Photo: Allard Martinius

# Application to Natural Resources Wales to release Eurasian beaver *Castor fiber* into a secure enclosure at Cors Dyfi Wildlife Centre

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Principal Applicants: Montgomeryshire Wildlife Trust

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## 1. Introduction

**This document sets out the details for the introduction of Eurasian Beavers (*Castor fiber)* to a fenced enclosure on Montgomeryshire Wildlife Trust's (MWT) Cors Dyfi Nature Reserve. The initial proposal is for a minimum five-year trial.**

Cors Dyfi is a 16.8ha wildlife-rich wetland nature reserve owned and managed by MWT. The reserve is a lowland peat bog, an extremely important habitat in Wales, but one that has, in many places, been inappropriately managed in previous decades. Cors Dyfi is one such site. The legacy of groundworks left by the site's former use as a conifer plantation (1960s – 1990s) has left a damaged ecosystem in need of restoration.

One of the main management issues on this site is controlling invasive scrub and tree saplings, particularly willow (*Salix* sp.) and birch (*Betula* sp*.)*. If left unchecked this growth will further degrade the peat bog habitat. Due to the difficult terrain, the network of ditches, tree stumps and the dense scrub re-growth, there are areas of the reserve that cannot be managed in traditional ways. Therefore, alternative habitat management options have been considered for the reserve.

As ecosystem engineers, the beavers would perform a vital scrub management role in the harder to access sections of the reserve. They would reduce the cover of willow and birch and enhance the network of channels and open water. The management of woody vegetation and maintenance of water levels are both important factors in the ongoing work to restore this lowland peat bog that was degraded by earlier forestry management and associated drainage.

The habitat restoration by the beavers would complement the existing management strategies that are used in the areas of the reserve with less dense scrub growth. To date the only livestock we have found suitable to cope with the wet, uneven terrain are domestic water buffalo. A pair of buffalo are currently deployed on two sections of the reserve between April and September each year. They are primarily used to keep re-growth vegetation in check. The buffalo, however, are not suitable to be employed elsewhere on the reserve as the habitat and terrain are too harsh and over-grown for them.

Areas of the reserve with more open vegetation are grazed with a pair of water buffalo in the summer months

Since the initial feasibility study of introducing beavers to the site was carried out in 2013/14 we have been working with the Welsh Beaver Project (WBP) to ensure that the plans to release beavers into an enclosure at Cors Dyfi are in line with the wider strategy for beavers in Wales. MWT is a key member of the WBP steering group and staff from Cors Dyfi are working closely with the WBP officer to ensure that all proposals relating to the beaver enclosure are founded on best practice for animal welfare and informed by up to date research.

As part of the research for this project Derek Gow, a well-known beaver expert from Britain and Gerhard Schwab, beaver expert from Europe, have visited the site in 2013 and July 2016, respectively. They have both confirmed that the reserve would be highly suitable habitat for a beaver enclosure and that beavers would be most likely to function in the management role required of them. The project development has also included visits to other beaver locations. In 2018 MWT visited the beaver enclosure near Llangors lake and met with the landowner to discuss fencing, beaver management and resources. In addition, the WBP officer has visited the Devon Wildlife Trust and Forest of Dean beaver enclosures. MWT have also had discussions over licensing requirements with NRW and the WBP, and discussions have also taken place with neighbouring landowners to ensure they are fully aware of the plans to have beavers in a secure enclosure at Cors Dyfi Nature Reserve.

Cors Dyfi is also the home of the Dyfi Osprey Project which welcomes around 35,000 visitors per year. The wide reach of the current project would provide an ideal opportunity to showcase the ecosystem engineering role beavers play and would offer excellent educational opportunities for the WBP and MWT to demonstrate the role beavers have in our ecosystems. There is the potential for Cors Dyfi to become a hub for beaver research and education in Mid Wales.

In order to deliver these educational and research opportunities the WBP have initiated baseline data surveying of the reserve, the results from which will be used in the monitoring of the ecological impact the beavers have following their release. Initial studies are looking at bat, invertebrate and bryophyte assemblages as indicators of biodiversity. Regular monitoring will continue and will be used as part of the education work that will accompany the beaver release.

Beaver chewed log in the beaver enclosure near Llangors Lake

## 2. Objectives

The objectives of this application are:

- To release one unrelated pair/or existing small family unit of beavers into a secure enclosure at the Cors Dyfi Wildlife Centre in order to provide vital scrub management on the reserve.
- To increase the general awareness and knowledge of the natural history of the beaver and their potential impacts on riparian and wetland habitats within the local community, stakeholders and the wider public.
- To assist the Welsh Beaver Project with the wider strategy for beavers in Wales.

## 3. Site Description

Cors Dyfi was a Forestry Commission Sitka spruce plantation for 30 years. The site was clear felled in 1995 and extensive remodeling undertaken to block ditches and form pools. Cors Dyfi can now be described as regenerating peat bog with swamp vegetation, wet woodland, gorse, scrub and areas of open water.

The reserve is bounded to the east by the A487, to the west by the railway line, to the north by Morben Isaf Caravan Park and to the south by the Garthgwynion Estate. The site is crisscrossed by a network of ditched and channels. The main north-south drain divides the site into essentially two different components. Saline water enters through drains under the railway at the west of the site, particularly the north-west corner. East of the drain, the land slopes gradually upwards towards the road where the hydrology of the site is dominated by fresh water. The diversity of habitats support a wide range of bird, mammal and invertebrate species.

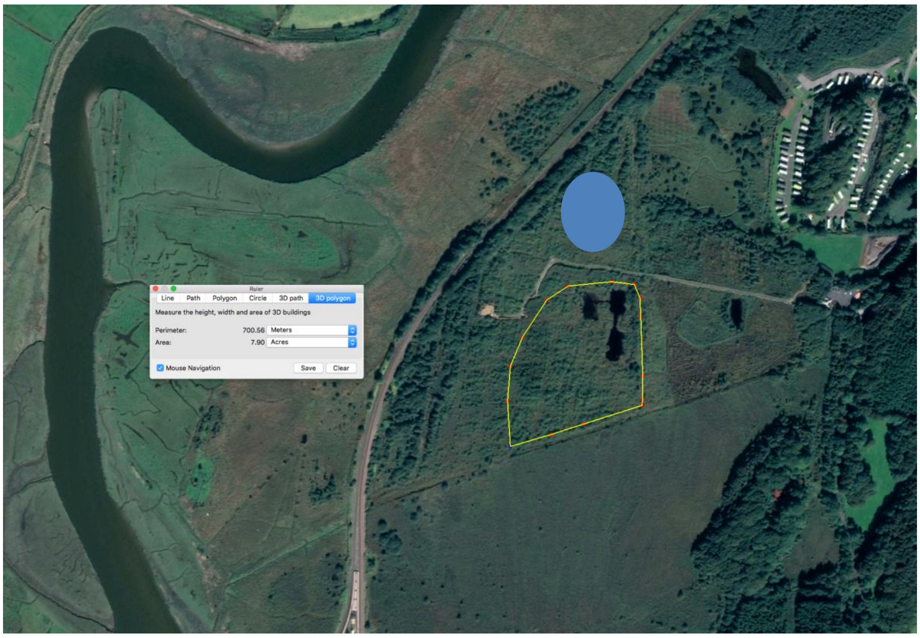
Cors Dyfi is a mosaic of open water, reedbed, swamp
and wet woodland/scrub habitats

There is good access through the middle of the reserve on wide, level boardwalk that connects the visitor centre and the 360 Observatory.

## 4. Location of preferred beaver location on Cors Dyfi Nature Reserve

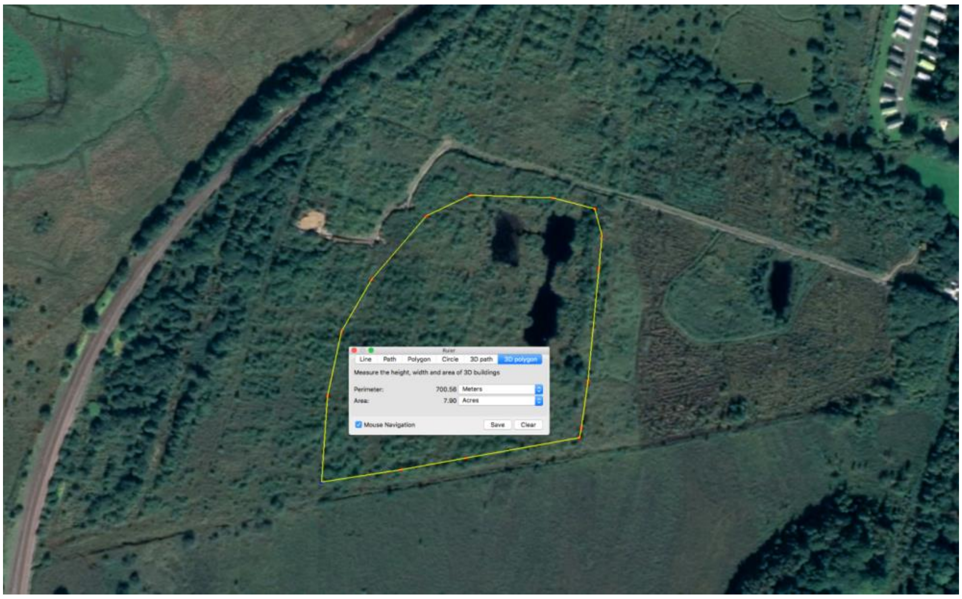
Through working with the WBP we have refined the area of the reserve in which management by beavers would be most appropriate in terms of suitable habitat, level of potential impact and accessibility for management and potential viewing.

Map 1 below shows the preferred location and size of the beaver enclosure relative to the Dyfi River, the A487 and neighbouring properties. At the closest point the beaver enclosure will be a minimum of 5 metres from the neighbouring property. The boundary is marked by the drainage line south of the enclosure.




Map 1 - Preferred location of Cors Dyfi Beaver enclosure shown in yellow and additional area of open water shown in blue

Map 2 below shows the same area in more detail. From this image you can see that the enclosure provides areas of open water and woody scrub habitat, both essential factors in considering where to place the enclosure.



Map 2 - Area containing open water and woody scrub habitat

The proposed enclosure has a perimeter of c700m and an area of approximately eight acres. This enclosure would comfortably support one pair of beavers together with their offspring from two or three breeding seasons. It is possible that kits may need to be removed from the family group at about 24 months to prevent territorial disputes, but this will be reviewed on an annual basis. The family will be monitored and if there is any evidence of the infighting, such as cut tails then the offspring will be removed from the enclosure. The WBP would look to place these youngsters at other beaver projects in Britain.

The chosen location has a number of advantages to other locations on the reserve. These are:

- There is easy access to the enclosure from existing boardwalk to allow monitoring and supplementary feeding as required.
- There is easily accessible and suitable terrain for a 'Beaver Hide' to enhance the visitor experience and public viewing should a budget be found.
- There is additional habitat adjacent to the enclosure that would allow for modular expansion of the project in future years.
- The area is manageable in terms of the funds and capacity we have for the project (£42,000).

The management of this area of the reserve with beavers will be in addition to the conservation grazing currently being undertaken with the pair of water buffalo in the summer months on a separate area of the reserve. Unlike the water buffalo, there will be no over-wintering facilities needed for the beavers.

Above: Beaver feeding station at Llangors beaver enclosure, used for monitoring and capture when required.

Left: Forestry England beaver enclosure in the Forest of Dean with an overhang along the top of the fence.

## 5. Fence Specifications

The beavers will be contained within a fence that meets the standard fencing specification for beaver enclosures and already used and licensed for various beaver projects around Britain, including Forestry England Forest of Dean.

***Enclosure Design and Materials***

The fence will be constructed of treated timber fence posts, ~1.2m high with intermediate stakes buried in the ground to 60cm and straining and turning posts buried in the ground to 90cm. All timber will be placed on the outside of the fence so that it is protected by the fencing mesh. Tornado wire mesh can be used to beaver proof the enclosure.

Fencing can either be taken high enough to prevent beaver escapes or be lower and include an overhang. At set locations around the perimeter fence some sections of fencing may not contain an overhang in order to facilitate the movements of otters in and out of the enclosure (see otter survey report), without comprising the security of the perimeter fence for beavers. Should further passages need to be made available to facilitate the movements of otters, then these can be fitted at a later date (see Appendix I). On the upstream and downstream ends of the enclosure this will be of Tornado RL19/180/5 C14 mesh which will extend 120cm vertically up the timber work with a 50cm section at the top which will be set at 45 degrees into the inside of the enclosure as an anti-climb device. At the base of the fence an anti-dig curtain of Tornado RL6/50/5 C5 mesh will be laid on the surface of the ground attached to the base of the vertical mesh with hog rings and pegged to the ground surface where it will extend 90cm into the enclosure on the floor. The wire mesh sizes allow for an overlap of at least 10cm preventing beavers from getting through at the join.

On the sides of the enclosure where the fence is well away from any water course or wet ground and it is unlikely any beavers will attempt to clear the fence the overhang can be excluded, but anti-dig precaution laid on the ground as above extending 90 cm into the enclosure and overlapping the vertical mesh by 10cm, and fixed to the floor with pegs and hog ringed to the vertical wire as above.

As an additional precaution where the water course exits the site and for 10m to either side galvanized weldmesh panels with 50mm mesh holes which will be made of 2.44m x 1.22m panels overlapped so that they extend 1.22m down into the ground to prevent burrowing out of the enclosure.

Where the water courses flow into or out of an enclosure culverts would be required with metal grill with a spacing of no greater than 10 cm between the bars.

All fencing and culverts would be carefully checked before any beavers are released into the enclosure and in the days following release.

Suggested commercially available wire specification or similar equivalent: Tornado Badger Wire, code HT15/158/8 (http://www.tornadowire.co.uk/product/ht151588/).

**Specification**

| | |
|---|---|
| No. of Line Wires | 15 |
| Overall Height (cm) | 158 |
| Distance between stay wires (cm) | 8 |
| Top & bottom line wire specification | 2.5mm dia - 1235-1390 $N/mm^2$ |
| Intermediate line wire specification | 2.5mm dia - 1235-1390 $N/mm^2$ |
| Vertical stay wire specification | 2.5mm dia - 695-850 $N/mm^2$ |
| Average Weight per 50 Metre Roll (kg) | 87.86 |
| Material Composition | Heavily galvanised steel wire |

*Figure 1. Wire Specification (product code HT15/158/8 Badger Fence) from http://www.tornadowire.co.uk/wp-content/uploads/2016/03/HT15-158-8-web.pdf [accessed 23rd March 2018].*

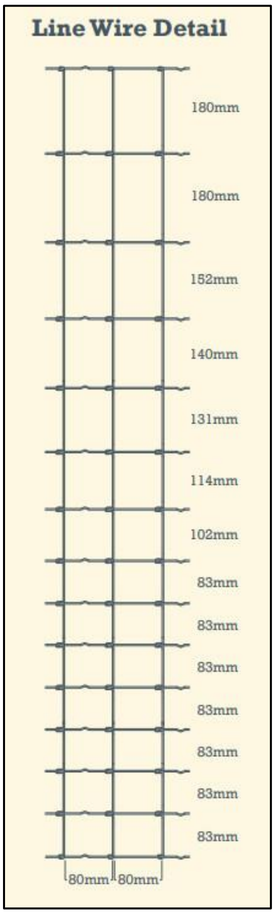



*Figure 2. Line Wire detail (product code HT15/158/8 Badger Fence) from http://www.tornadowire.co.uk/wp-content/uploads/2016/03/HT15-158-8-web.pdf [accessed 23rd March 2018].*

### *Culverts*

There is no evidence of any culverts or drainage systems within the proposed location for the enclosure. However, if any culverts or inflow/outflow points are uncovered during the construction of the enclosure, then these will be protected as appropriate. Culverts and other inflow/outflow points can be vulnerable to breaches, therefore any found will be secured with grills. At the base Tornado RL6/50/5 C5 mesh will be laid on the surface of the ground attached to the base of the vertical mesh with hog rings and pegged to the ground surface where it will extend 90cm into the enclosure on the floor.

***Access***

The enclosure will require access for monitoring and release/removal of animals as required. The enclosure will be accessed via a build-out from the existing boardwalk. There is no direct vehicle access however the boardwalk is wide enough to take a large trolley that can be used to transport materials, equipment and animals in travel crates.

Double access gates will be hung on posts (protected with weld-mesh guards or Tornado wire mesh similar to the fence) with pins through the hinges to ensure the gates cannot be lifted off. The gates will be fitted with a weld mesh or Tornado wire mesh to ensure beavers cannot fit through the bars in the gate or climb over the gate. A weld mesh or Tornado wire mesh skirt will also be fitted along the base of the gate to prevent burrowing.

***Construction***

All works relating to the construction of the enclosure will be undertaken outside of the breeding bird season. Prior to construction, the vegetation will be cleared either side of the proposed fence line using a bog master for the installation of the perimeter fence. This will also ensure that once the enclosure is constructed, there will be no trees within the vicinity of the fence line that are at risk of falling on to the fence. Fence posts will be installed by hand and the fencing inserted into place, strained against the fence posts. Due to the topography of Cors Dyfi the fencing may need to be adjusted for the area, but advice will be sought from contractors and advisors to ensure that the security of the enclosure is not compromised.

## 6. Source Population

Beavers are highly territorial (Wilson, 1971). Therefore, only one breeding pair or a small family unit will be released into the enclosure. A beaver family is usually composed of a breeding pair with up to three generations of youngsters; kits from that year, young from the previous year (yearlings) and slightly older offspring that have not yet dispersed (sub-adults) (Wilson, 1971). Beavers will be sourced by an independent contractor, Dr Róisín Campbell-Palmer under licence from Scottish Natural Heritage (SNH) assessed conflict zones within the River Tay and Earn catchment. This will be reactive to where the lethal control licences have been issued and there is landowner permission acquired to trap. Animals will be responsibly sourced and all individuals will be health screened according to current DEFRA requirements (Appendix II). The age of each individual will be determined by appearance and body weight. Age class will be assigned according to kit (young from that year), yearling (young from previous year), subadult (~2 years) and adult (> 2yrs). In addition, weight will also assign age class (Rosell & Sun, 1999); < 12 months 0-10 kg, 12-24 months 10-15 kg, ≥ 24 months ≥ 15 kg and adult >20kg.

***Trapping Protocol***

MWT and WBP will be working closely with Dr Róisín Campbell-Palmer. Róisín is an experienced field biologist and she was the Conservation Manager for the Royal Zoological Society of Scotland (RZSS) and Field Operations Manager for the Scottish Beaver Trial (SBT). She is currently acting as the service provider for SNH on the Scottish Government beaver mitigation scheme. Róisín is licensed by SNH to undertake all trapping and transportation procedures where lethal control licences have been issued and landowner permission for trapping granted. The following protocol will be followed:

- All beavers to be sourced from assessed conflict sites within the River Tay and Earn catchment, where lethal control licences have already been issued by SNH.
- Róisín can offer these sites trap and removal using agreed and approved trapping and animal handling procedures. Trapping can be undertaken where lethal control licences have been issued and landowner permission for trapping granted.
- Trapping will be undertaken by Róisín and the beavers will be lived trapped using specially designed cage traps. Site location is determined by lethal control licences. Prior to any trapping the site is assessed by the Róisín to determine if this mitigation is viable at the site, this includes overview of public access to traps, access of site to move equipment and removed crated animals, safe trap placement to ensure any water fluctuations do not impact trap, other wildlife or livestock are not targeted, trapped beavers not subjected to exposure to the elements, other animals or members of the public as far as reasonable.
- Beavers will be trapped under licence between 18$^{th}$ August to 18$^{th}$ April inclusive each year. This will avoid the kit dependency period in summer, as well as to avoid the trapping and translocation of heavily pregnant or lactating females.
- Traps will be set and baited in the evening and checked early every morning. This process will continue until all ‘conflict’ animals have been caught or further trapping not viable. Traps will be regularly moved within a site according to freshest field sign activity and availability of suitable sites.
- After the trapping period all traps will be removed from site.

Once an individual has been caught it will be transferred to a temporary specifically built beaver holding facility at Five Sister Zoo for full health assessment.

## 7. Beaver Health & Welfare

MWT (with the assistance from the WBP) will be responsible for the health and welfare of the beavers following release. If an individual beaver appears unwell MWT will seek veterinary advice and attempt to capture the animal if required. Any significant injuries or unwell individuals would be treated as far as possible and re-release back into the enclosure is deemed suitable by a veterinary surgeon under the project licence.

## 8. Public Health

A peer reviewed Disease Risk Analysis (DRA) (Appendix III) for the reintroduction of beavers to Britain has recently been published and it can also be used for the purpose of this project and the release of beavers into an enclosure.

Health screening has been routinely undertaken on a number of beaver populations in Britain (Knapdale, Tayside and Devon), additionally numerous animals have been screened for release into enclosed projects. There has been no significant diseases or parasites of concern found in any of these animals to date. The Tayside population is by far the largest and deemed a highly suitable source population.

The SBT established a health surveillance programme based on the IUCN and governmental guidelines (Woodford, 2000; Goodman, 2012 and Goodman, 2014). SBT screened all of their animals (wild caught beavers from Norway) prior to release and all animals were deemed fit for release, as no significant pathogens were found that prevented any individuals from being released into Knapdale (Goodman, 2012 and Goodman, 2014). Between 2012-2014 an additional health screening programme was set up for the River Tay and Earn catchment to assess the disease risk posed by the free-living beavers within the catchment (Campbell-Palmer *et al.* 2015b). This screening programme was based on the guidelines established for SBT and a sample of 21 beavers were screened during this period (Campbell-Palmer *et al.* 2015b), with significantly more beavers screened since this commissioned report. All animals examined were in good body condition and there was no evidence of ill health or any infectious diseases of importance to humans, domestic animals or other native wildlife species (Campbell-Palmer *et al.* 2015b). The Scottish Government has also declared the Scottish beavers to be *Echinococcus multilocularis* free and wild-caught beavers from within the UK are an acceptable source for licensed releases in Britain (Defra and Natural England, 2018). Ongoing monitoring of the River Otter beavers in Devon have also shown that all animals assessed are in good body condition and there has been no evidence of any significant injuries or diseases (Devon Wildlife Trust 2016 and Devon Wildlife Trust 2018). Wild caught Scottish beavers have been translocated to several high-profile licensed projects in England, including the Forestry England project in Cropton Forest, Yorkshire and the Spains Hall Estate in Essex (Forestry England, 2019; Spains Hall, 2019).

*E. multilocularis* or more commonly known as the fox tape worm has been raised as a health concern in unlicensed beaver releases. This parasite is absent from the UK, including Wales (Barlow *et al.* 2011; Campbell *et al.* 2015a; Girling *et al.* 2019), but it has been found in beavers, amongst other mammals, on the continent (Barlow *et al.* 2011; DEFRA, 2012; Campbell *et al.* 2015a; Girling *et al.* 2019). The adult tapeworm lives in the small intestines of the final host (carnivores) (Barlow *et al.* 2011; Campbell *et al.* 2015a). Red fox (*Vulpes vulpes*) are the usual definitive host, but domestic dogs (*Canis lupus familiaris*) are also susceptible to infection and parasite egg excretion, while cats (*Felis catus*) although becoming infected, rarely shed parasite eggs in their faeces (Campbell-Palmer *et al.* 2015a). Intermediate hosts (omnivores and herbivores) become infected when they ingest the parasitic eggs (Barlow *et al.* 2011; Campbell *et al.* 2015a). Beavers can act as a rare intermediate host for *E. multilocularis* (Campbell *et al.* 2015a), but they do not shed the parasitic eggs in their faeces, this only occurs in the final host (Campbell *et al.* 2015a). The only route by which beavers, and other intermediate hosts can transmit *E. multilocularis* is via predation or scavenging; a carnivore must, within a short time-span, ingest the cysts within an infected beaver that has recently died (Barlow *et al.* 2011; DEFRA, 2012; Campbell *et al.* 2015a; Girling *et al.* 2019). Therefore, an individual beaver cannot transmit this parasite directly to another intermediate host or between parent and offspring, as a final host is required (Barlow *et al.* 2011). Measures will be taken as described in the DRA to ensure that *E. multilocularis* will not be present in any beavers released by the project.

To minimise the risk of introducing *E. multilocularis* to the UK the founder stock for the enclosure will be wild-caught beavers, British born from the River Tay and Earn catchments in Scotland (Girling *et al.* 2019). Old adults (>10years) will not be used as a source for this project to ensure that only animals born in Britain are translocated to the enclosure. This will minimise the risk of *E. multilocularis* introduction even further, though it should be noted *E. multilocularis* has never been found in Scotland (Campbell *et al.* 2015a; Girling *et al.* 2019). All individuals will be fully health screened according to DEFRA requirements (Appendix II) prior to release to ensure that only healthy individuals will be released into the enclosure.

## 9. Release

Once the animals are deemed fit for release, all individuals will be transported in specially constructed crates. These crates will be lined with heavy-gauge weld mesh or sheet metal with a small inspection hatch to enable feeding and inspection during transportation. Each crate will be lined with a deep layer of straw or sawdust and apples provided for moisture. Adults and sub-adults will be transported in separate crates. If any yearlings or kits are to be translocated, they can either be crated together or with a parent, but they must have enough space for movement and should not be confined together for long periods of time. The animals will be driven from the holding facility to the release site, in a well-ventilated vehicle. On arrival at the Cors Dyfi Wildlife Centre, all animals will be given a final check prior to release into the enclosure.

The enclosure will contain three connecting freshwater ponds with adequate all-year round resources; soft vegetation including rush (*Juncus* sp.), reed (*Phragmites australis*) and bulrush (*Typha latifolia*) and woody vegetation, particularly birch and willow to maintain a beaver family. There will be opportunities for the beavers to expand the ponds, create channels within the wetland and create areas of new open water. In addition, there are areas of dry ground within the proposed enclosure, including an elevated dry bank. These drier areas will provide opportunities for shelter building, where lodges may be constructed or burrows dug into the bank. There is plenty of wooded vegetation within the enclosure for natural shelters to be constructed by the beaver family. An artificial lodge, consisting of straw bales will be installed within the enclosure to ensure the beavers have shelter upon immediate release. The lodge will be situated near the edge of a pond with the entrance facing the water’s edge. The transport crates will be placed near the water’s edge and opened. The animals will make their way out in their own time. The beaver pair/family will be closely monitored as they settle into their new environment.

## 10. Monitoring

The beavers and their activity will be regularly monitored by staff and volunteers. This will be through direct field observations and with the assistance of camera traps, which will also allow MWT to check the presence of animals within the enclosure, along with their general body condition and behaviours. The following parameters will be monitored:

- Evidence of breeding
- Age class presence – adult, subadult or kit
- Individual body condition, indication of any injuries
- Ear tag presence and individual identification
- Presence of any prominent scars or markings

Ecological monitoring has been undertaken on the reserve by Ecosulis Ecological Consultancy in order to establish a baseline prior to the release of beavers onto the reserve. This monitoring started in 2018 and it will continue throughout the duration of the project (King, 2018b). Aquatic invertebrates, bats and bryophytes have been chosen as indicator groups to assess the impacts on biodiversity and these three indicator groups will be monitored over three different study areas within the reserve; the proposed beaver enclosure location, water buffalo enclosure and a control area (King, 2018a). This will allow evaluations to be made between the effects that beavers can have on biodiversity compared with the effects of water buffalo and establish whether beavers are a suitable habitat management tool (King, 2018a, b).

In addition, fixed point photography will be undertaken at regular intervals to monitor the visual changes to the habitat within the beaver enclosure. The fixed points will be set up and a set of photographs taken prior to the release of beavers to establish a baseline. Fixed point photographs will then be taken every three months throughout the duration of the project.

Beavers are also known to influence the hydrology of wetland habitats where they can increase water storage through the creation of dams, pools and channels (Puttock *et al.* 2017). Due to the topography within the enclosure it is unlikely damming will be a key behaviour and it is more likely that the beavers will create areas of open water by digging channels and expanding the ponds, which will assist in restoring the lowland peat bog. To monitor the hydrological impact of beavers, dipwells will be installed within the enclosure and within the control area to measure the water levels. The wells will be left for one month after they are installed to allow them to equilibrate with the soil water table. Measurements will then be taken every month before and after beavers are released.

### ***Other Species***

Cors Dyfi Nature Reserve supports a range of wildlife from amphibians, grass snakes (*Natrix helvetica*), common lizards (*Zootoca vivipara*), dormice (*Muscardinus avellanarius*), otters (*Lutra lutra*) and ospreys (*Pandion haliaetus*). Many species can benefit from beaver activity, but we anticipate that amphibians and grass snakes will benefit particularly well due to the increase in suitable habitats and foraging opportunities (Rosell *et al.* 2005; Meβlinger, 2014; Elliott *et al.* 2017). Species, such as otter can also benefit due to the increase in foraging opportunities and measures will be taken to limit any potential negative affects the construction of the enclosure could have on otters. The proposed location of the enclosure is not within a known otter territory or traversing route. A survey undertaken in November 2019 found no evidence of holts, couches or sprainting sites within the proposed location for the enclosure. Prior to the construction of the enclosure a follow up otter survey will be undertaken to verify the presence/likely absence of an otter territory (see otter survey report). The presence of the enclosure is unlikely to affect the foraging opportunities for otters on site, as there are other accessible water bodies on the reserve (see map 1 on page 5).

## 11. Management

MWT (with the assistance of the WBP) will be responsible for the management of the beavers within the enclosure and enclosure maintenance. Cors Dyfi Wildlife Centre has 3 members of staff and c100 volunteers, which ensures that the fence will be inspected on a daily basis and maintained to a high standard. As part of a wider beaver strategy the WBP has been working closely with Welsh Government to establish a Beaver Management Network in the area and this will involve training key staff and volunteers on beaver management topics and the purchase of beaver management equipment, such as a beaver traps and crates. Equipment will be stored at Cors Dyfi Wildlife Centre.

The beaver family will be regularly monitored and if there is any evidence of infighting, such as increased cut tails then the older offspring will be removed from the enclosure and rehomed. These individuals will be lived trapped and moved on to other beaver projects within Britain. This will be reviewed on an annual basis over the five-year period. It is hoped that the project will continue after the 5 years and a breeding pair/family can remain on site to continue the habitat management work that is required. In the longer term, to avoid overcrowding within the enclosure, subadult beavers will be removed and translocated to other projects. In the event of mortality with one of the breeding adults, then it is possible that a new adult could be introduced to the enclosure. However, this will have to be assessed on a case by case basis. Any new introductions to the enclosure will be closely monitored to assess the welfare of all animals and to check for any evidence of infighting. If any infighting does occur the individual will be lived trapped and moved on to another beaver project within Britain.

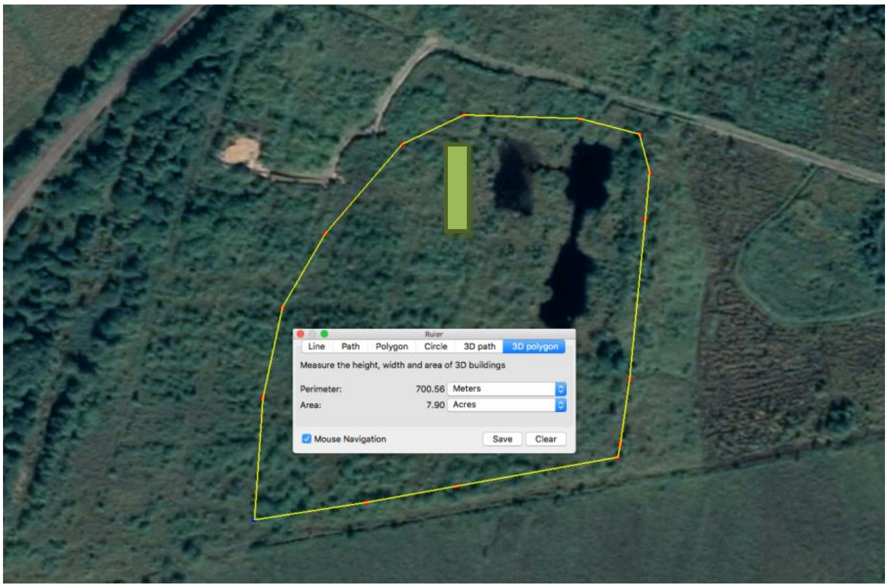
In the event that a beaver does escape from the enclosure, key staff and volunteers will be on hand to locate the animal and trap. The animal will be trapped under the project licence by the named ecologist or accredited agents and returned to the enclosure. An escaped beaver will be located by looking for evidence of signs, such as active feeding signs.

If an individual animal cannot be returned to the enclosure, then alternative arrangements will have to be made. These include:

1. Transferred to another British project (providing there are projects seeking new animals).
2. Housed in an enclosure or in captivity (providing there is space within these collections and it is not detrimental to the health and welfare of individual animals).
3. Humanely destroyed as a last resort.

An access track will be maintained around the perimeter fence to ensure that it can be checked on a regular basis. There will be no trees within the vicinity of the fence line that are at risk of falling on to the fence. Any additional trees within the enclosure that are close to the fence will be protected with wire mesh guards or anti-game paint. This will prevent the beavers from felling these trees.

Cors Dyfi is also prone to flooding, but the fence will be constructed to a minimum height (at least 1.2m) that will ensure the flood water will not overtop the fence line and permit beavers to escape. During flooding events the water level will be closely monitored to ensure the welfare of the animals and to assess the risk of any potential escapes. There is an area of higher ground present within the enclosure that will provide beavers with an area to retreat too, should the reserve experience severe flooding. The area of higher ground is shown on the map below in green. It is a sufficient distance from the perimeter fence and therefore, does not comprise the security of the enclosure. It is approximately 1m above the level of the surrounding area and is made of material that was dug out when the ponds were created around 20 years ago. During the extreme flooding event in 2012, this area of ground remained above the water level. Although sections of the reserve can flood easily, the water level often retreats quickly due to the tidal influence of the river catchment.




Map 3 - showing embankment area within the beaver enclosure

### 12. Exit Strategy

A clear exit strategy will form an integral part of the Cors Dyfi Beaver Project. MWT firmly believes that the project will be successful; however, a strategy for removal has been developed as a precautionary approach.

The exit strategy would be implemented in the event that:

1. Unsustainable and intractable detrimental effects arise on land, property or livelihoods as a proven direct result of beavers within an enclosure at Cors Dyfi Nature Reserve.
2. There is an unacceptable level of escapes from the enclosure, e.g. an animal escapes every week.
3. An unacceptable risk to human health or livestock becomes apparent as a proven direct result of beavers within an enclosure at Cors Dyfi Nature Reserve.

4. There is an unacceptable level of mortality in the beaver family or impacts on animal welfare within the enclosure.

In the event that the exit strategy is triggered and the beavers have to be removed, the following options are:

1. Transferred to another British project (providing there are projects seeking new animals).
2. Housed in an enclosure or in captivity (providing there is space within these collections and it is not detrimental to the health and welfare of individual animals).
3. Neutered and returned to the enclosure to live out their life-span in captivity.
4. Humanely destroyed as a last resort.

All parties involved in the project are committed to the Exit Strategy and fully understand its implications. Beavers would be live trapped in specifically designed beaver traps. The trapping will be undertaken under licence by the named ecologist or accredited agents. If any animals are to be humanely destroyed this will be undertaken by qualified personnel and this action must only be taken as a last resort, when all other management options have been exhausted.

Any cadavers would be stored appropriately for full post-mortem and sample collection by research organisations and/or collaborating vets/pathologists locally as far as possible. Following post-mortem specimens would be retained for research and education purposes as appropriate.

At the end of the project MWT will make formal recommendations (subject to revisions) to NRW regarding the long-term management of the beaver family. MWT envisage that the current project management structure will be dynamic and adapt to the requirements of the project programme.

***Procedures for Determining Exit***

The procedures for managing and delivering the Exit Strategy will be formally adopted by all MWT and the WBP steering group.

The procedures will be circulated to NRW for comment and amendments where appropriate will be agreed.

This determination will be informed by the publication of a report that will detail beaver impacts and associated acceptability. The steering group will also react to any event that triggers (or has the potential to trigger) an exit criterion immediately and convene extraordinary meetings, including additional stakeholders, where appropriate.

The final decision on whether the Exit Strategy will be triggered will rest with NRW. In the event of the Exit Strategy being triggered all project staff and advisors will work in unison to remove all beavers from the enclosure. All communications will be dealt with by the nominated lead organisation only.

NRW would be invited to attend all meetings in an observational and advisory capacity and be party to all correspondence relating to exit triggers.

The role of NRW, as independent monitors of the project, would be to licence the implementation of the Exit Strategy, if and as required.

***Criteria for Success/Failure***

During the project's lifetime, information on the beavers will be collated. At the end of the project the information gathered will be presented to NRW as a report.

***Criteria for success:***

- Survival of the animals is similar to successful enclosed projects elsewhere in Britain at similar period of population establishment.
- Their role as a habitat management tool has had a beneficial impact on the reserve.

***Criteria for failure:***

- Natural mortality levels preclude establishment of the beaver family within the enclosure.
- Significant and unsustainable damage is incurred to land, property or livelihoods as a proven direct result of beavers within an enclosure at Cors Dyfi Nature Reserve.

## 13. Health and Safety of Project Personnel

MWT have a responsibility to secure the health and safety all those involved with the operations of this project. This includes project staff, support staff, volunteers and students working on the project. All field staff and volunteers will be provided with full training on specific methods, which should be adhered to, to ensure the safety for all.

## 14. Project Management Structure

- Principal Applicants – MWT
- Cors Dyfi Beaver Project Team – Project Staff from MWT, WBP and independent advisors.
- The Welsh Beaver Project Steering Group (to oversee and manage the project):
    - Wildlife Trusts Wales
    - North Wales Wildlife Trust
    - Montgomeryshire Wildlife Trust
    - Natural Resources Wales
    - Dr Róisín Campbell-Palmer
    - Gwynedd County Council
    - Powys County Council
    - Ceredigion County Council
    - Visit Wales

## 15. Timeline for beaver plan

The table below outlines key dates and actions for the release of beavers to an enclosure at Cors Dyfi. The work is part of a cross-Wales strategy and as such timeframes may be affected by factors beyond our control.

| Date | Action |
|---|---|
| **2018 – ongoing** | Discussions with WBP, NRW and Welsh Government about the overarching strategy for beavers in Wales. |
| **2018-ongoing** | Public engagement – speaking to neighbouring landowners about MWT plans for a beaver enclosure at Cors Dyfi Wildlife Centre. |
| **Winter 2018** | Initial baseline biodiversity survey report due from WBP/Ecosulis Consultants.<br><br>First baseline survey report submitted in November 2018.<br>Second baseline survey report submitted in January 2020. |
| **Summer - Winter 2019** | Gather quotes from local contractors for the clearance work and fencing work relating to the enclosure.<br><br>Three quotes from local contractors were submitted in February 2020. |
| **Autumn - Winter 2019** | Site preparation and enclosure fencing installed.<br><br>Site preparation work was undertaken in January 2020.<br>Fencing work commenced in February 2020 and it will be completed by the end of March 2020. |
| **Winter - Spring 2019** | Work with WBP and their contacts to source suitable animals and ensure all, health checks and legal requirements are met. |
| **Spring - Autumn 2020** | Staff and volunteer training in beaver management and lookering.<br>Release of a pair of beavers/beaver family into the enclosure. |
| **After beaver introduction** | Monitoring of beaver health and wellbeing.<br>Maintenance of enclosure and fences.<br>Education work with visitors.<br>Beaver watching events and activities. |

## 16. Project Costs

The initial budget proposed for the beaver enclosure and associated costs is set out below:

| Fencing and enclosure construction | Beaver sourcing and screening for release | Interpretation and education |
|---|---|---|
| £30,000 | £6,000 | £6,000 |

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Thank you to Derek Gow and Gerhard Schwab for visiting Cors Dyfi and for all of their help, advice and inspiration in developing the project. Thank you to Dr Róisín Campbell-Palmer for all of her advice, support and time, and Dr Simon Girling for the Disease Risk Analysis. We would also like to thank Colin Preece near Llangors for hosting a MWT visit to Eligro Nature Reserve to view the beaver enclosure and Sara King from Ecosulis for undertaking the baseline monitoring at the reserve and their continued support of the project. Lastly, we are very grateful to all those who have commented on earlier drafts of this proposal.

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## Appendix I.

## Specification options for safe otter passage in beaver enclosures (by Roisin Campbell-Palmer, June 2019)

**Pipes of less that 12cm diameter would be sufficient: multiple pipes** must be inserted in the fence line **on either side of the main water course and lifted off the ground**. Beavers will tend to trundle along a fence line aiming to dig against it where the fence meets the ground to try and get out.

Raising pipes mean that beavers are less likely to find and notice them.

It is essential the pipe is not flush with the fence on the inside (beaver side) i.e. it extends out into the enclosure so it is harder for the beaver to find the end and associate it with escape. In theory a beaver would have to find the end and pull itself up above its head and push through a pipe which they aren't agile enough to do and quite reluctant.

**An alternative to piping could be a thin ledge (wood like 2x2 or metal**) that is slim and not able to support a beaver. A step / ledge can be constructed on the outside of fence to assist otter climbing up and into the pipe / ledge. As long as height in fence line and width of pipe /ledge and extension into the enclosure is met, it would be highly unlikely beavers would find or use it.

**12 cm gaps in fences** will certainly present a risk of beaver passage - especially of individuals <2years, so young and dispersers – however noting the general behaviour of beavers tending to follow water, and digging at fences as supposed to scaling (unless water levels high and they only have a short height to pull themselves over a vertical stretch), the above specifications should allow safe otter passage and prevent beaver escape.

# Appendix II. DEFRA Health Screening Requirements

## Defra and Natural England

**Acceptable sources of beavers and minimum requirements for health and disease screening for licensed releases into fenced enclosures and the wider countryside**

| **Source of beaver** | Source acceptable for release in England | | Disease screening requirements* | |
|---|---|---|---|---|
| | *Wild caught* | *Captive bred* | *Wild caught* | *Captive bred* |
| United Kingdom | Yes | Yes | List A & B | List A |
| Echinococcus multilocularis free countries (Finland, Ireland, Malta) | Yes | Yes | List A & B | List A |
| Norway (except island of Svalbard) | Yes | Yes | List A & B | List A |
| All other European countries and Svalbard (Norway) | No | Yes – but requires an attestation from the place of origin | n/a | List A, B and C and may require Rabies quarantine for 4 months |

| **Pathogen and parasite screening requirements*** | | |
|---|---|---|
| List A | List B | List C |
| • Bovine tuberculosis (High Risk Areas only: http://www.tbhub.co.uk/risk-map/ )<br>• Salmonella | • Leptospirosis<br>• Cryptosporidium parvum<br>• Giardia lambia<br>• Tularemia<br>• Hanta virus and related viruses, such as Puumala virus | • Echinococcus multilocularis |

| **Outcome if pathogen or parasite detected*** | |
|---|---|
| Cryptosporidium parvum<br>Giardia lambia<br>Hanta virus<br>Leptospirosis<br>Salmonella<br>Tularemia | **Release permitted** so long as the beaver is certified as healthy and fit for release by a suitably qualified veterinary surgeon and / or other suitably qualified person approved by Natural England, and the strain detected is not exotic to the UK. If the strain is exotic then the beaver should not be released.<br>Inform local water authorities and issue warning signage to prevent people drinking water. |
| Bovine tuberculosis<br>Echinococcus multilocularis | **Do not release** and destroy the positive animal |
| Rabies | **Do not release** and destroy the positive animal and any other animals in the same group |

*: Health and disease screening requirements and outcomes may be revised on veterinary advice. Advice correct as of 2 November 2018

## Appendix III. Disease Risk Analysis

A disease risk analysis prepared by Girling *et al.* (2019) for the reintroduction of beavers to Britain can be found on the following pages.

Mammal Review

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REVIEW

# Reintroducing beavers *Castor fiber* to Britain: a disease risk analysis

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**Keywords**
*Castor fiber*, Eurasian beaver, health screening, reintroduction, species restoration

*Correspondence author.

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## ABSTRACT

1. Eurasian beavers *Castor fiber* are potential hosts for a range of infectious diseases and parasites, including those typical of common European rodents. A number of infectious organisms are potentially zoonotic and may be notifiable under animal health legislation. The official trial beaver reintroductions to Scotland, the retrospectively licensed releases in England, and the increasingly obvious presence of large numbers of unlicensed illegally released animals have highlighted potential disease risks.
2. We aimed to conduct a disease risk analysis, based on peer reviewed publications, for selection and health screening of Eurasian beavers prior to release into the wild in Britain.
3. Adapted from the International Union for the Conservation of Nature's 'Guidelines for Disease Risk Analysis', a four-step process was used to formulate a disease risk analysis: 1) problem description; 2) hazard identification based on literature review; 3) risk assessment, which resulted in categorisation of pathogens into low, medium, and high risk; and 4) risk management: identification of mitigating measures, followed by risk re-evaluation in light of the reported effectiveness of the mitigation measures.
4. The highest-risk pathogens identified in the literature review process included: parasites, specifically *Cryptosporidium parvum*, *Echinococcus multilocularis*, *Eimeria* spp., *Fasciola hepatica*, *Giardia* spp., *Trichinella britovi*; bacteria, specifically *Escherichia coli*, *Franciscella tularensis*, *Mycobacterium avium*, *Salmonella* spp., *Yersinia* spp.; a fungus *Chrysosporium parvum* (*Emmonsia parva*); and terrestrial rabies virus. Most could be mitigated by sourcing beavers from Britain. The rest could be mitigated by pre-release testing procedures that are already established.
5. The risk of introducing significant disease to humans, domestic animals, or wildlife by releasing into the wild in Britain a beaver that was captive-bred in Britain or a wild beaver from Scotland, based on the current evidence of disease incidence, and assuming the use of robust, peer reviewed, pre-release health screening techniques, can be viewed as low.

## INTRODUCTION

Interventional conservation methods, such as translocations and reintroductions, have been increasingly employed to assist species' survival and ecosystem restoration (Seddon et al. 2014). Whilst there appears to be popular support for the concept of wildlife reintroductions, it is important to recognise that the way in which these reintroductions have taken place has been varied, in terms of method and legality. The International Union for Conservation of Nature's (IUCN) 'Guidelines for Reintroductions and Other Conservation Translocations' and 'Guidelines for Wildlife

Disease Risk Analysis' were developed to facilitate and improve the success and long-term acceptance of reintroductions, and are widely accepted to be effective codes for best practice (IUCN/SSC 2013, 2014).

The importance of animal health in conservation programmes is increasingly recognised, as the success of any reintroduction can be significantly reduced by infectious disease (Viggers et al. 1993, Ewen et al. 2015). Despite this recognition, the implementation and development of pre-reintroduction and post-release veterinary health programmes (i.e. disease risk analyses and disease surveillance programs, respectively) tends to receive less investment than other aspects of release projects, such as genetic management (Jamieson & Lacy 2012). Pre-reintroduction and post-release health assessments are recommended, as translocated animals can potentially introduce new pathogens into the release area (Cunningham 1996, Kock et al. 2010).

Driven to virtual extinction throughout Eurasia by the fur trade in the 19th century, the Eurasian beaver *Castor fiber* now once again inhabits large tracts of its native range, as a result of the cessation of hunting, natural expansion from relict populations and proactive translocation projects (Nolet & Rosell 1998, Halley et al. 2012). In over 26 countries in Eurasia there have been more than 200 beaver release projects, the histories of which are complicated and often lacking in documentation (Macdonald et al. 1995, Nolet & Rosell 1998, Halley & Rosell 2002, Halley 2011, Halley et al. 2012). Few projects have well-documented health surveillance, disease, and mortality figures, with Nolet et al. (1997) an exception.

From a health and biosecurity perspective, beavers have historically been considered to present no greater risk to human, livestock, or other wildlife health than any other native mammal. However, the identification of the zoonotic parasite *Echinococcus multilocularis* in England in a wild-caught captive beaver directly imported from Bavaria (Barlow et al. 2011) and, more recently, a beaver testing positive for the parasite at pre-release screening (B. Gottstein, personal communication) illustrates the risk of introducing non-native parasites and diseases. Although intended for conservation purposes, poorly managed beaver releases could result in serious health risks and have significant consequences, not only for human and animal health, but also for public support of future reintroduction projects.

Beaver reintroduction to Britain (mainland England, Scotland and Wales), where historic evidence of Eurasian beavers is apparent, has not been without its controversies, and health risks seem to have attracted particular concerns. Reintroduction of the Eurasian beaver is currently being actively considered in all countries of Britain. A trial reintroduction, the Scottish Beaver Trial, was carried out in Knapdale, Argyll, from 2010 to 2015. This was the first official reintroduction of a mammal species to Britain in modern history. Despite recommendations for a more comprehensive process of restoration, the return of the beaver to Britain has been a haphazard affair, highlighted by the presence of sizeable populations (113 active territories; Campbell-Palmer et al. 2018) of beavers from unlicensed releases along the Rivers Tay and Earn catchment areas in Scotland, as well as pockets of smaller family groups in England (e.g. the River Otter, Devon).

Disease risk analysis is a rigorous method used to evaluate whether important health-related risks are associated with a proposed activity, such as the translocation of wild animals (Leighton 2002). As part of any responsible reintroduction programme or trial, pre- and post-release health assessments are essential to ensure that health and welfare legislation is complied with.

In order to assess the quantitative level of risk associated with the reintroduction of the Eurasian beaver to Britain, a disease risk analysis was performed. We aimed to combine historic literature on diseases of the Eurasian beaver with more recent literature resulting from disease screening as part of the trial reintroduction of beavers to Scotland and surveillance of beaver populations elsewhere in Britain. The end-goal of the disease risk analysis was to provide efficient and cost-effective disease prevention and mitigation strategies for future reintroductions. The framework we used follows the IUCN's 'Guidelines for Wildlife Disease Risk Analysis' (IUCN/SSC 2014).

## METHODS

Following the IUCN's 'Guidelines for Disease Risk Analysis', a four-step process to formulate the disease risk analysis was carried out (IUCN/SSC 2014).

### Step 1: problem description

During the official reintroduction of beavers to the wild in Scotland (the Scottish Beaver Trial), knowledge of which infectious diseases can affect and be transmitted by beavers was significantly expanded, but this information has still not been fully elucidated (Goodman et al. 2012, Campbell-Palmer et al. 2015b, c, d, Goodman et al. 2017). Ongoing concerns over possible inadvertent introduction of infectious diseases, including zoonoses that may adversely affect domestic animals and wildlife, have led to a slow-down on further reintroductions in the UK (Barlow et al 2011, Goodman et al. 2017). The identification and quantification of risks associated with these diseases have been highlighted by central and devolved governments in the UK as vital to a pre-release disease risk analysis, following the IUCN's 'Guidelines for Disease Risk Analysis' (DEFRA 2012, IUCN/SSC 2014).

## Step 2: hazard identification based on literature review

In an attempt to identify all the infectious disease hazards associated with a beaver reintroduction, a literature search on reported disease in captive and wild beavers was performed with the use of CAB ABSTRACTS, BIOSIS, and MEDLINE databases (Woodford 2000, Goodman et al. 2012). The literature search was focussed on the Eurasian beaver, but also took into account diseases reported in North American beavers *Castor canadensis* and other semi-aquatic and terrestrial rodents (Order Rodentia), with an emphasis on those in the northern hemisphere and Europe. This was done in order to cover those diseases which theoretically may occur in the Eurasian beaver but which have yet to be reported. To ensure coverage of the widest range of potential pathogens within the risk assessment process, we reviewed just over 700 papers.

## Step 3: risk assessment

For each identified hazard, a qualitative risk assessment was determined, based on available scientific literature, so as to allow ranking of hazards into low-, medium-, and high-risk bands (OIE 2012, IUCN/SSC 2014). Each hazard was assessed using the following criteria (see Table 1):

1. Hazard severity – assessed by the severity of the disease caused (from subclinical to fatal) in beavers, wildlife, domestic animals or humans, and the degree of medical intervention required.
2. Likelihood of occurrence – assessed on the likelihood of recrudescence of subclinical disease and the introduction of a novel pathogen, based on whether the pathogen had previously been reported in *Castor fiber* (very likely), *Castor canadensis* (likely) or other semi-aquatic/related northern hemisphere rodent species (possible), and in all other rodent species (unlikely).

After assignment of hazard severity and likelihood of occurrence scores, these values are multiplied together to obtain the risk band (see Table 1).

## Step 4: risk management

For any hazard severity assessed by the above process and ranked as low, no further risk management was carried out and the overall risk was considered low. For all other hazards, risk management strategies were assessed (see Tables 2-6). Management strategies to prevent the introduction of pathogens included identification of diagnostic testing methods which could produce a high degree of sensitivity and specificity (>85%), allowing the exclusion of infected beavers from release. The presence of the pathogen in Britain was also considered at this stage, in order to assess the possible impact of inadvertent pathogen release. If the hazard could be effectively excluded through diagnostic testing and/or the pathogen is already widespread in Britain, then the post-management risk was considered to be low (see Tables 2-6).

**Table 1.** In the risk assessment, scores on a scale of 1–5 for the likelihood of occurrence (top row) and for the hazard severity (left column) were multiplied to give the overall hazard severity score, on a scale of 1–25, as shown in the table. Risk bands for pre-management strategy were allocated to the overall score as follows: 1–8: low risk, 9–12: medium risk, 13–25: high risk

| | Likelihood of occurrence → | | | | |
|---|---|---|---|---|---|
| ↓ Hazard severity | 1. Remote (almost never) | 2. Unlikely (occurs rarely) | 3. Possible (could occur, uncommon) | 4. Likely (recurrent occurrence episodes) | 5. Very likely (occurs frequently) |
| 1. Trivial (subclinical or no treatment required) | 1 | 2 | 3 | 4 | 5 |
| 2. Minor (minor discomfort, basic first aid only) | 2 | 4 | 6 | 8 | 10 |
| 3. Moderate (short-term treatment) | 3 | 6 | 9 | 12 | 15 |
| 4. Serious (supportive feeding, intensive treatment) | 4 | 8 | 12 | 16 | 20 |
| 5. Fatal (single or multiple) | 5 | 10 | 15 | 20 | 25 |

**Table 2.** Summarised disease risk assessment for haemo- and endoparasites in beavers for translocation. The table is laid out to take into consideration risk factors for each pathogen, such as: whether the pathogen has been reported in Eurasian beavers, North American beavers or other rodents (i.e. a decreasing risk scale); whether the pathogen is zoonotic; whether the pathogen has been associated with domestic animal or other wildlife disease and so may have other serious implications if introduced; and whether the pathogen is already present in Britain. If the risk assessment band is then considered low, no further risk management strategy is considered. If the risk assessment band is considered medium or high, suggestions for risk management strategies are given based on peer-reviewed publications to convert the risk band post-management strategy to low. See the text for details of specific pathogens, and Table 1 for the categorisation of risk bands for pre-management strategy.

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk band pre-management strategy | Present in Britain? | Risk management strategies | Risk band post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Anaplasma phagocytophilum* | No | No | Low prevalence or absence in rodents (Wiger 1979, Healing 1981). Field voles *Microtus agrestis* main reservoir in Britain (Bown et al. 2003) | Yes | Yes | LOW (score 3) | Yes | None | LOW |
| *Babesia microti, Babesia divergens* | No | No | *Babesia microti* common in North American rodents and less common in Northern Europe. *Babesia divergens* more common in Europe (Bown et al. 2008) | Yes | Yes | MEDIUM (score 12) | Yes | Blood smear assessment and PCR (Wilson et al. 2015, Tolkacz et al. 2017) | LOW |
| *Bartonella* spp. | No | No | Reported in wild rodents (Birtles et al. 2001) including water voles *Arvicola terrestris* (Oliver et al. 2009) | Yes | No | MEDIUM (score 9) | Yes | Blood smear assessment and PCR (Morick et al. 2009) | LOW |
| *Haemobartonella (Mycoplasma)* spp. | No | No | Infection rates of 77% in Polish common voles *Microtus arvalis* and 63% in bank voles *Myodes glareolus* (Bajer et al. 2001, Pawelczyk et al. 2004) | No | No | LOW (score 6) | Yes | Blood smear assessment and PCR (Goncalves et al. 2015) | LOW |
| *Hepatozoon* spp. | No | No | Commonly seen in Muridae; found in circulating leucocytes and body organs (Yarto-Jaramillo 2015) | No | No | LOW (score 2) | Yes | Blood smear assessment and PCR (Rigo et al. 2016) | LOW |

(Continues)

**Table 2.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk band pre-management strategy | Present in Britain? | Risk management strategies | Risk band post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Trypanosoma* spp. | No | No | Reported in South American rodents; *Trypanosoma lainsoni* in spiny tree rat *Mesomys hispidus* (Naiff & Barrett 2013), *Trypanosoma cruzi* and *Trypanosoma rangeli* in *Aegialomys, Akodon, Cavia, Mus, Rattus, Rhipidomys, Sciurus, Handleyomys, Hoplomys, Proechimys,* and *Transandinomys* (Ocano-Mayorga et al. 2015) | No | Yes | LOW (score 2) | Yes | Blood smear assessment and PCR (Ortiz et al. 2018) | LOW |
| *Calodium (Capillaria) hepatica* | Reported in the wild in Russia and in captivity in Russia and Hungary (Fuehrer 2014b) | Reported in the wild in Columbia and USA (Fuehrer 2014b) | Common in Muroidea (Fuehrer, 2014a) | Yes | No | LOW (score 5) | Yes | Use wild or captive-bred beavers from Britain as source population. PCR testing and endoscopic examination of the liver | LOW |
| Coccidiosis (*Eimeria, Isospora* spp.) | Reported in one young beaver (Goodman et al. 2012) | No | Common in many rodents but host-specific and generally subclinical infections (Yarto-Jaramillo 2015) | No | No | HIGH (score 15) | Yes | Faecal parasitology | LOW |
| *Cryptosporidium* spp. | Infection reported in Poland (Bajer et al. 1997) and UK (Goodman et al. 2012) | Infection reported in North America (Isaac-Renton et al. 1987) | Common in rodent species, such as *Cryptosporidium muris* in mice and *Cryptosporidium wrairii* in guinea pigs *Cavia porcellus*, not thought to be zoonotic (Bajer et al. 1997) | Yes (*Cryptosporidium parvum*) | Yes | HIGH (score 15) | Yes | Faecal parasitology (+/− acid fast staining) or real-time PCR | LOW |
| Cysticercosis or coenuriasis | Found during a survey of Scottish beavers (Campbell-Palmer et al. 2015a) | No | Rodents are intermediate hosts for many tapeworms; carnivores (e.g. domestic cat, dog) are the definitive host (Yarto-Jaramillo 2015) | No | Yes | LOW (score 5) | Yes | None | LOW |

(Continues)

**Table 2.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk band pre-management strategy | Present in Britain? | Risk management strategies | Risk band post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Echinococcus multilocularis* | Found in a captive animal in England imported from the wild in Bavaria, Germany (Barlow et al. 2011) | No | Reported in field and water voles; common in specific areas of Europe e.g. Bavaria, Germany (Miller et al. 2016) | Yes | Yes | HIGH (score 20) | No (except captive beaver reported by Barlow et al. 2011) | Use wild or captive-bred beavers from Britain as source population, or carry out testing protocol (Gottstein et al. 2014, Campbell-Palmer et al. 2015a) | LOW |
| *Enterocytozoon bieneusi* | No | No - negative results in 16 beavers tested (Guo et al. 2014) | Positive in 21 of 49 Sciuridae and 17 of 71 Cricetidae in a study in New York State (Guo et al. 2014) | Yes | Yes | LOW (score 4) | No | None | LOW |
| *Fasciola hepatica* | Found in 2 of 20 beavers (Shimalov & Shimalov 2000) | No | Recorded in coypu *Myocastor coypus* (Dracz et al. 2016) | Yes | Yes | HIGH (score 15) | Yes | Faecal parasitology | LOW |
| *Giardia* spp. | Yes – incidence 0–8% in the wild in Poland (Bajer et al. 2008); not detected in post-introduction site monitoring (Mackie 2014) | Prevalence 7–16% (Erlandsen et al. 1990) | Common in rodent species (Olsen & Buret 2001) | Yes | Yes | HIGH (score 15) | Yes | Faecal parasitology | LOW |
| *Rodentolepis (Hymenolepis) nana* | No | No | Common in Muridae and Cricetidae (Yarto-Jaramillo 2015) | Yes | No | LOW (score 4) | Yes | Faecal parasitology | LOW |

(Continues)

**Table 2.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk band pre-management strategy | Present in Britain? | Risk management strategies | Risk band post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Stichorchis subtriquetrus* | Yes (Goodman et al. 2012, Campbell-Palmer et al. 2013, Máca et al. 2015) | No | No | No | No | LOW (score 5) | Yes | None | LOW |
| *Travassosius rufus* | Prevalence 82% in Czech Rep. (Máca et al. 2015), 93% in Polish beavers (Drózdz et al. 2004) | No | No | No | No | MEDIUM (score 10) | No | Faecal parasitology | LOW |
| *Trichinella britovi* | Found in one beaver in Latvia (Seglina et al. 2015) | *Trichinella spiralis* (Russia, Romašov 1969) and *Trichinella nativa* (Dick & Pozio 2001) reported in North American beavers | Yes – rats in particular; brown rat *Rattus norvegicus* and black rat *Rattus rattus* (Dick & Pozio 2001) | Yes – requires digestion of raw beaver meat | Yes | HIGH (score 15) | No | Use wild or captive-bred beavers from Britain as source population | LOW |

# RESULTS

Results of the hazard identification, risk assessment, and risk management steps in the disease risk analysis are shown in Tables 2-6.

## Haemoparasites

As can be seen from Table 2, no haemoparasites have been reported in beavers, leading to low risk bands for all hazards (Cross et al. 2012).

## Endoparasites

As can be seen from Table 2, the highest-ranking endoparasite hazard is *Echinococcus multilocularis*, a zoonotic parasite of serious health concern that is regarded as one of the most pathogenic parasitic zoonoses in the northern hemisphere (Eckert et al. 2000, Vuitton et al. 2003). Although it is established in many countries in central Europe, other European countries are presently deemed free of this parasite, including the UK, which employs strict measures to prevent entry (DEFRA 2012). *Echinococcus multilocularis* has been identified in Eurasian beavers from Switzerland, Austria, Serbia and, more recently, in a captive imported beaver in England (Janovsky et al. 2002, Cronstedt-Fell et al. 2010, Barlow et al. 2011, Ćirović et al. 2012, Wimmershoff et al. 2012). Diagnosis of *Echinococcus multilocularis* in intermediate (non-egg-shedding) hosts such as beavers has historically been via post-mortem examination. Campbell-Palmer et al. (2015a) found that laparoscopic examination combined with ultrasound investigation for real-time diagnosis of *Echinococcus multilocularis* in beavers would allow the direct rapid identification of any abdominal lesions. Additionally, submission of blood samples for immunoblotting can be undertaken to identify early cases, raising combined test sensitivity to 85% (Gottstein et al. 2014). It is possible to reduce the risk from a low level to a negligible level by sourcing beavers for British introductions from pre-existing British (predominantly Scottish) free-ranging beaver populations that have been shown to be free of infection, or to use beavers that were captive-bred in the UK (DEFRA 2012, Campbell-Palmer et al. 2015d).

Other endoparasites are either considered non-pathogenic and host-specific (e.g. *Stichorchis subtriquetrus*) or are found at a low level and may easily be detected by pre-release faecal screening (e.g. *Fasciola hepatica*, *Cryptosporidium parvum*, *Giardia* spp.), making their risk band for post-management strategy low.

## Ectoparasites

As can be seen from Table 3, no ectoparasite has been associated with significant pathogenicity in Eurasian beavers, and all ectoparasites are easily screened for in a pre-release examination, making all risk bands for post-management strategy low.

## Bacterial pathogens

As can be seen from Table 4, the most significant bacterial pathogen from a zoonotic aspect is *Franciscella tularensis*, which is not found in Britain and has only been reported sporadically in Eurasian beavers (Mörner 1992, Schulze et al. 2016). The use of Eurasian beavers that were either captive-bred or wild-born in Britain as a source population would therefore reduce the risk for this pathogen to low (Mörner 1992, Schulze et al. 2016).

*Leptospira* spp. have been reported regularly in rodents and at a low level in beavers. Leptospirosis has been associated with *Yersinia* spp. infections and mortalities in Eurasian beavers in one introduction, although whether leptospirosis or yersiniosis was the cause of the mortalities was unclear (Nolet et al. 1997). In beavers tested in Britain, infection was identified but appeared not to be associated with clinical disease (Goodman et al. 2012, Campbell-Palmer et al. 2015b, 2015d). Based on these reports, it is theoretically possible that beavers could pose a potential source of *Leptospira* spp. infection to other animals, post-release, but persistent carrier status has yet to be demonstrated and seropositivity levels were considered low. This, combined with the ubiquitous nature of *Leptospira* spp. in Britain, makes the risk of leptospirosis associated with Eurasian beaver reintroduction low.

*Salmonella* spp. have been reported from Eurasian beavers in continental Europe, but not currently from beavers anywhere in Scotland (Romasov 1992, Rosell et al. 2001, Goodman et al. 2012, Campbell-Palmer et al. 2015d). Pre-release screening (by faecal culture) and/or using beavers from a captive-bred or Scottish source reduces the risk for post-management strategy for *Salmonella* spp.

Other bacterial potential pathogens that have resulted in the occasionally reported death of Eurasian beavers include strains of *Escherichia coli*, *Yersinia pseudotuberculosis*, *Yersinia enterocolitica,* and *Mycobacterium avium*. Pathogens that have been reported in rodent species other than beavers and which are potential risks to wildlife and humans include *Erysipelothrix rhusiopathiae*, *Brucella* spp. and *Listeria monocytogenes*. All of these pathogens have been reported in Britain, and all may be screened for in live beavers through faecal culture, polymerase chain reaction (PCR) or acid-fast staining, meaning any risk for post-management strategy is low.

**Table 3.** Summarised disease risk assessment for ectoparasites in beavers for translocation. The table is laid out to take into consideration risk factors for each pathogen, such as: whether the pathogen has been reported in Eurasian beavers, North American beavers or other rodents (i.e. a decreasing risk scale); whether the pathogen is zoonotic; whether the pathogen has been associated with domestic animal or other wildlife disease and so may have other serious implications if introduced; and whether the pathogen is already present in Britain. If the risk assessment band is then considered low, no further risk management strategy is considered. If the risk assessment band is considered medium or high, suggestions for risk management strategies are given based on peer-reviewed publications to convert the risk band post-management strategy to low. See the text for details of specific pathogens, and Table 1 for the categorisation of risk bands for pre-management strategy.

| Pathogen | Reported in *Castor fiber*? | Reported in *Castor canadensis*? | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Ixodes* spp. | Reported on beavers in the Scottish Beaver Trial (Goodman et al. 2012) | Animal infection 30%, lodge bedding infection 34% (Lawrence et al. 1956) | Yes (Barandika et al., 2007, Bown et al. 2008, Silaghi et al. 2012) | Yes | Yes | MEDIUM (score 10) | Yes (Barandika et al. 2007, Silaghi et al. 2012) | Pelage examination | LOW |
| *Platypsyllus castoris* | Common throughout range. Found on Scottish-born beavers (Duff et al. 2013) | Yes (Peck 2006) | No | No | No | LOW (score 5) | No | None | LOW |
| *Leptinillus validus* and *Leptinillus testaceus* | Additional Platypsyllinae species found in *Castor canadensis*, present in *Castor fiber* only where the species overlap (Peck 2006, 2007) | Yes (Peck 2007) | No | No | No | LOW (score 4) | No | None | LOW |

**Table 4.** Summarised disease risk assessment for bacterial pathogens in beavers for translocation. The table is laid out to take into consideration risk factors for each pathogen, such as: whether the pathogen has been reported in Eurasian beavers, North American beavers or other rodents (i.e. a decreasing risk scale); whether the pathogen is zoonotic; whether the pathogen has been associated with domestic animal or other wildlife disease and so may have other serious implications if introduced; and whether the pathogen is already present in Britain. If the risk assessment band is then considered low, no further risk management strategy is considered. If the risk assessment band is considered medium or high, suggestions for risk management strategies are given based on peer-reviewed publications to convert the risk band post-management strategy to low. See the text for details of specific pathogens, and Table 1 for the categorisation of risk bands for pre-management strategy.

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Aeromonas hydrophila* | No | Part of 'normal' conjunctival flora (Cullen 2003) | Opportunist pathogenicity, carrier status without disease (Lye 2009) | Yes | Yes | LOW (score 4) | Yes | None | LOW |
| *Arcanobacterium pyogenes* | Isolated in a deceased beaver but unsure if direct cause of death (Goodman et al. 2012) | No | Occasionally reported (Yarto-Jaramillo 2015) | Yes | Yes | MEDIUM (score 15) | Yes | Faecal bacterial culture | LOW |
| *Brucella* spp. | No | No (Moore & Schnurrenberger 1981) | Detected in capybara *Hydrochoerus hydrochaeris* (Lord & Flores 1983) | Yes | Yes | MEDIUM (score 12) | Yes | Serological testing | LOW |
| *Campylobacter* spp. | No | No | Reported in guinea pigs bred for food in South America (Graham et al. 2016). 4% incidence of *Campylobacter jejuni* by culture in wild rodents (Backhans et al. 2013) | Yes | Yes | LOW (score 6) | Yes | None | LOW |

(Continues)

**Table 4.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Chlamydia*-like organisms | No | No | Low incidence in small mammals (Stephan et al. 2014) | No | No (rodent strains not thought to be significant zoonosis; Longbottom & Coulter 2003) | LOW (score 8) | Yes | None | LOW |
| *Clostridium piliforme* (Tyzzer's disease) | No | No | Common in captive rodents, particularly Cricetidae, in the presence of stressors (Yarto-Jaramillo 2015) | No | Yes | LOW (score 8) | Yes | None | LOW |
| *Clostridium sordelli* | No | Reported in one animal without disease (Cullen 2003) | No – natural infections not reported (Yarto-Jaramillo 2015) | No | Yes | LOW (score 4) | Yes | None | LOW |
| *Enterobacter* spp. | No | Reported in one animal without disease (Cullen 2003) | No – not reported as a pathogen (Yarto-Jaramillo 2015) | No | No | LOW (score 4) | Yes | None | LOW |
| *Erysipelothrix rhusiopathiae* | No | No | Reported in coypu *Myocastor coypus* (Kohler et al. 1987) and other rodents particularly mice (Yarto-Jaramillo 2015) | Yes | Yes | MEDIUM (score 12) | Yes | Faecal bacterial culture | LOW |
| *Escherichia coli* | Isolated in a deceased young beaver during quarantine for Scottish Beaver Trial (Goodman et al. 2012) | Commonly identified but no enteropathogenic strains reported (Wong et al. 2016) | Commonly encountered enteric bacteria in rodents - enteropathogenic strains have only been reported as part of experimental studies (Yarto-Jaramillo 2015) | Yes | Yes | HIGH (score 25) | Yes | Faecal bacterial culture | LOW |

(Continues)

**Table 4.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Franciscella tularensis* | Sporadic reports in the wild (Schulze et al. 2016) | Considered a reservoir for type B form (Mörner 1992) | Reported in musk rats *Ondatra zibethicus* in North America, ground voles *Arvicola terrestris* in Russia (Mörner 1992), and voles in general (Koskela et al. 2016) | Yes | Yes | HIGH (score 25) | No | Use wild or captive-bred beavers from Britain as source population | LOW |
| *Lawsonia intracellularis* | No | No | Reported in domestic Cricetidae (Fiskett 2011) | No | Yes | LOW (score 8) | Yes | None | LOW |
| *Leptospira* spp. | Present in Scottish beavers and cause of translocation mortalities (Nolet et al. 1997, Goodman et al. 2012, 2017, Marreros et al. 2018) | Yes (Lopez-Perez et al. 2017) | Widely reported in captive and wild rodents (Yarto-Jaramillo 2015, Gelling et al. 2015) | Yes | Yes | HIGH (score 20) | Yes | Serological testing | LOW |
| *Listeria monocytogenes* | No | No | Widely reported in rodents (Yarto-Jaramillo 2015) | Yes | Yes | MEDIUM (score 10) | Yes | Faecal bacterial culture | LOW |
| *Micrococcus* spp. | No | Common isolate from North American conjunctival specimens (Cullen 2003) | Not reported as a pathogen (Yarto-Jaramillo 2015) | No | No | LOW (score 4) | Yes | None | LOW |

(Continues)

**Table 4.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Mycobacterium avium* subspecies *avium* | Single dead beaver during a Netherlands beaver reintroduction project (Nolet et al. 1997) | No | Occasional reports in immuno-compromised individuals (Yarto-Jaramillo 2015) | No (unless immuno-compromised; Christ et al. 2016) | No unless immuno-compromised | HIGH (score 25) | Yes | Acid fast staining of faeces or faecal real-time PCR | LOW |
| *Mycobacterium avium* subspecies *paratuberculosis* (Johne's disease) | No | No | No | Yes | Yes | LOW (score 4) | Yes | None | LOW |
| *Mycobacterium tuberculosis* complex (including *Mycobacterium microti* and *Mycobacterium bovis*) | No | No | *Mycobacterium microti* in wild rodent populations (Cavanagh et al. 2002, McClure 2012), *Mycobacterium bovis* in south American capybara (*Hydrochoerus hydrochaeris*; Mol et al. 2016) | Yes – NB: *Mycobacterium microti* only reported in immuno-suppressed humans (Niemann et al. 2000, Horstkotte et al. 2001) | Yes | LOW (score 6) | Yes | None | LOW |
| *Mycoplasma* spp. | No | No | Common in captive rodents, particularly *Mycoplasma pulmonis* in Muridae (Yarto-Jaramillo 2015), also in wild voles (Koskela et al. 2016) | No (murine strains not thought to be zoonotic (Piasecki et al. 2017) | Yes | LOW (score 8) | Yes | None | LOW |
| *Pasteurella* spp. (*Pasteurella multocida* and *Mannheimia haemolytica*) | No | No | Common in captive rodents. *Pasteurella multocida* gains access through wounds or respiratory tract (Yarto-Jaramillo 2015) | No | Yes | LOW (score 8) | Yes | None | LOW |

(Continues)

**Table 4.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Peptostreptococcus* spp. | No | Reported in one beaver without disease (Cullen 2003) | Not reported as a pathogen (Yarto-Jaramillo 2015) | No | No | LOW (score 4) | Yes | None | LOW |
| *Pseudomonas* spp. | No | Reported in one beaver without disease (Cullen 2003) | Occasional opportunistic pathogen (Yarto-Jaramillo 2015) | No | No | LOW (score 4) | Yes | None | LOW |
| *Rickettsia* spp. | No | No | *Rickettsia akari* reported in house mice in N. America and *Rickettsia typhi* reported in rats; neither in Britain or northern Europe (Yarto-Jaramillo 2015) | Yes | No | LOW (score 8) | No | None | LOW |
| *Salmonella* spp. | *Salmonella* spp. have been identified in wild beavers in Norway (Rosell et al. 2001), Germany and Russia (Romasov 1992) but not speciated | No | Common in Muridae and Cricetidae. *Salmonella enterica* serotype *typhimurium, Salmonella enteritidis* and *Salmonella typhimurium* are common in these taxa (Yarto-Jaramillo 2015) | Yes | Yes | HIGH (score 20) | Yes | Faecal bacterial culture and/ or use Scottish-born animals as source population (Campbell-Palmer et al. 2015d) | LOW |
| *Staphylococcus* spp. | No | Reported in 3/10 beavers without clinical disease (Cullen 2003) | Occasional reports of lung disease and skin disease in rodents have been recorded (Yarto-Jaramillo 2015) | No | No | LOW (score 4) | Yes | None | LOW |

(Continues)

**Table 4.** (Continued)

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| *Streptobacillus moniliformis* | No | No | Host is the brown rat, reported in domestic mice, gerbils and squirrels (Yarto-Jaramillo 2015) | Yes | No | LOW (score 8) | Yes | None | LOW |
| *Streptococcus* spp. | No | Reported in one beaver (Cullen 2003) | Common in captive rodents, particularly *Streptococcus zooepidemicus,* causes lymph node abscessation and lung disease (Yarto-Jaramillo 2015) | Yes | Yes | LOW (score 4) | Yes | None | LOW |
| *Yersinia* spp. | *Yersinia enterocolitica* in 17% of wild beavers in Poland (Platt-Samoraj et al. 2015) *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* isolated as post-release cause of mortality (Nolett et al. 1997) | *Yersinia pseudotuberulosis* was the cause of mortality in one beaver in Washington State (Gaydos et al. 2009) | All strains commonly reported in rodents, which are significant reservoirs of *Yersinia* spp. (Yarto-Jaramillo 2015) | Yes | Yes | HIGH (score 25) | Yes | Faecal bacterial culture | LOW |

## Fungal pathogens

As can be seen from Table 5, no fungal organism has been associated with significant pathogenicity in Eurasian beavers with the exception of *Chrysosporium parvum* (now known as *Emmonsia parva*), which has been reported as the cause of death due to pneumonia in one animal in Sweden (Mörner et al. 1999). The organism is a ubiquitous soil-associated occasional pathogen and is found in Britain. The straightforward detection of infection (significant respiratory disease expected) and ubiquitous presence in Britain makes the risk for post-management strategy low.

## Viral pathogens

As can be seen from Table 6, no viral pathogen present in Britain has been associated with significant pathogenicity in Eurasian beavers. Therefore, ensuring that beavers used for British reintroductions have been bred in Britain should reduce the risk for post-management strategy to low.

# DISCUSSION

As with all translocations, the reintroduction of the Eurasian beaver to Britain should show close adherence to Office International des Epizooties and IUCN guidelines on the quarantine and health screening of animals prior to importation (Woodford 2000). Beavers directly imported from mainland Europe without robust health screening may present a risk for introduction to Britain of non-native diseases and parasites, namely *Echinococcus multilocularis*, rabies, tularaemia, or specific parasites. Though this can be mitigated through pre-planned sourcing from particular regions deemed free from these pathogens, using British captive-bred stock or beavers from the wild in Scotland is a simple and effective means to reduce any risk to low or negligible.

It is possible that, following release, beavers may acquire common wildlife diseases and parasites already present in Britain (such as leptospirosis and giardiasis; Gaywood 2015). It is difficult to ascertain whether this would actually increase current transmission rates to other wild animals, domestic livestock, or humans, particularly given the ecology and behaviour of beavers. There has been no evidence to suggest that beaver reintroduction to Scotland has presented any additional health risks (Campbell-Palmer et al. 2015a, 2015b, 2015c, 2015d). Testing of British feral beavers (from unknown origins) for a range of parasites and diseases has found no evidence of any pathogens that may cause an increased risk to human, livestock, or other wildlife health (Campbell-Palmer et al. 2015a, 2015b, 2015c, 2015d). This mirrors findings by Rosell et al. (2001) in the Telemark region of Norway.

The presence of species-specific parasites (e.g. *Stichorchis subtrequetrus* and *Travassosuis rufus*) may not produce clinical signs in beavers at low infection levels. However, at high levels of endoparasitism, these parasites may lead to debilitation and, if combined with physiological stress associated with a translocation or reintroduction, may lead to increased mortality rates in beavers post-release.

## Pre-release health management and screening recommendations

Attempts at previous disease screening protocols for beavers in Britain had been developed (Goodman et al. 2012). These protocols were applied to beavers released in the official Scottish Beaver Trial prior to their release. They were also applied retrospectively to feral beavers currently present on the River Tay and Earn catchment (Scotland) and on the River Otter (England), under license by Scottish and UK Governments (Goodman et al. 2012, Campbell-Palmer et al. 2015d). These protocols incorporate recommendations for reintroductions and translocations of wildlife by the Office International des Epizooties and World Conservation Union (Woodford 2000). In addition, a number of other diagnostic tests were undertaken to address specific concerns raised by various stakeholders, particularly relating to livestock diseases, including Johne's disease (*Mycobacterium avium* subspecies *paratuberculosis*) and bovine tuberculosis (*Mycobacterium bovis*). All findings have been published (Goodman et al. 2012, Campbell-Palmer et al. 2015a, b, c, d, Goodman et al. 2017).

Any pre-release assessment should include a veterinary clinical examination, including an assessment of body condition (Campbell-Palmer & Rosell 2015). Blood sampling is recommended from the ventral tail vein for assessment of organ function and evidence of immune system responses to disease (Girling et al. 2015). Blood smear assessment for the presence or absence of haemoparasites should also be carried out. Standard parasitology screening should be undertaken on faecal samples taken directly from the beaver's rectum. Faecal samples should undergo flotation with saturated salt solution for the identification of nematodes, coccidia and *Giardia* spp., and sedimentation techniques should be used to assess for trematode eggs (*Fasciola* and *Stichorchis* spp.). Direct microscopy enhanced by modified or acid-fast stains is preferred to identify *Cryptosporidium* spp. Standard microbiological culture for bacterial enteric pathogens, including *Salmonella*, *Campylobacter,* and *Yersinia* spp. are also useful based on European isolates, although no evidence of these pathogens has so far been found in beavers in the wild in Britain (Goodman et al. 2012, Campbell-Palmer et al. 2015b, d, Goodman et al. 2017).

**Table 5.** Summarised disease risk assessment for fungal pathogens in beavers for translocation. The table is laid out to take into consideration risk factors for each pathogen such as: whether the pathogen has been reported in Eurasian beavers, North American beavers or other rodents (i.e. a decreasing risk scale); whether the pathogen is zoonotic; whether the pathogen has been associated with domestic animal or other wildlife disease and so may have other serious implications if introduced; and whether the pathogen is already present in Britain. If the risk assessment band is then considered low, no further risk management strategy is considered. If the risk assessment band is considered medium or high, suggestions for risk management strategies are given based on peer-reviewed publications to convert the risk band post-management strategy to low. See the text for details of specific pathogens, and Table 1 for the categorisation of risk bands for pre-management strategy.

| Pathogen | Reported in *Castor fiber*? | Reported in *Castor canadensis*? | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| Blastomycosis | No | No - associated with the environment but does not cause infection or disease (Klein et al. 1986) | Reported in juvenile mice in particular areas e.g. southern USA (Yarto-Jaramillo 2015) | Yes | No | LOW (score 6) | No | None | LOW |
| *Candida albicans* | Cutaneous candidiasis (Saez 1976) | No | Occasional reports; usually enteric, after antibiotic treatment (Yarto-Jaramillo 2015) | No | No | MEDIUM (score 10) | Yes | If giving antibiotics, faecal culture. Physical examination for cutaneous candidiasis +/– culture of lesions | LOW |
| *Chrysosporium parvum (Emmonsia parva)* and *Emmonsia crescens* | Found in a wild adult female in Sweden (*Emmonsia parva*; Mörner et al. 1999) | Yes (Erickson 1949) | Reported in several rodent species, including wood mice *Apodemus* sp., voles *Microtus* sp., and water shrews *Neomys fodiens* (Dvorak et al. 1965, Jellison 1981) | No | Yes (wildlife semi-fossorial species – considered an environmental pathogen; Bormann et al. 2009) | HIGH (score 15) | Yes | Veterinary clinical examination for signs of respiratory disease and bronchioalveolar lavage if suspected | LOW |
| *Histoplasma capsulatum* (histoplasmosis) | No | No | A few reports in chinchillas *Chinchilla laniger* and brown rats in the USA (Yarto-Jaramillo 2015) | No | No | LOW (score 6) | No | None | LOW |

(Continues)

**Table 5.** (Continued)

| Pathogen | Reported in *Castor fiber*? | Reported in *Castor canadensis*? | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| Ringworm (*Trichophyton mentagrophytes, Microsporum canis, Microsporum gypseum, Epidermophyton* spp.) | No | No | Common in pet rodents, often asymptomatic (Yarto-Jaramillo 2015) | Yes | Yes | LOW (score 6) | Yes | None | LOW |

*Echinococcus multilocularis* infection of Eurasian beavers has caused considerable interest in the UK, where this pathogen does not currently exist in the wild. We recommend that, although testing using a combination of laparoscopy, ultrasound examination and serology (anti-beaver IgG immunoblotting) has an 85% sensitivity, it may be preferable to source beavers from the wild in Scotland or to use British captive-bred animals for British reintroductions, as these animals would not have been exposed to the infectious agent (egg sachets passed in the faeces of a carnivore; Gottstein et al. 2014, Campbell-Palmer et al. 2015a, 2015d).

Testing for Johne's disease was requested by the Tayside Beaver Study Groups' National Farmers' Union of Scotland representative, and has been performed by means of modified acid-fast staining of faecal smears and PCR testing (Scottish Agricultural College Consulting Veterinary Services, Scotland's Rural College). No evidence exists currently of the ability of Eurasian beavers to act as either a carrier or paratenic host to this pathogen and no evidence of the disease has so far been found in beavers in Britain (Campbell-Palmer et al. 2015a, 2015c, 2015d). For *Mycobacterium bovis* testing, a bronchoalveolar lavage can be performed. This has been carried out in the past in Britain, at the request of stakeholders, although the disease has not been reported in beavers. Our assessment, based on the available literature, ranks the risk of transmission of *Mycobacterium bovis* as low.

## Post-release health monitoring recommendations

The level of post-release health monitoring should reflect the assessed level of risk. As recommended in the IUCN's 'Guidelines for Reintroductions and Other Conservation Translocations' and 'Guidelines for Wildlife Disease Risk Analysis', there should be a level of assessment to determine to what extent an establishing population is experiencing disease, adverse welfare conditions or mortality (IUCN/SSC 2013, 2014). Should any beavers be found dead, full post-mortems and collection of samples from the body (including samples for histopathology, microbiology, endoparasitology, and ectoparasitology) for further diagnostic testing should always be carried out. Any evidence of wildlife or domestic animal disease in release areas related to those pathogens previously associated with beavers should be fully investigated.

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**Table 6.** Summarised disease risk assessment for viral pathogens. The table is laid out to take into consideration risk factors for each pathogen, such as: whether the pathogen has been reported in Eurasian beavers, North American beavers or other rodents (i.e. a decreasing risk scale); whether the pathogen is zoonotic; whether the pathogen has been associated with domestic animal or other wildlife disease and so may have other serious implications if introduced; and whether the pathogen is already present in Britain. If the risk assessment band is then considered low, no further risk management strategy is considered. If the risk assessment band is considered medium or high, suggestions for risk management strategies are given based on peer-reviewed publications to convert the risk band post-management strategy to low. See the text for details of specific pathogens, and Table 1 for the categorisation of risk bands for pre-management strategy.

| Pathogen | Reported in *Castor fiber?* | Reported in *Castor canadensis?* | Reported in other rodents? | Zoonosis? | Wildlife or domestic animal impact? | Risk pre-management strategy | Present in Britain? | Risk management strategies | Risk post-management strategy |
|---|---|---|---|---|---|---|---|---|---|
| Cowpox virus | No | No | Common in voles in Britain (Robinson & Kerr 2001) | No | Yes | LOW (score 4) | Yes | None | LOW |
| Encephalo-myocarditis virus | No | No | Level of 9% on real-time PCR detection of tissues in wild rodents in Sweden (Muridae and Cricetidae; Backhans et al. 2013) | Yes | Yes | LOW (score 6) | No | None | LOW |
| Hantavirus | No (Girling et al. 2019) | No | Reported in the Britain in Muridae (brown rat, bank vole; McElhinney et al. 2016, Bennett et al. 2010) | Yes – a low-risk pathogen to humans (Thomson et al. 2001) | Yes | LOW (score 8) | Yes | None | LOW |
| Lymphocytic choriomeningitis virus | No | No | Worldwide distribution. Causes chronic wasting disease in juvenile hamsters. Common in domestic mice (Yarto-Jaramillo 2015) | Yes | No | LOW (score 8) | Yes | None | LOW |
| Monkeypox virus | No | No | Prairie dogs *Cynomys* spp. and Gambian pouched rats *Cricetomys gambianus* (Falendysz et al. 2014, 2016) | Yes | Yes | MEDIUM (score 10) | No | Use wild or captive-bred beavers from Britain as source population | LOW |
| Omsk haemorrhagic fever virus | No | No | Found in Siberia (water voles and non-native muskrat *Ondatra zibetheca*; Mills & Childs 2001, Yarto-Jaramillo 2015) | Yes | No | MEDIUM (score 12) | No | Use wild or captive-bred beavers from Britain as source population | LOW |
| Rabies terrestrial | No | No (Krebs et al. 2002) | Yes – but not present in the UK | Yes | Yes | HIGH (score 15) | No | Use wild or captive-bred beavers from Britain as source population | LOW |
| Sendai virus (Para-influenzavirus 1) | No | No | Common in captive rodents (Muridae and Cricetidae; Yarto-Jaramillo 2015) | No | No | LOW (score 2) | Yes | None | LOW |

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