees by applying a latex and sand mixture to deter beaver gnawing.

Sometimes the trackways through the maize reach as far as 40 m from the water. An area of approximately 15 m² was impacted, which based on the John Nix pocketbook[1] would have a value of £1.33.

In order to minimise the risk of machinery collapsing undetected beaver burrows, it was suggested a buffer strip of 5 m width, 50 m length be left unharvested against the stream (marked with flags). This would represent a profit foregone of £22.10[1].

Beavers and maize crops

Riverside maize appears to attract beavers. There is evidence of them feeding on this crop in late summer – sometimes some distance from the water. Dams appear to have been built during this period to access the crop during low flows, and burrows have also been detected in one area.

Volunteers protecting trees

Volunteer support for management

A small group of volunteers have been recruited to assist with occasional tasks such as protecting important landscape trees, and regular monitoring of beaver activity. The training, management and supervision of volunteers is initially time consuming, but over time could be a more sustainable model for managing conflicts.

Landowner perceptions

"In terms of the impact, we are very relaxed in terms of that bit of land. [...] It's an area that I want to let go wild as much as it wants to and so I'm not bothered in terms of what they've done."

"There shouldn't be an assumption that we will give up our time for free. It's been us who are walking up and down the riverbank and monitoring the activity."

"We love it, so I'm very happy to go down on a Sunday morning and spend half an hour pulling a dam apart, but I understand that there's a lot of people that would probably be happy for the beavers to continue but they don't want to have to do stuff to make it happen."

"I don't want to sit and listen to someone telling me about how great beavers are when I'm concerned about my land."

"I believe that they could have a very important role to play in terms of flood alleviation. But that does mean that people upstream of population densities need to be prepared for the fact that their fields may get flooded as a result. I think that that's where the government, if they're serious about this, as part of the 'public money for public goods'. [...] I personally believe they are a part of a longer term solution."

"The landowner shouldn't have to take [management] responsibility."

1. Redman, G. *The John Nix Pocketbook for Farm Management 2019.* (Agro Business Consultants, 2018).

Knowledge gaps / future research

Whilst the following list is not exhaustive, we present a range of themes that could warrant further research, should beavers remain in the River Otter catchment or be reintroduced more widely.

- Ongoing research concentrating on effective management of conflicts, deterrent methods and dam manipulation.
- Monitoring implementation of a full beaver Management Strategy Framework in context of larger and increasing beaver populations to inform a national roll-out of the Strategy Framework.
- Further research on aquatic ecology, and on effects on migratory fish.
- Geomorphic changes as populations expand.
- Demonstration of circular economics, to bring funding from beneficiaries to those bearing the costs of beaver reintroduction.
- Targeting beaver restoration in flood prone areas to deliver benefits, including use of analogue dams to encourage damming.
- Interspecies interactions that result from structural changes in habitats caused by beavers.
- Radio tracking devices for beavers allowing them to be monitored across a catchment over longer periods with minimal welfare implications.
- Measuring and managing the genetic health of populations.
- Attitudes towards the beavers as a contribution to flood alleviation relative to other techniques and intervention types.

There is scope for research into many aspects of beaver recolonisation if populations are permitted to expand.

Recommendations for further reading

It was not felt necessary to provide a detailed review of literature as part of this report, as much has been carried out elsewhere. In addition to those scientific papers referenced throughout this report there are a number of locations where extensive information has already been collated.

These include:

The Scottish Beaver Trial
https://www.nature.scot/scottish-beaver-trial

The Beaver Advisory Committee for England
https://beaversinengland.com

The Eurasian Beaver Handbook – Ecology and Management of *Castor fiber*
Dr Roisin Campbell-Palmer et al. (2016) Pelagic Publishing (ISBN 9781784271138)

Beavers in Britain's Past
Dr Bryony Coles (2006) - WARP (ISBN 978-1-84217-2261)

Avanke, Bever, Castor: the story of Beavers in Wales.
Dr Bryony Coles (2019) – WARP (ISBN-13: 978-0954022419)


The green tagged male beaver feeding near Otterton

Photo: David White

This ROBT Science and Evidence Report and all the case studies and appendices are available as PDF at **https://www.exeter.ac.uk/creww/research/beavertrial/**

Information and supporting documents about the ROBT including Annual Reports, the proposed Beaver Management Strategy Framework and Monitoring Plan can be found at **https://www.devonwildlifetrust.org/what-we-do/our-projects/river-otter-beaver-trial**

Information about the Enclosed Beaver Project in West Devon can be found at **https://www.devonwildlifetrust.org/what-we-do/our-projects/enclosed-beaver-project**

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