# 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.

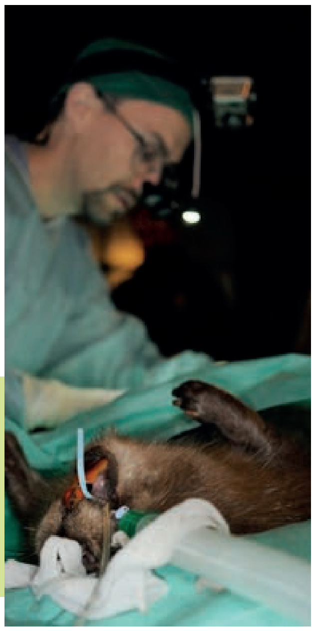
There was also a need to clarify that the species was Eurasian beaver and not the North American species (*Castor canadensis*).

## 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.

↓ 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

# The population dynamics of beavers on the River Otter

## Historical beaver population and colonisation of the catchment

▶ **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.

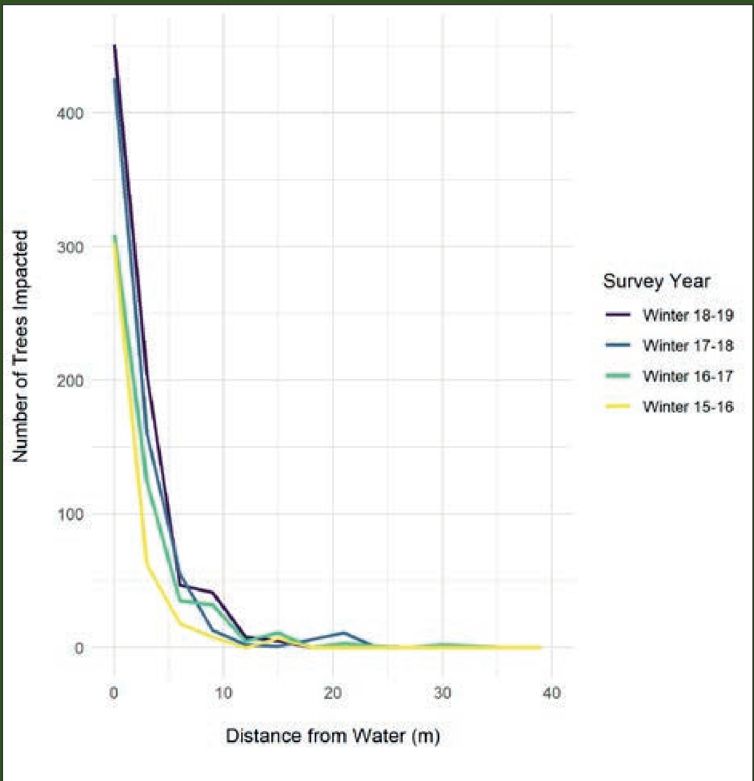
Sightings of this female have been recorded throughout a length of 4.5km of the main River Otter between White Bridge in the estuary and north of Colaton Raleigh. This female has been extremely productive with five kits confirmed in 2016 and four in 2017, and breeding confirmed every year since.

Photo: Nick Upton

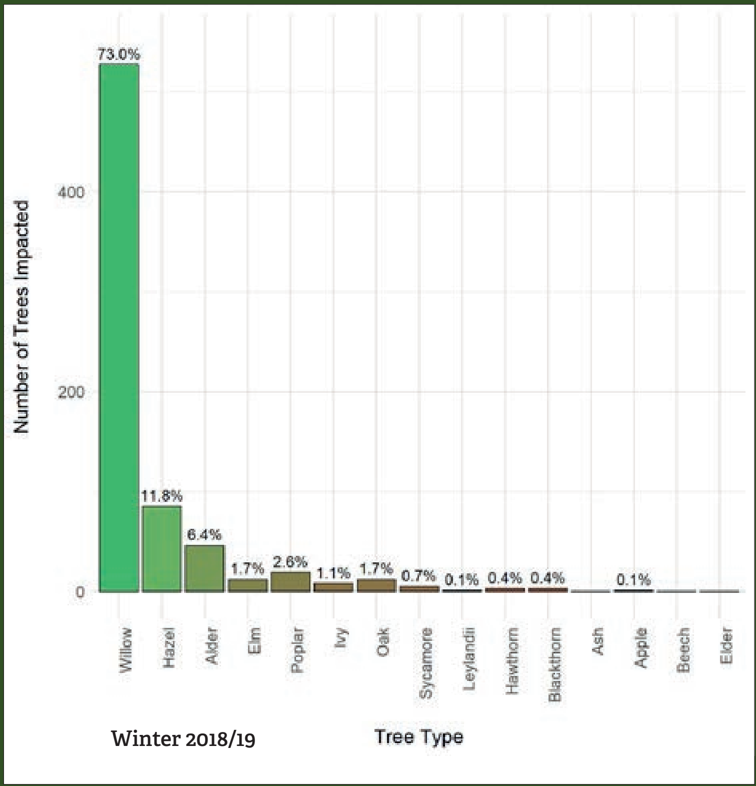
▶ **Pink tagged female and kits (Sylvia Meller)**

## Browsing on woody species

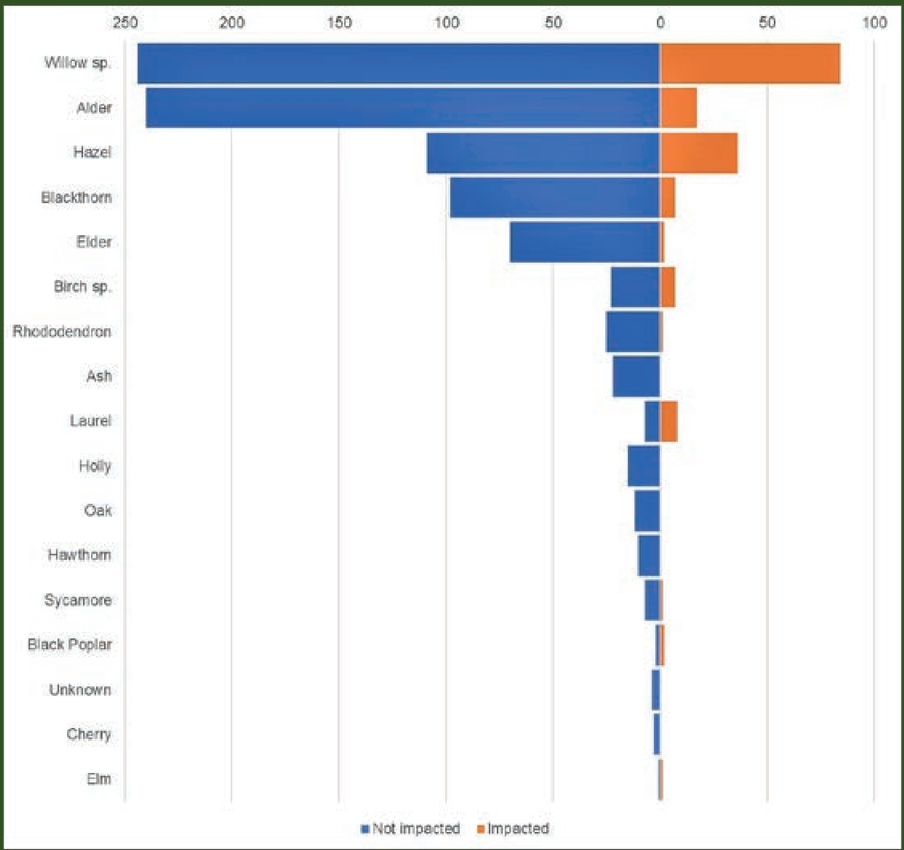
The annual systematic surveys of the catchment have provided a dataset of 2,356 trees that have been fed on since the first surveys were conducted in 2015. These clearly show how the majority of feeding is very close to, or within water (Figure 5.1) and that winter browsing in the River Otter catchment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

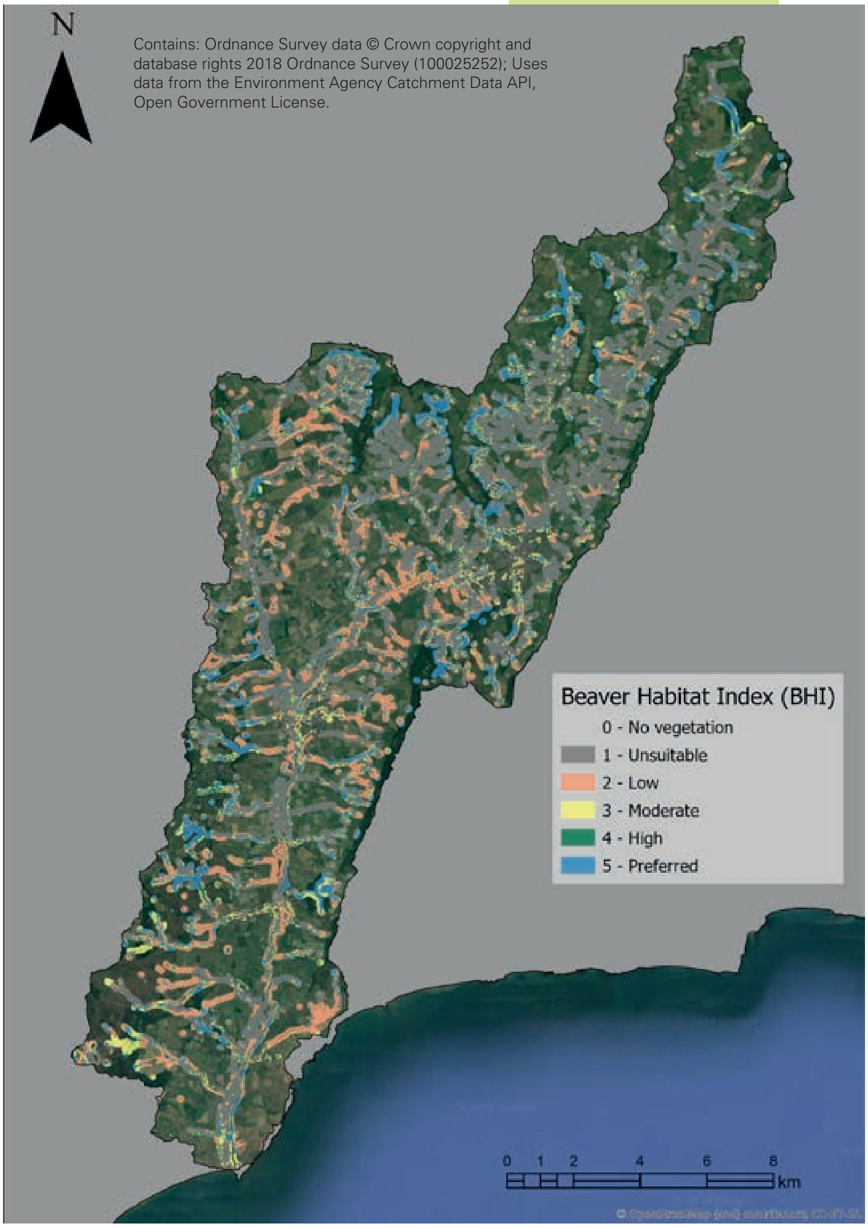
Typically, beavers rarely forage more than 30-40 m from water[13] and spend the majority of time either in water or bankside locations. However, in some instances they may forage up to 100 m from a watercourse[15]. Therefore, we have excluded all areas >100 m from a river or lake from the model and classified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

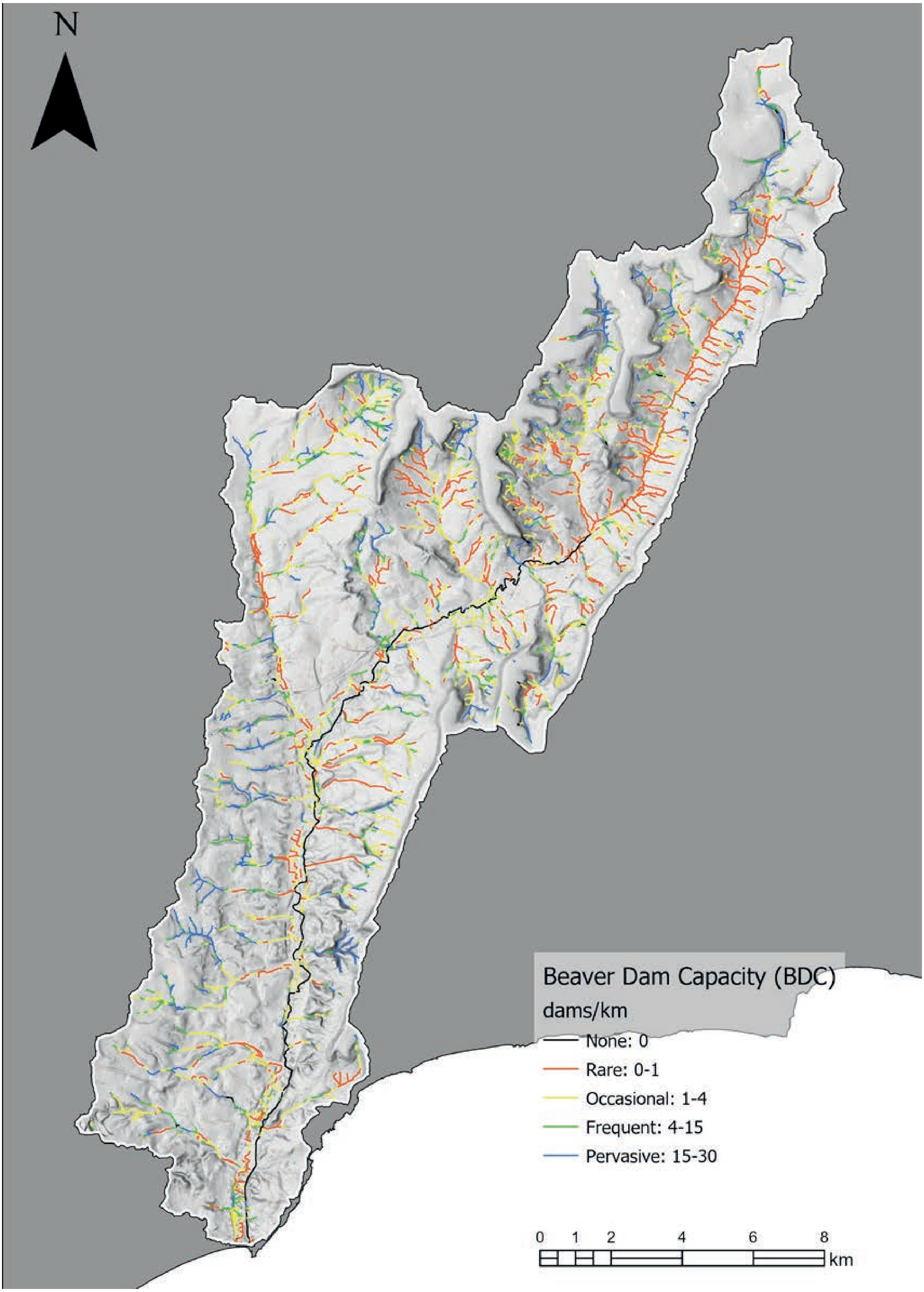



Figure 5.5 Beaver Dam Capacity model results for the River Otter catchment.

## 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 ≤4$^{th}$ 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.

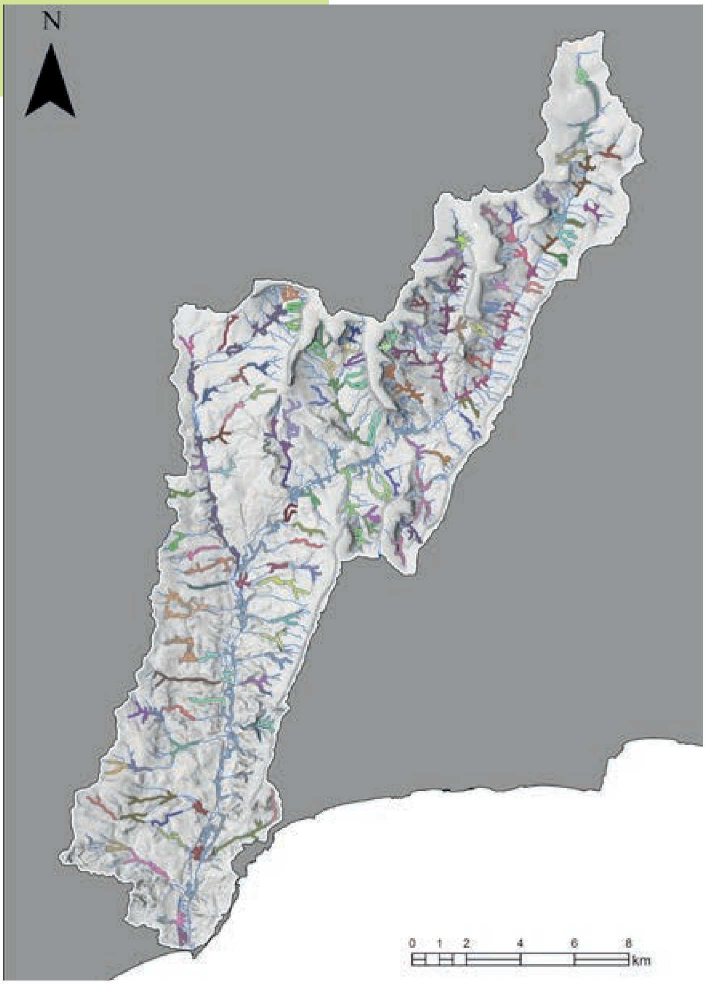
Additionally, we do not attempt to estimate the number of individual animals, rather the number of territories that may be occupied. Therefore, our approach is referred to, as a Territory Capacity Model (TCM).

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.

**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.





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