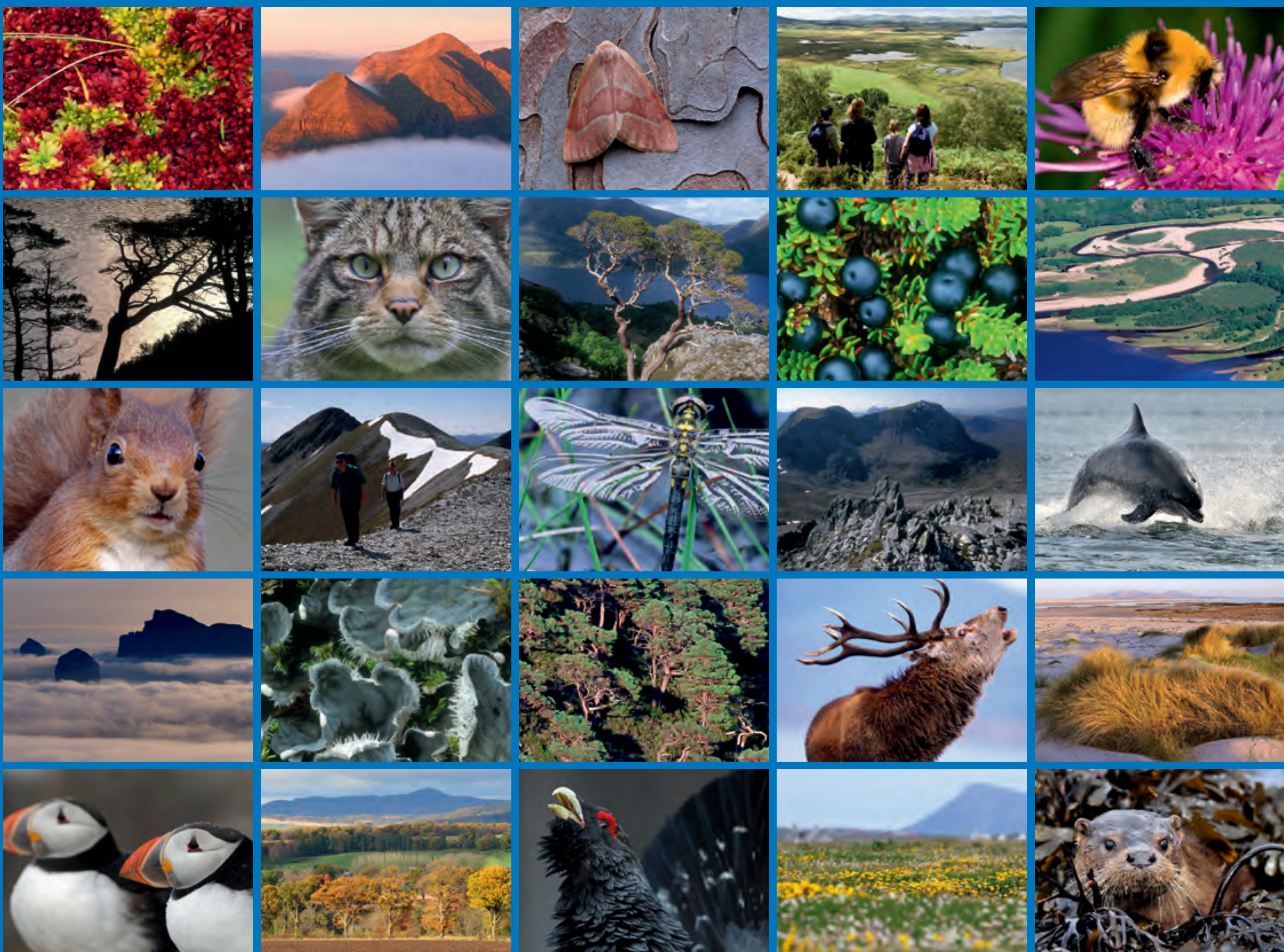
Scottish Natural Heritage
Commissioned Report No. 812

Managing wild Eurasian beavers: a review of European management practices with consideration for Scottish application



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COMMISSIONED REPORT

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For further information on this report please contact:

James Scott
Scottish Natural Heritage
Great Glen House
INVERNESS
IV3 8NW
Telephone: 01463 725363
E-mail: james.scott@snh.gov.uk

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COMMISSIONED REPORT

Summary

Managing wild Eurasian beavers: a review of European management practices with consideration to application in Scotland

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Keywords

Beavers; management; Scotland; European; Eurasian; techniques; mitigation.

Background

There is general agreement that as well as providing a range of ecological benefits in certain locations, wild beavers can have a negative impact on a range of land and water uses through the alteration of water levels, burrowing and foraging activity. This report focusses on the range of beaver management techniques, in particular to mitigate any negative impacts including flooding of forestry and agricultural land, weakening flood protection banks, threatening infrastructure such as roads, obstructing passage for migratory fish and altering the ecological condition of protected species and/or habitats.

Scottish Ministers are due to decide on the future of wild beavers in Scotland in 2015. Part of this consideration is likely to include an evaluation of what steps could be put in place to mitigate any negative consequences for land, water and infrastructure managers, should beavers be formally reintroduced. The purpose of this report is to assist SNH in developing its advice to Scottish Ministers on the question of beaver reintroduction. SNH will use the information on practical management techniques, including their animal welfare implications, costs and efficacy, to undertake a study of the risks surrounding the use of each potential management technique and any legal implications. It may also form the basis for a future manual for the management of wild beavers in Scotland. It is likely that the efficacy, costs and legal considerations surrounding the use of any technique will change over time. This report assumes that beavers, and their breeding sites and resting places, will receive strict protection under the Habitats Regulations 1994 (as amended in Scotland), but reference has been made to derogations associated with beaver management by some European countries.

Main findings

- The Eurasian beaver is formerly native to Britain before being hunted to extinction. The beaver has been reintroduced to over 24 European countries and it is generally accepted to provide a range of ecological benefits. This species can lead to negative impacts, particularly in intensively modified landscapes, and can conflict with modern land uses.
- Scottish ministers are set to decide on the future of wild beavers in Scotland in 2015. The presence of wild beavers is already requiring management considerations on a local

scale. To date, all indications are that Eurasian beavers will survive in a Scottish environment and could restore to population densities comparable to other European countries. Similar conflict concerns are likely to arise, with comparable management solutions.

- A re-establishing beaver population cannot be excluded from any given part of a river system where no significant barrier exists, once it is present. '*Beaver-free zones'*, whilst accessible to other colonising animals, would require constant removal effort. More cost-effective solutions may include tolerating the presence of beavers using a variety of control measures.
- Beaver-related conflicts have been previously documented and tend to be focused within agriculture, forestry, fisheries and infrastructure (particularly gardens and water management systems).
- A range of techniques for the effective management of beaver impacts is now well developed across Europe and North America. These range from non-lethal methods, including tree guards, dam mitigation and bank protection, to lethal control – with varied results, costs and implications for animal welfare. It is likely that the efficacy, costs and legal considerations surrounding the use of any technique will change over time.
- Specific species and habitats of conservation concern, such as freshwater pearl mussel and riparian aspen stands, require further monitoring to determine whether potential impacts of beavers and their activities could be of concern and require intervention.
- Lack of education on beaver ecology, unclear instructions on practicable and permitted mitigation methods, overly-bureaucratic licencing systems, financial burden and unclear benefits of beaver presence to landowners are likely to all lead to increased actual and perceived negatives impacts of beaver presence.
- It is highly likely that any future programme of beaver management in Scotland would be an evolving process as populations establish and expand, and if applications for further releases are approved. Early and reactive intervention, according to a proactive management plan developed ahead of any significant increase in population densities and associated colonisation of sub-optimal areas for beavers, is recommended to reduce conflicts.
- Long-term land use planning to incorporate land buffer zones along freshwater bodies, and to allow the natural regeneration of these areas with native riparian plant and tree species, is likely to reduce the majority of beaver conflicts. Where this is not practicable or desirable, it is likely that removal of beavers will be necessary. Translocation of 'problem' individuals and families is a viable, but a time-limited management option. As populations rise, targeted culling will likely become an essential beaver management tool, to reduce conflicts in areas where non-lethal management methods prove to be ineffective or too expensive.
- Further monitoring and scientific investigation will be required to determine the role beavers can play in the Scottish environment, including the impact on migratory fish and agricultural land, and their role in habitat management and flood alleviation planning.

For further information on this project contact:
James Scott, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725363 or james.scott@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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1. INTRODUCTION

The Eurasian beaver (*Castor fiber* Linnaeus 1758) is formerly native to Britain and was widespread throughout mainland Scotland. By the 15th century the trade in beaver furs in Scotland was no longer economically viable due to over-exploitation and while oral tradition suggests they may have survived in and around the Loch Ness and Lochaber areas until the late 17th century, there is no further mention of their presence after this time (Coles, 2006). This extinction was generally considered to be caused through over-hunting for meat, fur and castoreum (Conroy & Kitchener, 1996). Whilst the feasibility and desirability of restoring beavers to Scotland has been widely discussed in the scientific literature (Macdonald *et al*., 1997; Kitchener & Conroy, 1997; Halley, 2011; South *et al*., 2000) at the time of writing it has not yet formally been reintroduced to Britain. Legal status, along with conservation protection and permitted management strategies, have therefore yet to be defined should a formal reintroduction occur in the future.

The Eurasian beaver has been successfully restored to much of its former native range across Europe through protective measures, proactive reintroductions and translocations (Halley & Rosell, 2002). Whilst initially some countries (such as Finland and Russia) reintroduced beavers to support a commercial fur trade, the majority of recent releases have been implemented for conservation purposes. These reintroductions have been undertaken as a greater scientific awareness of the ecological benefits of restoring this wetland mammal has developed.

Where beaver populations are re-established, the immediate physical impact of their activities is often confined to a small group of land and water users such as farmers, foresters or water authorities (Siemer *et al*., 2013). As their populations increase (especially in density) the novelty of their presence can be replaced by hostility from wider elements of society when more visible impacts such as flooding of sensitive areas or the felling of mature trees in public parks or along river banks occurs. Although beavers will modify the landscape in ways that conflict with human land use, some impacts can be perceived rather than actual. Intensively utilised, cultural landscapes which are dominated by agricultural production with amenity woodlands, recreational areas or engineered water bodies are relatively unchallenging environments for beavers provided that food and areas to create shelter are available. Though it has been demonstrated that environmental factors such as topography, hydrology and vegetation can influence beaver distribution (Schwab *et al*., 1992; Rosenau, 2003; Rosell *et al*., 2005), beavers have displayed a remarkable ability to adapt to heavily modified environments. Seemingly adverse factors such as water pollution or human disturbance (Dzięciołowski & Gozdziewski, 1999) have proved to be no barrier to their presence. Careful consideration and concern over habitat requirements during site selection for reintroduction projects are often displayed, but in fact beavers have high adaptability and limited habitat requirements beyond fresh water and food (Schwab & Schmidbauer, 2003).

There is general agreement that as well as providing a range of ecological benefits in certain locations, wild beavers can have a negative impact on a range of land and water uses. These negative impacts may include flooding forestry and agricultural land, weakening flood protection banks, threatening infrastructure such as roads, obstructing passage of migratory fish and alteration of protected conservation sites.

1.1 Beaver reintroduction to Scotland

In 1994 Scottish Natural Heritage, Natural England (then English Nature) and Natural Resources Wales (then Countryside Council for Wales) began to consider the potential for restoring beavers in Britain. To date this process has progressed furthest in Scotland with an official trial reintroduction and the scientific study of the larger unlicensed population on the River Tay and Earn catchments. Feasibility studies on beaver reintroduction to Wales

(Halley *et al*., 2009) and England (Gurnell *et al*., 2009) have been published, and as of 28/01/15 a licensed trial is occurring in England on the River Otter, Devon.

In 1998 SNH launched a public consultation to ascertain wider attitudes to beaver reintroduction in Scotland (SNH, 1998). Whilst the majority of those who responded favoured reintroduction, opposition was expressed by others concerned that beaver activity would have detrimental impact on various land uses including agriculture, fisheries and forestry. In response to these findings, SNH took the decision to develop a proposed, time-limited, trial reintroduction in the Forestry Commission Scotland (FCS) managed Knapdale Forest in mid-Argyll, to explore the feasibility of releasing beavers and to study their impacts. Although this initial SNH licence application (2002) was turned down in 2005 by the then Scottish Executive, a joint licence application submitted in 2007 by the Scottish Wildlife Trust (SWT) and the Royal Zoological Society of Scotland (RZSS) was successful. This led to the creation of the Scottish Beaver Trial (SBT), a five-year trial reintroduction of the Eurasian beaver after an absence of over 400 years.

Since 2006 SNH has been aware of evidence of wild-living beavers in and around the River Tay catchment. A distribution survey undertaken by Campbell *et al.,* (2012a), determined that a sizeable population was established within this area, outside of the official beaver trial. This population arose from unlicensed releases or escapes, presumably from one or more locations within the Tay catchment. In March 2012, the Minister for the Environment and Climate Change announced that the presence of these beavers living in Tayside would be tolerated until a decision on the future of beaver reintroduction to Scotland was made, expected 2015. During February 2014 the presence one to two families of free-living beavers was confirmed within a ~20km section of the River Otter, Devon. This has now been granted a licence by Natural England to form the basis of a scientific trial to determine the impact of beavers here.

Scottish Ministers are due to decide on the future of wild beavers in Scotland in 2015. Part of this consideration is likely to include an evaluation of what steps could be put in place to mitigate any negative consequences for land, water and infrastructure managers should wild beavers be formally reintroduced. This report will assist SNH in developing its advice to Scottish Ministers on the question of reintroducing the beaver. SNH will use the information on practical management techniques, including their animal welfare implications, costs and efficacy, to undertake a study of the risks surrounding the use of each potential management technique and any legal implications. It may also form the basis for a future manual for the management of wild beaver in Scotland, should the species be officially reintroduced. This report assumes that beavers, and their resting places, have received full protection under the Habitats Regulations 1994 (as amended in Scotland), but references to derogations associated with beaver management by some European countries have been made.

1.2 Current legislation

The Eurasian beaver is protected across Europe through a number of legislative measures. International protection is provided through The Convention on the Conservation of Flora, Wildlife and Natural Habitats (Bern Convention, Annex III) and the Council of Europe Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (Annex II and Annex IV(a)). Therefore, wild beavers present within their natural range are protected from deliberate capture, injury, killing and/or disturbance under certain circumstances.

In some countries (including Estonia, Latvia, Lithuania, Sweden, Finland, and Poland), beaver populations have reduced protected status, allowing management options such as regulated hunting, whilst maintaining the favourable conservation status of the species. The Eurasian beaver is classified as ‘least concern’ under the IUCN Red List. Additional protection of beaver habitats through other legislation such as the Ramsar Convention and Natura 2000, are also afforded.

Formal reintroduction to Scotland is likely to require the Eurasian beaver being added to Schedule 2 of the Habitats Regulations 1994 (as amended in Scotland), making them a European Protected Species (EPS) in Scotland. At present, beavers in Scotland receive some limited legal protection. The possession (alive or dead), transportation or exchange of a wild beaver requires a licence under the Habitats Regulations 1994. It is not an offence to kill a beaver at present in Scotland (providing animal welfare and firearms regulations are abided), although this would change if beavers are added to Schedule 2 of the Habitats Regulations 1994. In Scotland, under the Wildlife and Natural Environment (Scotland) Act 2011 (WANE), states former native species which are reintroduced are legally regarded as non-native species, and hence do not have native range within Scotland. Hence any future release of beavers would need to be licensed by SNH.

1.3 Objectives

The objectives of this review are stated below.

1. To present a range of potential negative impacts to the main sectors effected by beaver restoration.
2. Comment on beaver population growth and how these may develop in Scotland.
3. To review the options for mitigating the impacts of wild beavers on a variety of land and water uses in Scotland.
4. Consideration is given to the financial and animal welfare implications of these various management techniques.
5. Detail the practical options available based on beaver management currently undertaken worldwide.

2. BEAVER POPULATION GROWTH AND DENSITIES

Beaver survival, population establishment, development and distribution in Scotland will directly impact on the management of this species. At low densities beavers have the ability to blend unobtrusively into an environment, with any conflicts tending to be localised. During this initial phase of colonisation they select the most favourable sites, typically larger rivers and lochs, where dam building activity is rare. As beaver populations grow and their densities increase, successive generations are forced to occupy less favoured habitats (i.e. those more likely to be modified by beavers), in minor water-courses or anthropogenic environments. In such locations their presence can become more obvious as environments are modified often through a process of dam creation to increase water levels for protection of natal lodges and access to food resources, often with more obvious feeding impacts. It is generally at this point that conflict with human land use interests become more likely. Dam creation and its attendant landscape alteration is the most common cause of conflicts with an associated requirement for management.

Findings from the SBT and free-living beavers throughout the River Tay and Earn catchments demonstrate that Eurasian beavers can survive in Scotland (Campbell-Palmer *et al*., 2015; Harrington *et al*., 2015). Though adult beavers here have no significant predators apart from humans, kits and young individuals can be predated by red fox (*Vulpes vulpes* L. 1758), domestic dogs (*Canis lupus familiaris* L. 1758), pine marten (*Martes martes* L. 1758), birds of prey and even large pike (*Esox lucius* L. 1758) (Kile *et al*., 1996; Rosell & Hovde, 1998). There are anecdotal reports that otters (*Lutra lutra* L. 1758), American mink (*Neovision vision* Schreber 1777) and badgers (*Meles meles* L. 1758) may also be opportunistic predators, this would warrant further monitoring. As beaver populations increase in density, dispersing sub-adults will often be wounded or even killed in territorial conflicts with non-related individuals. Deaths due to road accidents may also become a more significant cause of mortality, with small numbers of beaver fatalities already reported on roads in Perthshire (H. Dickinson, pers comm., 2014; Campbell-Palmer *et al*., 2015). In other reintroduced populations in areas of Sweden and Norway, it has taken several decades for beavers to attain typical population densities and start to occupy sub-optimal habitats (Hartman, 1994; Halley, 1995). It is typically not until this stage that a higher incidence of human-wildlife conflicts occur (Bhat *et al*., 1993; Deblinger *et al*., 1999).

As with all wildlife, beaver population density varies considerably in time, space, and with habitat quality. In addition, beaver density is influenced by their territorial behaviour, with mean territory size tending to decline as habitat quality increases (Parker & Rosell, 2012). Since beavers rarely move more than 60 meters from water (Barnes & Dibble, 1988; Donkor & Fryxell, 1999; Parker *et al*., 2001b), and most activity is within 20m of fresh water shoreline, they occupy landscapes along banksides in a linear fashion. However, in most landscapes there are lengths of unsuitable beaver habitat, e.g. mountain moorland. Therefore, at the landscape scale, the distribution of beaver territories is often highly discontinuous (Parker *et al*., 2001a). Growth rates in newly establish beaver populations are initially slow as individuals find suitable territories, form pair bonds and produce enough offspring to enable dispersers to form pairs prior to establishing territories of their own. As dispersing offspring may travel dozens of kilometres from their family territories the process of population establishment creates a ‘patchwork’ pattern of beaver territories. The mean litter size for the Eurasian beaver at birth is approximately 2.5 (Danilov & Kan’shiev, 1983; Mörner, 1990; Parker, H. *et al*., in preparation). Mortality rates across Europe vary greatly depending upon a range of factors such as habitat quality, population density, varying climatic conditions, extremes of weather (particularly spring flooding), hunting and trapping, predators (in particular wolves), and disease (Novak, 1987; Rosell *et al*., 2005). Many studies demonstrate that mortality rates are highest in the first two years of life (e.g. Payne, 1984; Campbell *et al*., 2012b).

Another aspect of beaver ecology with considerable influence on the spatial and temporal distribution, and density of occupied territories, is the alternating pattern of site occupation and abandonment. As the number of beavers in an environment rises the gaps between territories and areas of poorer habitat are gradually in-filled by dispersers who in turn create more territories. Often there is a 'lag phase' of slow growth following reintroduction or colonisation of an area, which is often then followed by rapid expansion. The length of time required for rapid population expansion varies depending on the characteristics of the river system and may take 15-20 years on larger river systems (Hartman, 1995). After this phase of population growth, a decrease in territorial sizes may become evident (Campbell *et al*., 2005). At this point the availability of habitat becomes a limiting factor and territorial disputes become more common. Mortality rates increase directly through fighting and indirectly through the subsequent stresses of living in smaller territories that require to be defended more vigorously. This whole process can become physically evident in a decrease in breeding rates, delayed dispersal and lighter individual body weights (Busher *et al*., 1983). While a developing beaver population with abundant habitat can display growth rates of between 15-20% per annum (Hartman, 1995), this process will stagnate with no demonstrable growth once their whole environment is occupied. Therefore, although environmental factors will influence the fluctuation of beaver populations, on the whole they are self-regulating (Saveljev & Safonov, 1999). As long as there is available suitable habitat, beaver populations will grow and expand. It is worth noting that a lack of genetic diversity may result in inbreeding depression that could limit the rate and geographic extent of population growth.

Precise counts of beavers for monitoring and management purposes are difficult to obtain (Rosell *et al*., 2006). Signs of previous beaver activity remains visible for many years, and since previously and presently occupied sites are usually discriminated based on such signs, it is possible during an autumn census to map both presently and previously occupied sites (Parker *et al*., 2002a), leading to a potential over-estimate of abundance. Following extensive foraging, sites may be abandoned for a varying number of years if food resources become limiting. Once preferred food species have grown back in sufficient quantity, a new period of colonisation will eventually occur. Thus a dynamic source-sink pattern of site occupation and abandonment becomes established; with rotation times varying depending on habitat quality and harvest levels (Fryxell, 2001). In these populations, and at a landscape scale including both good and poor beaver habitat (e.g. > ≈100 km2), the proportion of sites occupied at any time, i.e. the site occupation rate, tends to vary between 0.33 and 0.50. Thus, in populations that have somewhat stabilised following an initial population peak, between ⅓ to ½ of the potential beaver habitat within a larger area will be in use at any particular time (Parker & Rosell, 2012).

How beaver population size varies in the long term following the initial peak and subsequent trough is poorly documented, though in the absence of excessive harvesting (Parker *et al*., 2002b) and heavy browsing competition from wild ungulates (Baker *et al*., 2012) or livestock (Parker *et al*., 2000), a stochastic pattern of population fluctuation around a mean, below the initial population peak is to be expected (Parker & Rosell, 2012). In management terms, after reintroduction, slow establishment may be expected, followed by a period of rapid growth and dispersal, before becoming more self-regulating at a lower population size and density. Therefore, regular culling before this stage is likely to be followed by rapid re-colonisation by surplus animals. Once beaver territories become fully occupied, non-lethal management, which permits beaver presence within tolerable limits, should actually slow or prevent further colonisation and significant increase in density due to the territoriality of this species.

3. BEAVER MANAGEMENT TECHNIQUES

The behavioural activity of beavers create aquatic environments that are dynamic in nature. Beaver activity can provide a wide range of ecological benefits including elevated species richness, heterogeneity and habitat creation (Collen & Gibson, 2000; Meßlinger, 2009; Rosell *et al*., 2005; Wright *et al*., 2002; Willby *et al*., 2014). However, species biodiversity may exhibit short-term declines at a local scale in areas of intensive foraging (Jones *et al*., 1997; Fryxell, 2001). While a range of practical measures can be employed to mitigate against some of their undesirable impacts, any sustainable long-term view of their presence should aim to develop a niche for their existence in a multiple-use landscape. Widespread European and North American experience demonstrates that solutions to reduce the negative economic impacts of beaver reintroduction need to be understood and implemented at the earliest opportunity. Rapid intervention can ensure the resolution of issues before they become extensive and more expensive to rectify.

The extent and impact of beavers on human land-use is largely determined by the character of the landscape (particularly typography, location and relief). In more mountainous countries like Norway, with a relatively low level of agricultural land-use and high level of forest cover compared to British landscapes, beaver impacts are generally minor, with damage from flooding and tree-felling being less significant (Parker *et al*., 2001a). Beaver reintroduction has proved more challenging in the flat lower valleys of Bavaria. This is a highly developed landscape with associated infrastructure of roads, settlements and intensive agriculture. An extensive and historical system of land drains, ditches and canalised water-courses with high flood banks are an essential component of this system. In environments of this type the impact of beavers can be significant and wide spread.

Many management methods exploit the general reluctance of beavers to move far from water when foraging. A distance of 150m between two streams has been shown to have a strong effect on the chances of beavers colonising from one to another (Halley & Rosell, 2002; Halley *et al*., 2013). In Sweden this effect has been shown at a national scale (Hartman, 1995), in France and Switzerland the authorities have built special '*beaver ladders'* which make it possible for beavers to pass large artificial dams and other barriers in heavily regulated rivers. Though beavers have also been recorded travelling overland to traverse human made dams in Norway, including large hydroelectric plants. The motivation for some beavers to travel larger distances than generally expected should not be underestimated, however this motivation will vary between individuals, available resources and reproductive status i.e. dispersers versus breeding family members.

Beavers can readily adapt to highly developed urban landscapes where woody browse and other riparian vegetation is available (e.g. inner city of Bratislava, Pachinger & Hulik, 1999). Whilst the initial arrival of beavers often invites a lot of media attention and is commonly welcomed by wider society (Müller-Schwarze, 2011), their activities over time can be negatively perceived when, for example, they consume garden plants, ornamental or fruit trees (Campbell *et al*., 2007). On larger rivers that flow through urban environments their presence in areas of well-established riparian woodland or islands is commonly unobtrusive. Beavers demonstrate flexibility in their feeding habitats and can survive in a broad range of fresh and even brackish water environments.

Techniques for the effective management of beaver impacts are now well developed across Europe and North America. These will have potential application in Scotland if beaver populations are permitted. Many of these techniques have been developed in response to both legal constraints and a wider social interest in non-lethal wildlife management solutions. It is likely that the efficacy, cost and legal considerations surrounding the use of any technique will change over time. In Campbell *et al.*'s (2007) survey of European beaver managers, non-lethal mitigation constituted the majority of management practices. Whilst this may reflect the conservation status of this species, it also offers a more practical solution as the culling of problem individuals in a highly territorial species just creates a vacuum to be filled by further dispersers (Campbell *et al*., 2007). Continual dam and/or beaver removal programmes are expensive and time-consuming (Jensen *et al*., 1999), particularly in areas of suitable, accessible beaver habitat (Houston *et al*., 1995). However, this is not to say lethal management should not be employed at higher population densities.

Table 1. General beaver management techniques according to rapidness of implementation and likely ease of application to land managers. Longer-term techniques are more likely to be subject to licencing procedures and/or wider multi-organisational collaboration.

Immediate management techniques	Longer-term management techniques
Individual tree protection	Trapping
Deterrent/protective fencing	Translocation
Removal/management of non-lodge protecting dams	Culling/beaver free areas
Canal and non-residence burrow management	Flood-bank protection/realignment

3.1 Damming activity and associated management techniques

3.1.1 Ecology

Damming activity and the incidence of dams varies depending on habitat characteristics. On lakes or wide rivers (>10m) damming is uncommon. Beavers living on narrower water bodies, (> 6m wide and in 97% of cases in water originally 0.7m deep, Hartman & Törnlov's, 2006), often build dams, and can create extensive systems of multiple dams and impoundments. In a Polish study approximately 19.5% of beaver territories had active damming (Zurowski & Kasperczy, 1986); whilst Russian studies have reported figures ranging from 19 to 53% (Danilov & Kan'shiev, 1983). On the Numedalslågen River system in Norway beaver dams were only constructed in five out of fifteen tributary stream territories, with no dams present on the main river, where most beaver territories were located (Parker & Ronning, 2007). The length of time that dams persist in the environment varies and can be relatively short lived particularly if the food resources they enable access to become depleted and/or they are not worth maintaining compared to the costs and benefits of exploiting resources elsewhere in the territory (Halley *et al*., 2009).

3.1.2 Issues

Along with any benefits it is important to accept that beaver damming can conflict with human interests and impose a cost in terms of resources (including time and financial impacts), especially in intensively managed landscapes. The potential blockage of water in some areas maybe particularly problematic, e.g. in agricultural land drainage, water treatment plants. Beavers can construct new dams quickly, and generally use fresh material each time, so regular monitoring of a sensitive site for any rebuild is often required.

The most significant impact of beavers on agriculture is the damming of drainage ditches and/or nearby water bodies so that the backup of water directly floods agricultural land. Additionally, the increased ground water levels can impede drainage function and cause water logging of crops (Schwab, 2014). These activities cause more significant economic impact and resultant conflict. Where livestock grazing is the predominant land-use, beavers will graze in pastures close to water bodies. Although the flooding of pasture will potentially impact upon its grazing value the significance of this issue will be dependent on the topography of the surrounding landscape, its land use and the extent of any areas of wet woodland or riparian vegetation. While it is possible that the localised felling of trees adjacent to a water-course could damage stock fencing, there have been few reports of this to date. A survey of beaver managers and researchers across Europe, Campbell *et al.*, (2007) determined that most beaver conflicts within forestry plantations were localised and small scale, involving loss of commercial trees due to flooding as a result of beaver dams (and due to tree felling).

The capacity of beaver dam systems to interfere with migratory fish movements, particularly salmonids, is a contentious issue receiving particular interest associated with beaver reintroduction to Scotland. This has been reviewed by the Beaver-Salmonid Working Group, and their findings were presented in their final report for the National Species Reintroduction Forum (BSWG, 2015), so will not be discussed here. Some studies have documented beaver dams affecting fish migration, particularly during periods of low/summer water flow, in Lithuania (Ratkus, 2006) and North America (Alexander, 1998; Cunjak & Therrien, 1998). Other effects of damming such as changes to the water velocity or temperature have also been considered in terms of their potential influence on fish spawning and population growth (Collen & Gibson, 2000; Halley & Lamberg, 2001; Mitchell & Cunjak, 2007). Such effects of beaver dams on fish migration are likely to depend greatly on both the topography and hydrology of a given site. The location, composition and age of either a set of tiered dams or single beaver dam will result in a variable impact (Halley & Lamberg, 2001; Rosell *et al.*, 2005).

Research on the closely related North American beaver has shown some dams, particularly in low-gradient systems, can temporarily limit adult and juvenile fish migration, particularly during low water flow (Alexander, 1998; Cunjak & Therrien, 1998). In Lithuania the rapid population growth of the beaver population has led to an increase in the number and distribution of dams with a resultant increase in the disturbance of fish migration (Ratkus, 2006). The formation of dams reduces stream velocity and increases silting upstream of the dams. This process can reduce the quality and quantity of spawning habitats (Knudsen, 1962) and alter the distribution of riffles and runs that are the preferred habitat of salmonids' (Mitchell & Cunjak, 2007). Alternatively beaver dams can improve fish habitat below dams through creating silt free spawning habitats, areas of deeper water, with cooler temperatures at the bottom during the summer months.

3.1.3 Management options

Any land manager in Scotland considering removing a beaver dam or installing a flow device on natural watercourses would be advised to liaise with the relevant regulatory authorities such as Scottish Environmental Protection Agency (SEPA) and SNH. SEPA consider that beaver dams can be partial or completely removed from watercourses using hand tools, ropes or grapnels, without prior authorisation by SEPA under the CAR Regulations. Such work must be completed without causing pollution. Any dams on artificial drainage channels are not subject to a requirement for prior authorisation by SEPA under CAR Regulations (SEPA, 2014).

Considerations put forward by SEPA (2014), are independent of other legislation, such as species protection or animal welfare legislation, therefore further regulations may apply. For example, if a dam is protecting a lodge when pregnant females and/or their dependent offspring are likely to be present, then any removal may be inappropriate on animal welfare grounds. Similarly the removal of dams which maintain water levels around an occupied lodge in the winter can result in the beavers abandoning the lodge and its attendant winter food cache. If water supplies cannot be managed by flow devices then the most durable solution may be the installation of beaver exclusion fencing. Where this solution is not feasible then the capture and removal of beavers may be the only practicable alternative. However, this may become a repetitive process with any captured beavers being translocated or culled as appropriate. If such areas can be continually accessed by dispersing beavers, then long-term management that permits a residential family is often more cost effective in the longer term.

There is a paucity of documented management techniques employed throughout Europe specifically addressing migratory fish movement through beaver dams (largely due a lack of reported issues) but a summary of dam management techniques is given below.

Dam notching – is the removal of a small section of beaver dam to increase water flow over that section. It is most often associated with aiding fish passage but can also be used to lower water levels in beaver ponds behind the dam. In active territories beavers will often repair notched dams within 48 hours. As a management technique this can be labour intensive, especially on a catchment scale. Dam size and longevity should be considered before implementing dam notching on a wider scale as many dams are small, temporary in nature and/or will be breached during periods of heavy rainfall or snow melt. It is most likely that only large and/or mature dams should be considered for any seasonal dam notching programme and/or during years of low rainfall.

Documented evidence of dam notching as a regularly employed management technique in Europe is lacking. In North America, seasonal implementation of active beaver dam notching is undertaken just prior to or during fish spawning, to reduce the risk of impeded passage for adult fish (such as Atlantic salmon *Salmo salar* L. 1758) attempting to access spawning areas during years of low water flow. The Miramichi Salmon Association focuses on the conservation of Atlantic salmon stocks within the Miramichi catchment, New Brunswick. Similarly the Gitanyow Fisheries Authority undertakes a ‘Beaver Dam Breaching Programme’ in the Kitwanga catchment, British Columbia. Beaver dams within the catchment are notched 2 or 3 times per week during the spawning migration period for these salmon species (Kingston, 2004). In 2013 the Miramichi Salmon Association targeted >100 beaver dams for breaching in a water shed of 13, 552 km2 (Parker, 2013). To aid in finding dams, and target mitigation efforts and resources, aerial and canoe surveys were employed. Dam notching over a number of years has resulted in good populations of salmon and brook trout in catchments where they were previously low (Parker, 2013) and is viewed as a useful practice for habitat managers wishing to restore Canadian salmon populations (Taylor *et al*., 2010). To obtain the maximum benefit from dam notching, management efforts should be co-ordinated with fish migration (Parker, 2013) or coupled with a flow device to manage water levels long-term.

Dam notching in Scotland could currently occur on watercourses without prior authorisation from SEPA, using hand tools, rope or grapnels, providing such work is undertaken without causing pollution, including the escape of ‘silty water’ downstream (SEPA, 2014).

Flow devices – the use of flow devices is a standard technique for lowering the water level behind beaver dams by influencing damming behaviour. Several types of flow devices have been described, with varying terminology (e.g. Roblee, 1987; Wood *et al*., 1994; Lisle, 1996, 2001, 2003). Although initially this process will also address any associated issues with upstream flooding, beavers can readily create a series of subsidiary dams elsewhere in the landscape. If the objective is purely to reduce the water level at a specific point in a water-course, then this technique has been shown to work well in parts of North America and Europe, provided that appropriately robust materials are used and installed in the correct manner. Periodic monitoring and maintenance may be required. The basic principle of this process is that the pipes going through the dam should be positioned so as to allow the water level to drop to the required depth, so that water is still present but at an acceptable level (as opposed to draining an area completely). If this design is incorrectly applied beavers tend to respond by adding more material to the dam and/or building a new dam beneath the flow device. This management method is generally considered to be effective in any depth of water if constructed correctly. In Bavaria wildlife managers have found that if the intention is to drop the water level behind the dam below a depth of ~80cm, this has tended to encourage the beavers to construct another dam. Experiences in North America have successfully maintained lower water levels behind dams with well-constructed flow devices.

The installation of flow devices can be a very effective, relatively low cost, method for resolving beaver damming conflicts in comparison to regular road maintenance, dam or beaver removal programs (Boyles & Savitzky, 2009). Failure rates can be significant, and tend to occur in the first 2-12 months if they are installed by inexperienced personnel, placed at inappropriate sites or are incorrectly designed (Czech & Lisle, 2003; Callahan, 2003; Lisle 2003). One study recorded a flow device success rate of 87% at 156 beaver conflict sites in North America, with most failures resulting from insufficient pipe capacity, lack of maintenance and damming of the fencing associated with the flow device (Callahan, 2005). The construction of new dams downstream by the beavers was also considered a 'failure' in this study, though it should be noted beavers may have multiple dams with a territory and build tiered dam systems depending on habitat type. Insufficient pipe capacity can be rectified through replacing with a more appropriate pipe. Higher success rates have been demonstrated by other experienced practitioners, it should be noted that skill and knowledge will significantly influence flow device success.

Culverts are a common feature in developed landscapes. Although they vary in style and dimensions, they provide a basic drainage function for water-courses crossing beneath roads, or through various infrastructure. While the removal of material causing blockages can sometimes be effective, beavers can be persistent rebuilders, so that regular blockage removal may prove ineffective or not economically viable. The most time efficient, cost-effective or long-term management solution to reduce culvert blockage is to install appropriate flow devices. The installation of oversize culverts where possible in the construction stage has also been proposed as a management solution (Jensen *et al*., 1999), although even wide culverts can act as a damming point in suitable habitat. Alternatively a beaver trapping programme can be implemented especially in areas with a history of repeated damming conflicts (Jensen *et al*., 1999; Czech & Lisle, 2003), although this can be more expensive, especially over the long-term (Boyles, 2006). Additionally, draining an area completely may be a non-lethal way to encourage beavers to inhabit alternative sites especially if the vulnerability of nearby properties is an issue. However, careful consideration must be given to the legality and expense of such actions, along with impacts on other wildlife and land management practices.

Advice sought from SEPA, through the Tayside Beaver Study Group (TBSG), regarding the placement of flow devices, has determined these are likely to be classified as temporary structures and could be installed without prior authorisation under the General Binding Rules (GBR) under CAR. This would be on the condition that they are temporary structures (e.g. not fixed with concrete), and their installation was undertaken with minimal substrate disturbance (TBSG, 2015). Additionally under CAR, SEPA consider flow devices using boulders to secure any ancillary fencing can be installed without prior authorisation, as long as work is undertaken according to the conditions of CAR GBR14 (boulder placement in a river or burn). For any alternative approaches, prior consultation with SEPA is advised to determine any regulatory requirements (SEPA, 2014).

<u>Dam removal</u> – removing dams may often stimulate beavers to rebuild again, usually felling additional trees in the process which may exacerbate negative impacts. It may be more effective to allow a dam, to remain, and manage its size and the extent of resultant

backwater. If the decision is made to remove a dam then any discarded material should be placed above the high water line to prevent it being washed away and potentially causing blockage downstream. Such material tends not to be re-utilised by beavers. Dams can be removed by hand (this can be more resource intensive and expensive but more controlled) or with an excavator where access is practicable, although the latter may result in damage to riparian habitat, and is more difficult to control any sudden surge of silt and water downstream. Any removal of beaver dams using machinery may be currently undertaken without prior authorisation from SEPA, if according to the conditions of CAR GBR 9 (operating any vehicle, plant or equipment (machinery) when undertaking GBR activities 5, 6, 7, 8, 10, 12, 13 and 14) (SEPA, 2014).

Discouraging dam building - the absence or removal of woody material from the banks of a water-course will not eliminate the possibility of dam construction or the area being inhabited by beavers, and may cause additional issues such as bank instability. Where beavers attempt to construct another dam on the same site various different dissuasive techniques have been attempted. The most effective include the use of electric fencing strung across the water-course above the normal water level. Flashing lights (such as those used at road works) and ultrasound have proven to be temporarily effective in discouraging reconstruction at some sites (Schwab, 2014). Other methods such as plastic barrels filled with gravel hanging from chains have been demonstrated as being effective on many occasions, whereas CD's suspended by cord above the dam have proven less so.

Grilles – metal grilles are often used to protect small culverts. These are not management devices that control damming behaviour, but are included here for completeness. It should be noted that beavers may just circumnavigate such management techniques, and direct activities elsewhere in a water course. Various designs of grilles have been developed to prevent beavers either blocking drainage pipes, culverts or gaining access to an area. The main issue with these structures is that while they are generally effective if robust enough, they can be blocked by beaver activity or by other detritus. Their requirement for regular clearance means that they are unlikely to be used widely outwith situations where routine checks are practicable. Grilles must be designed to ensure that they cannot be undermined by beaver burrowing and that gaps between grill bars do not impact on fish passage. There are many different designs for these structures, which vary according to the requirements at individual sites.

In Scotland, the use of such management has not been generally discussed, and would most likely fall under 'other activities', therefore consultation with SEPA to determine the regulatory requirements would be required (SEPA, 2014).

3.1.4 Animal welfare consideration

The impact of dam removal on beaver welfare is generally only considered significant for those dams maintaining water levels directly associated with natal lodges or burrows. Therefore the timing of any sudden water level drop during the breeding season may jeopardise the welfare and survival of kits. The sensitive period for kit birth and emergence for any natal dam removal is April to August/September. Removal of dams maintaining water levels around active lodges or burrows with an associated food cache from October to February should also receive greater consideration. Timescales could be reviewed upon consideration of local circumstances. Particularly in harsh winters or regions experiencing shorter vegetation growing seasons, e.g. Northern Scotland in comparison to the Scottish borders. Any resultant impact on winter survival should be avoided. Removal of such dams may encourage further tree felling, relocation of beavers, or present welfare challenges associated with appropriate food acquisition. In harsh winters welfare concerns over exposure, abandonment of food caches and increased energetic requirements associated with relocation and shelter creation would be of concern. Dams, especially more mature structures, are likely to provide refuges for other wildlife so if deemed necessary should be deconstructed with care. It should be noted, if a dam stays in place long enough for it to be considered as ‘mature’ without causing conflict, then the need for its removal could be questioned. If heavy machinery is used, consideration to its use in close proximity to other protected species and sensitive habitats should be given. There are no directly associated welfare concerns to beavers in the removal of non-natal dams.

3.1.5 Associated costings

- A two year Salmon habitat restoration project ‘ Improving Access to Critical Spawning Habitat for Wild Salmon within the Miramichi River Watershed’ undertaken by the Miramichi Salmon Association had a budget of $102,000 (£69,808) ($51,000 (£34,167) provided by the Canadian Government, with match funding by MSA). This project included the active removal of abandoned beaver dams, notching of active dams and small scale beaver trapping and removal.
- The minimum hourly rate for agricultural workers in Scotland £7.14 (min rate for 39hr week £278.46, The Agricultural Wages (Scotland) Order (No 62) Oct 2014), in reality this figure may be deceptive as land based workers frequently work highly variable and unsocial hours. Ghillies and game keepers are likely to regularly encounter beaver activities, with typical annual salaries from £12,000 (trainee) to £20,000. It is difficult to accurately ascertain specific labour costs appropriate for monitoring the presence of dams in agricultural areas and spawning tributaries as some of the actual costs may be incorporated in existing routine works. For example, fisheries staff habitually check spawning tributaries for blockages as part of their regular work programmes. The River Monnow Fisheries Association have indicated an hourly consultancy rate of ~£15 (R. Denny, pers comm., 2014).
- While the notching of a dam by hand is likely to take <1hr using basic hand tools such as forks, spades, axes etc, complete dam removal can take much longer.
- Dam removal can be undertaken using an excavator which can typically be hired with a driver for ~£300 - £400 per day, or a mini-digger and driver for a daily hire of ~£165 - £275. Many farming operations will retain a JCB or other agricultural vehicle with a backactor suitable for ditch repair/clearance.
- Costings for flow devices can vary according to the topography of a site and the complexity of an appropriate design. A simple flow device including labour and materials could be costed at ~£300. A demonstration flow device constructed and trialled as part of the Tayside Beaver Study Group cost ~£400.
- Material costs for high quality flow devices in North America are approximately $500 per device. Effective, long-lasting and low-maintenance flow devices built by private contractors generally cost between $1500 – 3000. Flow devices can be installed more cheaply but these are reported as being much less effective, and tend to result in a waste of resources.

3.2 Burrowing and associated activities

3.2.1 Ecology

Beavers are strong, able burrowers, and can readily excavate burrows, chambers and canals, for shelter and/or access to food resources. Such structures may collapse and/or increase bankside erosion to varying extent depending on associated water flow and substrate type. Beaver burrows tend to be large, and can end in sizeable chambers. Beavers will readily excavate burrow systems which begin underwater, and may be obscured by vegetation, so that their location may be difficult to determine.

3.2.2 Issues

In landscapes where networks of agricultural ditches are an essential land drainage requirement, beavers will readily excavate burrows at the waters' edge that can lead to bankside erosion and/or extend to the surface in adjacent fields. The secondary implications of equipment damage due to the collapse of beaver burrows, the delays caused to contractors work schedules at harvest times, the flooding of field edges and service roads may be much more significant and generally unacceptable to the majority of land managers. Where embankments are set back from the main water channel >20m, the impact of burrowing animals is insignificant. However, in flood banks, dykes or other engineered structures <20m from the water's edge, beaver burrowing may be more significant. Whilst the documented instances of beaver generated burrows causing the collapse of engineered flood walls are few, the concern that their presence generates has led some European Water Agencies to develop a range of remedial measures to counteract their activities (not only to mitigate for beaver activity, but also for muskrats *Ondatra zibethica* L. 1766, coypu *Moycastor coypus* Molina 1782, red foxes, badgers and rabbits *Oryctolagus cuniculus* L. 1758). Beaver burrowing into flood banks has been reported in Tayside and has been linked to at least a single instance of flood wall failure and resultant crop flooding (TBSG, 2015).

The cultivation of arable crops in the immediate vicinity of water-courses will often encourage beavers to burrow from the edge of the water into the surrounding fields. Beaver canals can also be excavated in flatter landscapes. While their actual feeding impact on crops is relatively limited the collapse of their burrows can result in operational delays and damage to agricultural vehicles or machinery. Burrow collapse may pose an issue for livestock grazing. There have been a few anecdotal reports from Bavaria of cattle and sheep falling into beaver burrows, and some injuries have been recorded. Overall there is very little information from Europe on the collapse of beaver burrows in livestock or equestrian pastures, given its rarity.

3.2.3 Management options

<u>Discouraging burrowing</u> – a number of effective anti-burrowing techniques (including those for beavers, badgers, rabbits, water voles (*Arvicola amphibius* Shaw 1801), musk rats and coypu are employed across Europe. These include the insertion of an interlocking system of sheet metal piling or welded wire fabric, through the centre of a main flood bank structure or the facing of river banks with large rocks, concrete or stone gabions to the bottom of the water-course have been effective. Attempts to use various geo-textiles to deter burrowing in the design of new flood walls have been unsuccessful to date.

Although burrowing can generally be prevented by the installation of such "hard" reinforcements, these options may be neither commercially viable nor ecologically desirable along extensive lengths of water-course. Mitigation solutions such as the in-filling of non-natal/residential burrows to prevent their use can be undertaken. The original entrance holes should be covered with an additional barrier such as square welded wire mesh to prevent re-excavation. Examples of fisheries owners draining ponds to extend lengths of conventional livestock netting along the banks to prevent burrowing at the water level have generated cheap but generally ineffective solutions, especially if the shoreline is already pitted by beaver excavations or burrows. While the best mesh type to use for natural contours is chainlink, this mesh is pliable and beavers can rapidly open large holes in this material. Plastic coated mesh will corrode when it is permanently submerged, and lighter mesh gauges can be bitten through by beavers with relative ease. Mesh designs with unlocked joints can be easily distorted by pulling. At best, such techniques are dissuasive and it is quite probable that other burrows will be excavated elsewhere.

Realignment of flood banks - the majority of all human-beaver conflicts occur within a relatively slim strip of habitat adjacent to fresh water habitats. In Bavaria over 90% of beaver conflicts occur within ten metres of the water's edge, while 95% occur within 20m (Schwab *et al*., 1994). Although conflicts further away than this are possible, they are rare and are usually associated with an attractive food source. The creation of 10-20m buffer strips of bankside vegetation, particularly wet woodland, will have the most significant impact on the reduction of potential beaver-human conflicts. While the purchase of the land behind an existing flood wall and the re-establishment of a new flood bank out-with the burrowing range of beavers is the most practicable long-term solution, it is an expensive option. However, if implemented correctly this can improve flooding alleviation downstream.

3.2.4 Animal welfare considerations

The filling of, or covering the entrances of burrows that potentially are still in use, especially during the breeding season in which dependent offspring may be present would have serious animal welfare implications. The disturbance through use of heavy machinery for beaver mitigation techniques in and around natal burrows or lodges, should be considered. If long-stretches of water are faced with high gabions or smooth, steep concrete there may be a welfare issue as beavers (and other wildlife) may not be able to exit the water safely, if at all.

3.2.5 Associated costings

- Unoccupied burrows can be backfilled with stones, pea shingle or sand bags filled with a dry cement aggregate mix concrete and/or entrances meshed. Costs for a section of bank will vary greatly depending on size and number of burrows. Equipment such as crushed stone starts from ~£9 per ton, 2 inch square weldmesh sheets (2.4m by 1.2m) start from ~£20 per sheet.
- To isolate a lodge from the surrounding bank, preventing further expansion and burrowing is estimated to cost ~£750, including labour for two workers, equipment and mini digger hire. To create a sunken mesh lined trench, filled with gravel, is estimated to cost ~EUR 300^{+}/metre.
- A broad range of flood bank reinforcement solutions exist across Britain and Europe, which although not specifically designed to mitigate against beaver burrowing would be effective. These vary greatly in cost depending on their extent, topography and the availability of local materials (Schwab, 2014).
- In the Czech Republic recent flood bank protection work against various burrowing mammals including musk rat and beaver, have seen costs of ~5,600,000 Czech koruna (approx. £157,228) to net wire 1600m of flood bank. Metal sheet piling of 800m of flood bank cost ~8,000,000 Czech koruna (approx. £224,611), similar costs as Austria (300-500 euro per metre).

3.3 Foraging activity and associated management techniques

3.3.1 Ecology

Beavers are entirely herbivorous and will readily consume a wide range of bark, shoots and leaves of woody (primarily broadleaf species), herbaceous and aquatic vegetation. During spring and summer up to 90% of beaver diets are comprised of terrestrial, semi-emergent and aquatic species of plants (Nolet *et al*., 1995), although this drops to under 30% in Norway (Campbell *et al*., 2013). Whilst beavers can fell quite large trees (>1m in diameter) they tend to favour smaller saplings (<5cm diameter) in order to obtain their bark, side branches and leafy stems (Haarberg & Rosell, 2006). Foraging generally takes place close to the bank; in Denmark, for example, 95% of beaver cut stems were within 5m of water (Elmeros *et al*., 2003); in Norway, 70% of cut stems are within 10m and 90% within 20m (Haarberg & Rosell, 2006); in Russia, 90% of cut stems were within 13m of water and 99%

within 20m (Baskin & Sjöberg, 2003). Beavers will forage a few hundred metres away from water on occasion to typically obtain highly preferred forage species such as aspen or poplars (*Populus* spp.), or agricultural crops such as corn or sugar beet. .

Beavers can exist in both commercial hardwood and softwood plantations where deciduous tree species, shrubs or vascular plants are available. While Eurasian beavers do not commonly feed on evergreen tree species they will occasionally ring bark conifers or feed on their saplings in the late winter/early spring. Conifers can be felled for construction purposes but this tends to occur if few broad leaf trees are available. There have been no reports across Europe of nationally significant economic or ecological damage to woodlands caused by beavers (Reynolds, 2000).

Beavers display regular routines and feeding patterns, with well-worn foraging trails and canals being easily visible. This characteristic can be used to deter them in some situations where their presence is unwanted. If possible, felled trees should be left in-situ as beavers will continue to feed on their side branches and bark. They will also utilise these materials for construction. The removal of such trees is likely to encourage further felling.

3.3.2 Issues

The consequences of tree felling by beavers into or across a water body will vary greatly in accordance with the size, depth, width and associated water flow. If the water-course is very large such activities may have little impact. Woody debris in river and stream systems is a naturally occurring feature which large commercial users of water, such as hydroelectric projects, routinely manage. It is possible that in some environments which are heavily wooded with narrow water-courses beaver felled timber could present an access issue, e.g. for canoeists. Extracting trees from a water-course once they have been felled or undermined by beavers can be a specialised and expensive undertaking. The felling of large, specimen trees in certain landscapes can generate a sense of cultural loss. In large scale forest blocks beaver foraging is largely an insignificant issue, with impacts generally more significant through flooding of tree stands. In smaller, community forests where particular trees are desired by individuals for carpentry or firewood purposes, their loss can have a greater impact to local stakeholders.

Beavers will occupy intensively utilised agricultural landscapes. They have been reported feeding on a range of crops including sugar beet, maize, cereals, oilseed rape, peas, asparagus and carrots in close proximity to a water-course (Nolet & Rosell, 1998). Beavers will also readily consume fruit trees and soft fruit shrubs, and may dam areas to access crops more easily (Nolet & Rosell, 1998). Although their crop feeding pattern is generally seasonal and limited to areas within 20 metres of the water's edge (e.g. Campbell *et al.*, 2012a) they can expand their feeding zones through dam and pond creation or the excavation of canals or burrows. Beaver feeding on commercially valuable trees or crops is relatively limited in extent and its commercial impact is minor in comparison to other more wide ranging species such as rabbits, wild boar or deer. In Bavaria, direct crop loss through feeding tends to be low and generally accepted by farmers, with seasonal use of temporary electric fences on small sections of fields bordering fresh water (Schwab, 2014).

3.3.3 Management options

<u>Individual tree protection</u> - individual wire mesh tree guards are an effective method of protecting trees from beaver browsing. Beavers will commonly ignore trees with guards of this type, providing they cannot push under or pull down the mesh to access the trunk or side branches. Any meshing should not impact on tree growth. Where amenity trees are to be protected but mesh guards are considered unsightly then a variety of anti-game paint, e.g. "*Wöbra*", have proven effective against beavers. A cheaper, 'home made version'

consisting of non-toxic exterior paint and mason sand, will also deter beaver feeding. Both these abrasive paints have been successfully trialled in Scotland (Tayside Beaver Study Group, 2015).

Deterrence techniques - practical deterrents that impact on new beaver activity, before they have become established, can be useful under certain circumstances, e.g. to deter the rebuilding of dams in a specific location or to discourage beavers from using a feature such as a garden pond, especially when their presence is still at an exploratory level. Again techniques such as flashing road lamps and ultrasound have been reported as being successful on a temporary basis. The presence of free running dogs in private gardens has also been reported as an effective deterrent.

Electric fencing - this can be employed to deter beavers, provided they are positioned correctly. These are portable, easy to install and can be relocated rapidly in response to any change in activity. Electric fencing tends to be commonly used by many landowners. Typically this technique has been used effectively to prevent beavers feeding on arable crops. It can also be utilised as a temporary measure to deter beaver activity in a variety of situations e.g. dam height restriction or deterring beaver movement between a water body and ornamental pond or garden.

Exclusion fencing – can be used to more permanently protect an area, e.g. stand of trees or discourage colonisation of small streams or use of ditches. A beaver deterrent fence that crosses a ditch or burn and "wings" back toward the stream (also called a Swept-Wing Fence™), aims to turn any beaver exploring the area around and double-back upon itself as supposed to navigating around the fence. In more mountainous/rocky terrain, it may be possible to select a point along the ditch or burn where the fence can incorporate a natural barrier. A flow device may also be required should any beaver get inside the 'exclusion zone' and incorporate any fencing into a potential dam.

There are also well established practical designs of permanent beaver fencing. These are most effective when they are positioned well back (~20-30m) from the edge of a water-course. Fencing, particularly that close to the water or protecting an area regularly used by a significant beaver population (as supposed to infrequent exploratory, dispersing individuals), should extend underground, or have a mesh collar at ground level to discourage beavers from digging along a fence line. Any trees within falling distance on the outer side of the fence line should be removed, coppiced or protected from gnawing to ensure beavers do not fell them onto this fencing causing damage or breaching. Although expensive to construct these fences could have a role in protecting commercial orchards or important conservation area. Captive beaver retention fencing is similar but with the use of more robust materials and may be accompanied by the use of an electric hotwire fence, and/or sunken fencing.

3.3.4 Animal welfare considerations

A small number of mortalities have been reported in captive collections, involving beavers biting 'hot wire' fences in which front teeth locked behind the wiring. The use of such fencing should be carefully considered and incorporate monitored via remote camera traps. Any deterrent should be situated so that a beaver is able to remove itself.

3.3.5 Associated costings

- Trial of tree protection in Tayside using tree guards saw 16 trees protected using 50m rylock stock fencing £31; fence posts £19.80. Labour was provided by the landowner (TBSG, 2015).
- Individual tree protection through painting of trees with commercial anti-game paint '*Wöbra*' specifically used against beaver foraging in Germany, 10kg costs £90 - £135

plus shipping can protect up to 20 trees (RBH ~ 1m height, depending on tree diameter). Self-made version using masonry paint and sharp sand costs ~£22 (5 litres) and can cover the same number of trees. So far testing on both these methods has proved successful against beaver felling in Tayside (TBSG, 2015).

- Beaver retention or heavy duty exclusion fencing (as described in Campbell-Palmer & Rosell, 2013), including the electric wire, solar panel, all materials and labour was ~£39 per metre (Devon Wildlife Trust).
- Electric fencing costs per 200m, including tape, posts, insulators and battery can cost from ~£180.

3.4 Animal management

The management techniques described in the preceding section focused on the management or mitigation of beaver impacts. This section considers the management of the animals themselves.

The perceived need for, and methods of, regulating beaver populations vary greatly across Europe, from hunting quotas in Norway (frequently unlimited due to demand for hunting being below the rate of natural increase in many river systems), to trap and remove by employed staff or trained volunteers in Germany. In countries where beaver populations are still recovering they are usually fully protected and mitigation through non-lethal management methods prevail. The potential population management strategies for Britain have yet to be fully investigated and will be subject to further discussion and legal considerations should beavers be formally reintroduced.

There is no effective method for excluding beavers from large areas of suitable habitat. Fresh water bodies with rocky or concrete banks and no attendant food resource are relatively hostile environments but the creation of such environments to specifically exclude beavers will not always be a practical or desirable solution. In cases where beaver conflicts cannot be suitably managed, as costs are too high or the impacts too great, removal through trapping and translocation, or culling may be the only practical solution.

3.4.1 Ecology

Disease - The range of pathogens that can be harboured by the Eurasian beaver has been previously reviewed along with the screening recommendations for beaver importation to Scotland (Goodman *et al*., 2012; Campbell-Palmer & Rosell, 2013) and sampling of the Tayside beaver population has been undertaken (Campbell-Palmer *et al*. 2015), provide recommendations for any beaver health monitoring programme. Beavers can carry host specific parasites not currently present in Britain, though these are not known to infect or harm other species. These include the beaver beetle (*Platypsyllus castoris* Ritsema 1869), *Travassosius rufus* (Khalil 1922) a stomach nematode, and *Stichorchis subtriquetrus* (Rudolphi 1814) a specialised trematode or intestinal fluke. These species have now all been recorded in wild beavers in Scotland (Campbell-Palmer *et al*., 2012; Goodman *et al*., 2012; Duff *et al*., 2013). Non-native, host specific parasites are not of concern to human, livestock or other wildlife health, so no active management for these species are presumed to be required. Other parasite such as Giardia spp. and Cryptosporidium spp. are already present in Scottish wildlife and domestic animals, therefore it is likely beavers may also be carriers.

For any current beaver population of unknown origin, non-native disease and parasite concern would be the presence of *Echinococcus multilocularis*, Rabies and Tularaemia. Any health screening programme involving beavers should include the sampling of any cadavers and/or live-trap programme to collect blood and faecal samples as required. *E. multilocularis* is a zoonotic parasite of serious health concern, and regarded as one of the most pathogenic parasitic zoonosses in the Northern hemisphere (N. America, northern and central Eurasia) (Eckert *et al*. 2000; Vuitton *et al*. 2003). Although established in many countries across central Europe, other European countries are presently deemed free of this parasite, including the United Kingdom which employs strict measures to prevent entry, i.e. Pet Travel Scheme (DEFRA, 2012). Barlow *et al*. 2011 diagnosed *E. multiloculcaris* in a captive beaver at post-mortem. This individual was held in an English captive collection but had been directly wild-caught and imported years previously from Bavaria, Germany. Sample screening across the Tay and Earn catchments, and ongoing post mortem examination of beaver cadavers, have demonstrated no evidence of *E. multilocularis* in free- living beavers in Scotland. The rabies virus has not been reported in Eurasian beavers but theoretically may affect any mammal. Screening of the live animal is not currently possible so any imported beavers should be sourced from rabies free areas or quarantined according to the current Rabies Importation Order (as amended). Like all other rodents, beavers may harbour common European rodent pathogens (Goodman *et al*., 2012 It is recommended that any imported, wild caught beavers are screened for the following as a minimum: *E. multilocularis*, Hantavirus; Tularaemia; *Yersinia* spp.; Leptospirosis; *Salmonella* spp.; *Campylobacter* spp.; *Toxoplasma gondii* and quarantined for rabies.

<u>Trapping and translocation</u> – any trapping effort to remove beavers from an area should seek to ensure no dependent offspring remain. Juvenile beavers for at least their first year of life are reliant on their parents and older siblings for shelter, protection and food provision. They also rely on the communal body warmth of larger individuals in winter. The trapping and relocation of heavily pregnant or lactating females should be avoided. Any trapping programme must recognise that a repetitive process of trapping and monitoring (pre- and post), will be required to remove a completely remove beavers from an area. Beavers commonly display varying levels of bait and trap shyness, with sub-adults tending to be more easily trapped than adults, and males tending to be more easily trapped than females (Schulte & Müller-Schwarze, 1999; Müller-Schwarze, 2003).

As beavers are a highly territorial species, fighting can inflict serious wounds and even death, so care must be taken to ensure that any translocated individuals are not released directly into the territories of non-related animals. Beavers from different family units should never be mixed in the same transport crate. Ideally pairs or family groups should be released together in available habitat. Any translocation should follow best practice guidelines including IUCN (2013) and Best Practice Guidelines for Conservation Translocations in Scotland (National Species Reintroduction Forum, 2014).

3.4.2 Issues

Currently there are low numbers of beaver trapping equipment and expertise in Britain, so any future translocation or culling programme would probably need to consider a greater investment in appropriate trapping management. The "*Bavarian*" beaver trap which has been developed over a number of years, is probably the most effective and accessible trapping method. They are designed to afford any captured beavers a considerable degree of protection from the weather, while reducing trap inflicted injuries. Care must be taken with trap placement, position of bait and regular servicing. Any beaver trapping project must be aware of likely water level fluctuations in the area which may endanger any captured beavers, and also ensure traps are set away from likely locations of human interference. Any set traps should be checked at least once a day when in operation, ideally being set in the early evening and then checked the following morning. Although these traps have the ability to capture other species, incidental captures are low. In five years of use at the SBT, one badger and two pine martens were incidentally trapped, unharmed, and one pheasant was incidentally trapped during the monitoring project for the Tayside beaver population (Campbell-Palmer *et al*., 2015).

The transport of beavers over long distances should only be undertaken in specially constructed, robust, transport crates. Adult and sub-adult beavers should be transported in separate crates while yearlings and kits can be crated with another family member. Groupings of this type should not be confined together for long periods and must have enough space for free movement. Where individuals from different families are being moved in the same vehicle care must be taken to ensure that their paws or teeth cannot come into contact with other beavers through the wire as serious injuries from bites can easily occur.

The trapping and translocation of 'problem' individuals is a viable but ultimately limited management tool. It is generally resource intensive as a number of criteria would need to be satisfied for its implementation, including legislative compliance, suitable equipment, assessment and identification of release sites, monitoring at trapping and release site, and appropriate health screening of individuals as required.

Few wildlife rescue centres currently have appropriate facilities for beaver care, though modifications could be made to otter or seal facilities. Such modifications or the building of suitable facilities would generate costs. These are likely to be absorbed by the relevant wildlife charities. A more significant potential issue would be the release of any rehabilitated beavers. Although under the Habitat Regulations (as amended), a licence would not be required for possession and transportation for rehabilitation purposes, it would be currently considered illegal under the Wildlife and Countryside Act 1981 (as amended) to re-release any rehabilitated beaver without a licence. Further consideration must be given to their future prospects by wildlife rehabilitators who encounter these individuals and/or a legal framework established to enable rehabilitated beavers to go back into the wild.

Based on the current evidence from free living beavers in Britain, any populations which are not eliminated swiftly are likely to establish and expand. As Eurasian beavers are now largely recovered across throughout most of Europe and there is no credible prospect of translocating beavers from Britain as a means of ameliorating local beaver conflicts. If internal translocation is not possible or becomes exhausted within mainland Britain, then management through culling when irresolvable conflicts arise will be the only practicable option over time.

3.4.3 Management options

<u>Wildlife rehabilitation</u> - if the Eurasian beaver is reintroduced to Scotland, or if current populations in Knapdale and Tayside are allowed to remain in place, it is highly likely injured and/or orphaned beavers will be encountered by members of the general public and wildlife rescue organisations, as numbers increase.

The Scottish SPCA is already aware they are likely to start receiving injured beavers in the future and are considering how they would accommodate future requirements (C. Seddon pers comm., 2014). Beaver captive care can be relatively straight forward though their veterinary and hand rearing requirements are less well documented so some training and information dissemination amongst wildlife rescue or veterinary facilities may be appropriate. Many wildlife hospital organisations have an ethical opposition to the euthanasia of healthy animals. Without any option for the re-release of rehabilitated beavers, alternative solutions for their long-term care would be required. It is unlikely that many zoological and wildlife collection facilities would provide an outlet for such individuals.

<u>Live trapping</u> - if beavers are reintroduced in Scotland or permitted to spread from existing areas, trapping and relocation is likely to be required, particularly in circumstances in which protective measures are too expensive or impractical to implement (Schwab & Schmidbauer, 2001). Beaver live-trapping methods vary between countries and there are several designs of beaver traps and trapping techniques (Rosell & Kvinlaug, 1998). In North America and

parts of Europe live snares, and '*suitcase-type traps'* such as Hancock and Bailey traps are regularly used (e.g. McKinstry & Anderson, 2002), whilst live-trapping from a boat using specifically design nets is used in Norway, and cylindrical '*Belarus*' beaver traps used in Russia and Mongolia (Müller-Schwarze, 2003). Capture rates previously recorded as 11% for Hancock traps, 16% for Bailey traps (Hodgdon, 1978), and 21% for box traps (Koenen *et al*., 2005). Live boat and net trapping, by experienced personnel report a trapping rate of approximately one beaver per hour on river systems (F. Rosell, pers comm., 2015). Trapping mortality has been reported as 4% in live snares, 1% for Hancock traps (McKinstry & Anderson, 2002), 0% in box traps (Koenen *et al.,* 2005), 1-2% in Bavarian traps, and 0% for the boat trapping method (F. Rosell, pers comm., 2015). At time of writing there are no approved spring traps for beavers in Scotland, so cage trapping is presently the only option. Any trapping should cease when heavily pregnant females and/or dependent juveniles are potentially present (end of March to August/September).

<u>Translocation</u> – under appropriate licencing, translocation could provide a relatively cost effective source of beavers for re-colonisation projects, if the health and genetic status are considered favourable. Additionally translocation could be a practical management tool to relocate 'problem' animals. Potential relocation sites should be identified in advance, with landowner permission secured. Trapping protocols and equipment should be standardised, through an authorising body, to ensure consistency and appropriate animal welfare standards.

<u>Hunting / harvesting</u> - hunting is widely employed in northern and Eastern Europe, both as a recreational activity and for a lesser extent to manage beaver populations. The advantages of hunting, if appropriately structured and regulated, can include reduced bureaucracy and be an almost cost free management technique which generate income in some countries; and can also contribute to reducing conflicts over management issues. It should be noted that hunters will tend to dispatch a portion of animals from a family, typically those more easily targeted, so that the majority of family members may remain, and hence any conflict. It is highly unlikely beavers would ever be managed through hunting or harvesting for meat and fur in Scotland, given the general unpalatability of hunting to general public and strong reactions against wildlife culling, e.g. hedgehog culling in the Western Isles, and badger culling for control of bovine TB.

Hunting works most pragmatically in those counties where the landowner controls the hunting resource on his/her land. In places where the landowner does not control the harvest, public opinion can limit the practical application of this approach. At present beavers are protected in Europe by the Habitats Directive, but a number of countries have derogations (allowing beaver shooting/culling). Management could then be decided wholly at a national/regional level. In countries in which hunting is currently permitted, beavers can be removed by landowners at their own discretion, and without subsidy. In modern conditions this seldom constitutes a threat to beavers at a population level. Experience demonstrates many landowners are more willing to tolerate beavers under such conditions than when they are perceived as 'wards of state agencies'. However, for hunting to be a consideration in Scotland, it is most likely that hunting would be on a small scale, at limited sites on a recreational basis in which hunters remove beavers with land owner permission for the experience, potentially paying for the opportunity. Therefore, this is unlikely to be an effective population management strategy across Scotland.

Lethal beaver control could be best presented to the wider Scottish society, including conservation and animal welfare groups, as a targeted response to 'problem' individuals or family groups. In instances where lethal control is deemed necessary then live trapping followed by humane euthanasia is most appropriate, as any lethal/kill traps would have to be significantly large enough to kill an adult beaver, and hence present a risk to a wide range of wildlife, domestic animals and potentially humans.

Humane dispatch - successful beaver management will eventually require humane lethal control initially through the identification of problem animals; or the removal of beavers to prevent colonising of predetermined 'beaver free zones', or to achieve annual culling quotas (realistically not a perceived management requirement for a number of decades, once beaver populations are widely established). If beavers are to be dispatched by shooting, then certain factors should be considered to ensure dispatch is humane. Currently beavers can be shot without a licence in Britain, provided landowner permission is granted, firearm and animal welfare laws are complied with.

Trapped individuals may be dispatched at close range of <1m as far as possible (e.g. within kill pens), by rifle. If a shot gun is used, shot should be of at least 4mm diameter from a range of less than 20m. Distances beyond this are not recommended, given the particularly thick skin of beavers as this may result in an individual which has incurred significant but non-lethal injuries entering the water as a natural defensive reaction and then drowning or dying at a later stage from their wounds or infections. Smaller diameter shotgun shot ('bird shot' i.e. shot graded smaller than number 6) is not recommended as a reasonable or humane method for killing beavers unless it is used at point blank range firing from behind the ear aiming towards the opposite eye. For close range dispatch a .22 Winchester rifle can also be used by experienced operators, with the rifle shot administered from above, aimed between the shoulder blades in order to destroy the heart and associated vital structures (spine, major vessels and airways). Head shots with rifles in beavers should be avoided as these bones here are thick and the brain cavity small.

Euthanasia can also be achieved through humane injection by a qualified veterinary surgeon, using sodium pentobarbital as with other mammals (80-160mg/kg intravenously via the ventral tail, cephalic or saphenous vein).

Fertility control - sterilisation of beavers has been tried but has not become a widespread management technique (Brooks *et al*., 1980). Currently in parts of Germany (Rhineland-Palatinate), wild North American beavers are being sterilised, as opposed to culled, as a result of public objection to them being removed. This project has resulted in ~60 beavers being sterilised in over 6 years, and is funded by the government. This management option was selected to control the invasive North American beaver, whilst benefiting from the positive ecological benefits of beavers and generating public support for the reintroduction of Eurasian beaver to Germany in the interim before this species naturally recolonises this region (S. Venske, pers comm., 2015). While this method may be used at selected sites, it is costly and labour intensive (Schulte & Muller-Schwarze, 1999). Beavers of both sexes, can be permanently sterilised surgically. While standard veterinary ovariectomy or ovariohysterectomy in females, and castration techniques in males, where the gonads are removed, have been performed in beavers, this can have the notable adverse effects of altering behaviour and causing family group dispersal. This method is employed in the sterilisation of North American beavers in parts of Germany, with recovery time of a few days. Successful recapture of sterilised individuals in different locations have been recorded, with no negative impacts observed (S. Venske, pers comm., 2015).

It is preferable if performing surgical permanent sterilisation, to perform tubal ligation in females, and vasectomy in males. This preserves the normal gonad and production of sex hormones, with retention of normal behaviour, social and hierarchy integrity. Both tubal ligation and vasectomy can be performed in a minimally invasive manner, by means of two 3-5mm size incision, by laparoscopy (also referred to as "*keyhole*" surgery) (Pizzi *et al*., 2012, 2014). This minimally invasive approach can be performed without the need to clip any fur, with the advantage of minimal effect on water-proofing and thermal regulation. If either the male or female from the adult breeding pair are sterilised, then other family members do not tend to breed for as long as they remain in the family unit (Brooks *et al*., 1980). Sterilisation may be an option to reduce breeding in an area with stable families instead of culling, as breeding pairs are likely to remain in their territory.

3.4.4 Animal welfare considerations

Some common wildlife diseases may be harmful to individual beavers, particularly if left untreated, however many, particularly *E. multilocularis* do not appear to be immediately harmful or challenge individual welfare despite being significant zoonoses. Any reintroduced beavers of unknown origin should be screened to ensure they are free of these diseases but this raises a potential issue of immunological naivety as many of the above diseases (e.g. Leptospira spp.) are widespread in the UK wildlife population. So far disease monitoring at SBT has failed to demonstrate significant disease developing in the trial beavers associated with wildlife disease reservoirs (Goodman, 2015).

Anyone taking a beaver into captivity becomes responsible for its welfare under the Animal Health and Welfare Act (Scotland) 2006. This would also cover the release of any beaver that was unfit to be returned into the wild (e.g. sick or very young individuals). Welfare standards, enclosure provisions and husbandry practices of any long-term captive care facility, along with associated stress of taken wild animal into captivity. Suitable release point selection should include; beaver presence (as placing an unrelated individual within an active territory could result in stress and injury), assessment of food provisions, landowner permission to reduce conflict and likelihood of culling.

The method and timing of trapping should be carefully considered. Trapping of females in late gestation and/or lactation, with dependent young should be avoided. March to August being particularly sensitive. Mortalities and significant injuries have all been recorded in beaver trapping using live snares, Hancock and Bailey traps (Davis, 1984; Smith & Peterson, 1988), in which beavers may be held partially in water, exposed to predators and elements of the weather. Welfare concerns using these methods include discomfort (Grasse & Putnam, 1950), entanglement (e.g. injury, respiratory arrest, Davis, 1984), stress, injured or mortality by predators (McKinstry & Anderson, 2002), drowning (Buech, 1983; Davis, 1984), and exposure to the elements (hypothermia, Grasse & Putnam, 1950). Young beavers (4-7 months) lose heat faster in water temperatures of 1-12C compared to those >1 year (Macarthur & Dyck, 1990), therefore mortality from hypothermia could result if held in partly submerged trap for 4-5 hrs (Rosell & Kvinlaug, 1998). Although Bavarian (or other box-type traps) are difficult to manoeuvre in the field, they enable trapped beavers to move, groom, feed, and be more protected from the elements (Koenen *et al.,* 2005). Placement of traps should avoid temperature extremes, over exposure and sudden or unexpected water level rises. Long exposure to the sun should be avoided in beavers (Hill, 1982). Pre and post trapping monitoring would be required to ensure no dependent offspring remain. A trapper is responsible for an individual beaver under the welfare legislation (Animal Health and Welfare (Scotland) Act 2006), as well as complying with transport legislation i.e. Welfare of Animals (Transport) Order 2006 which govern the suitability of transportation crates, including dimensions and ventilation, along with grouping of animals etc. Incidental trapping of other species, particularly pregnant mammals, should be avoided through appropriate precautions including trap placement, bait, trap type and timing of trapping effort.

Bailey and Hancock traps can be triggered by a range of species including ducks, dogs, pike, otter and deer, for example, which may potentially result in injuries and mortality has been recorded (grey heron, *Ardea cinerea*) (Rosell & Kvinlaug, 1998). Health and safety of people setting such traps, would be an additional consideration. Inappropriate equipment, not designed for beaver use, has caused injuries including facial cuts, claw and teeth damage. Deep layers of straw will reduce injury and slippage in transport, whilst apples should be provided for moisture. Beavers being translocated should be screened for significant diseases (see above) and as this may take a few days to report, beavers may need to be held in appropriate captivity for a brief period. Transporting any mammalian species in its last 10% of gestation or with significant wounds is prohibited under the Welfare of Animals (Transport) Order 2006 council regulation (EC) 1/2005, unless approved by a veterinary surgeon on site. An additional consideration would be the welfare of any released individuals particularly in relation to the identification of suitable release points.

Additional welfare considerations for any beaver undergoing veterinary procedures under anaesthetic would include suitability of holding facilities for surgery and animal recovery, in compliance with animal welfare legislation in Scotland. The anaesthetic regime employed will impact on release times, particularly relative to animals being released into the wild. Purely gaseous anaesthesia reduces this risk, whilst injectables, even used with partial reversal agents, have longer recovery times. Individual recovery time varies, so animal should be fully recovered before release near water to avoid any risk of drowning. Any anaesthesia carries some risk of fatalities. Heat loss during anaesthesia should be monitored and prevented through use of heat pads and/or wrapping feet and tail in tin foil. Open surgery sterilisation techniques are likely to result in larger areas of shaved fur, larger incisions and resultant stitching which increases the risk of post-operative wound breakdown, infection and loss of heat (hypothermia). Consideration should be given to thermoregulatory impacts of larger shaved area, aim to reduce area and/or undertaken in warmer seasons. Wounds may present risk of infections. Beavers can be sterilised at any age after they weaned (3 months and above), though consideration of proportion of shaved area and time kept away from rest of family is an important consideration in kits (Pizzi *et al.*, in prep).

Any hunting would require a closed season on animal welfare grounds to protect dependent young during the spring and summer months. The shooting of heavily pregnant females, whilst not considered a welfare issue if dispatched correctly may be unpalatable to hunters and the general public. Ideally any trapped animal should be humanely dispatched at trapping site and not transported. Appropriately dispatched animals should not present a welfare issue.

3.4.4.1 Associated costings

- Testing for non-native parasites or diseases of zoonotic concern – live screening for EM ~£450per individual (highly variable according to trapping regime and number of animals being screened), immunoblot screening ~£80 per individual or post-mortem examination ~£400 including histopathology. Laboratory costs for Tularaemia ~£60 per individual.
- General full health screening, including radiographs, full haematology and blood biochemistry, leptospirosis serology, bacteriology, parasitology, and targeting testing for TB, Johnes etc ~£300 (including trapping and veterinary surgeon fees).
- Typical call out fee for veterinary surgeon is highly variable depending on location, distance travelled etc ~£45-100.
- Costs of rehabilitating an injured beaver or rehoming are highly variable depending on level and length of care required. Housing an injured individual for a few days is unlikely to cost significant amounts, though enclosure refurbishment or even new build may be required. Long-term care of orphaned individuals is likely to be a more significant expense. Following current SSPCA estimates orphaned otter cubs may take up to a year's care before release. This can cost around the region of £1,000 per cub. Beaver kits would most likely require similar or even slightly longer care periods before release. Although much of the expenses for otter cub rehabilitation includes food costs beavers require fresh browse which may need to be sourced regularly, and some enclosure modifications are likely.

- In Massachusetts (2002) problem beavers are removed by ‘wildlife-damage control professionals’ who charge $150 to remove a single and $750 for a family of 5 beavers (Sterba, 2002).
- Recent costs to commission the construction of Bavarian traps in Scotland were ~£450 per trap.
- International Air Transport Association standard beaver crates can be used to house beavers for long journey or hold over night, and have previously been constructed for ~£300. Whereas metal transport crates for shorter distances, and/or via vehicle transportation, have been priced as ~ EUR 150.
- Opportunistic dispatch by land managers, particularly those already undertaking lethal control, is not expected to have significant costs. The checking of live traps may incur more labour costs.
- Traditional open/laparotomy ovariohysterectomy costs would be in the region of £200-400 depending on the size of the animal. In Germany a single sterilisation costs ~300 euros, whilst total staff and equipment costs for the whole procedure (trapping, transportation, surgery and release) reportedly costing 1500-2000 euros (S. Venske, pers comm., 2015).
- Minimally invasive surgical neutering would be in the region of £200-400 depending on the size of the animal, but finding a veterinary surgeon with the appropriate equipment may be more difficult than for traditional open techniques.

3.5 Additional considerations requiring further investigation

3.5.1 Forestry

The composition and character of riparian woodland is variably impacted by beavers. While some tree species such as willow (*Salix* spp.) are relatively tolerant to the partial or seasonal inundation of their root systems, others such as elm (*Ulmus* spp.) or juniper (*Juniperus* spp.) cannot tolerate extended periods of inundation. In 1993 Parker *et al.* (2001a) investigated the proportion of the landscape and productive forest affected by beaver in a typical montane landscape in southeastern Norway, with forest vegetation similar to that originally found in much of Scotland. The study area (34.7 km^2) consisted of 648 managed forest stands. Immigrating beaver first became established in the study area in 1965 and the population peaked about 1990. Nineteen beaver territories (0.55/km^2) were occupied in the study area in 1993 and 19 additional sites had recently been abandoned. Only 0.1% of the productive forest in the study area had been inundated due to beaver dams. This low proportion of impacted area was due mainly to the beaver’s use of naturally existing ponds and lakes as sites for lodge building, plus the mountainous nature of the landscape. Where dams were constructed they were small. No Norway spruce (*Picea abies* L. 1881) or Scots pine (*Pinus sylvestris* L.1753) were felled. Beavers had removed approximately 50% of the birch (*Betula pubescens* 1791) and 60% of the aspen ≥ 10 cm diameter breast high (the minimum tree size defined in the study as having commercial value) from that proportion (2.6%) of the total study area where beaver felling occurred. This amounted to approximately 1.3% of the harvestable birch and aspen on the total study area. Since heavy thinning of most young birch and aspen to enhance conifer growth on productive commercial forests was part of their management strategy, the felling of these trees by beavers could be construed as a benefit for the forest owner, rather than damage. In addition, the sale of beaver hunting licenses helped reimburse some of the income loss incurred from tree felling and dam building. Forest managers in Finland have expressed greater concerns over beaver damage than those in Norway (Härkönen, 1999), this is most likely due to smaller mean forest property size, and therefore damage experience is relatively higher per individual forester (Parker *et al*., 2001a).

3.5.2 Conservation areas and species

Concern regarding the potential of negative impacts on aspen conservation in Scotland have been expressed, particularly in relation to important mature stands of high biodiversity value and sensitive, dependent species such as the aspen hover fly (*Hammerschmidtia ferruginea* Fallen 1817) and a range of red data book *Diptera*, lower plants and fungi. Recommendations to promote aspen hoverfly conservation include the protection of fallen aspen/dead wood as a breeding resource, managing sites to promote sustainable quantities of dead wood, and in the long-term the reduction of grazing (including fencing), to promote natural regeneration (Malloch Society, 2007). The protection with deterrent fencing of key aspen sites may be appropriate, and could be planned and mapped in advance if beavers are reintroduced in Scotland.

A recent study has demonstrated that whilst beavers can reduce mature tree coverage, beaver felling significantly increases sprouting, and therefore beavers could be utilised to facilitate aspen clone regeneration (as long as ungulate browsing pressure is low) (Runyon *et al*., 2014). However, given that the main biodiversity benefits come from larger, mature aspen, it would be likely that beavers would need to be excluded for extended periods of time, as they will tend to fell saplings thus preventing trees reaching significant size and maturity. Other tree species often taken by beavers, such as willow, readily coppice, re-root from felled stems, partially debarked cuttings or grow rapidly from wind borne seed in damp environments.

It is not only the direct felling of larger trees which is an issue. A further impact of beavers on aspen which has not been fully explored is their ability to de-bark large fallen trees. This removes the critical habitat for the aspen hoverfly and a range of rare *Diptera*. Further scientific study and monitoring for the actual scale of such an impact would be recommended and protection of key mature stands in associated fresh water bodies would most likely be required.

Batty (2002) concluded that overall beavers would have beneficial role for aspen in Scotland, however, potential conflicts could be reduced by protecting sensitive stands, avoidance of beaver reintroduction into areas prioritised for conservation of stands containing mature aspen trees, but most importantly by increasing the quality (range of sizes and ages) and quantity of aspen currently present. The co-existence of beavers and aspen (both mature trees and smaller shoots), has been documented across Europe. However, in Scotland the mature aspen resource is extremely limited and fragmented due to historical land management and is vulnerable to any new impacts. There is little doubt that beavers can have a significant impact on certain stands (Puplett, 2008). Studies undertaken in Scotland within fenced beaver enclosures suggest that rapid regeneration of aspen would occur following significant beaver felling activity in riparian woodlands (Jones *et al*., 2009), but critically replacement of mature trees would be slow, and may not occur at all especially if grazing pressure by livestock or deer for example, is significant.

Concerns have been raised over potential beaver impacts on specific fresh water species of conservation concern in a Scottish context. A knowledge gap concerning beaver interaction with other species including the European eel (*Anguilla anguilla* L. 1758), lamprey spp. and freshwater pearl mussel (*Margaritifera margaritifera* L. 1758) has been highlighted by the BSWG, and would require further monitoring in a Scottish context (BSWG, 2015). In one study questionnaires sent to beaver and fish biologists in Austria and Norway suggested that the European eel may benefit from beaver damming activates through increased cover and feeding opportunities (Collen, 1997). The endangered fresh water pearl mussel) is exhibiting declining populations across Scotland (Cosgrove *et al*., 2000). Published data is limited, but in Latvian rivers populations of pearl mussels are influenced by beaver damming activities leading to silting, water temperature change, shading and eutrophication (Rudzīte, 2005;

Rudzīte & Znotina 2006). Rudzīte (2005) stated that Eurasian beavers represent 'a threat for the pearl mussel population', therefore their presence is 'unacceptable in streams inhabited by *M. margaritifera'*. Active management in such areas has included removal of beaver dams and beaver culling undertaken by Nature Conservation Agency staff (Rudzīte & Rudzīts, 2011). However, the evidence presented by this above studies has been challenged due to the lack of a robust study design and supportive results, and also highlighting that pearl mussel recruitment appears to actually be occurring on beaver inhabited rivers (Campbell, 2006). Campbell (2006) argues that beaver activities can result in more sediment retention improving water quality downstream, and reducing extreme water fluctuations and so might actually benefit pearl mussel populations downstream from beaver ponds.

3.5.3 Fisheries

The reintroduction of beavers has the potential to result in a number of conflicts with native fisheries through the disruption to the migration patterns of fish species, including salmonids. There is lack of published data on interactions between beavers and fish in Europe, with most studies originating from North America. The potential benefits of beavers and their associated activities have been discussed in a number of publications (e.g. Macdonald *et al*., 1995; Collen & Gibson, 2000; Rosell *et al*., 2005; Kemp *et al*. 2010), and so will not be reviewed here. Potential negative impacts have also been reviewed and are generally considered to include damming activity acting as a barrier to fish movement, physical damage and siltation of spawning habitats (Knudsen, 1962) and fish mortality due to reduction in oxygen levels in beaver ponds (Kemp *et al*., 2010). Research has shown this increase in lentic (still water) habitat can benefit both juvenile trout, which have a strong affinity with pool environments, and large migrating adult salmonid species where ponds can offer an important refuge (Collen & Gibson, 2000). Beaver dams do not present a solid barrier to migratory fish such as salmon, if there is sufficient water passage over the dam itself for a fish to swim up and/or a deep enough column of water to enable the fish to jump (Mitchell & Cunjak, 2007; Thorstad *et al*., 2008). Beaver dams are 'leaky' structures with changeable flows. Water passes around, over, through and under dam structures (Lokteff *et al*., 2013). The majority of published research, though often citing beaver dams as barriers to fish movement, do not provide evidence that beaver dams are routinely impassable to anadromous species (Kemp *et al.*, 2012). In Norway, beavers commonly share the same watersheds with salmon and trout fisheries. Populations of hatchling salmon have been recorded above a series of beaver dams up to 1.6m high over a 600m stretch of stream, indicating the passage of adult fish (Halley & Lamberg, 2001). There is no perception of any beaver-salmonid issue in Norway (D. Halley, pers comm., 2014), and so almost no research has been undertaken despite their economic importance. Beaver populations are present at carrying capacity on many salmon rivers (Kemp *et al*., 2010).

Other studies demonstrate that juvenile salmonids are able to pass over or through dams to continue their downstream migration (Bryant, 1984; Swanston, 1991; Alexander, 1998) and that adults use side channels created by the diverted flow to bypass dams. Lokteff *et al.* (2013) found that Bonneville Cutthroat trout and Brook trout readily by-passed even large beaver dams, and argue that many fish passage concerns are largely speculative. Parker & Ronning (2007) concluded that due to the low frequency, small size and short life-span of beaver dams on spawning tributaries in Norway, their effect on upstream and downstream migration of salmonids would be negligible even assuming any temporary impoundment (which was not tested), and that this feature of their presence should have little overall impact on the reproductive success of salmonid populations in the long term. This assumption is supported by field studies of Pacific and Atlantic salmon populations in North America (Collen & Gibson, 2000). One example where fish-beaver inactions have been actively managed was in North America where beavers were removed from water-courses in parts of California occupied by the endangered Paiute cutthroat trout (*Oncorhynchus clarki* *seleniris* Snyder 1933) (Hunter, 1976). The role that any particular system of beaver dams may have on fish movements will depend on the character of formation, its size and location, as well as the river flow and seasonality (Halley & Lamberg, 2001; Rosell *et al*., 2005; Kemp *et al*., 2010).

The passage of fish through various flow devices has not been reported as an issue as long as the filter mesh size is adequate. Larger mesh size can be installed for flow devices where migratory fish passage is of particular concern. Fish ladders and slotted box fish ways (found on the Snohomish Pond Leveller) are designed as 'fish friendly' management techniques designed to encourage fish passage through flow devices by creating stronger currents and areas of white water attractive to these fish. Previously the Clemson leveller has been designed to encourage fish passage through flow devices (Close, 2003), but this is now generally accepted to be less effective than some of the more modern designs.

Selective felling may also reduce the species composition of leaf litter entering streams, which could alter their insect fauna and, consequently, the nutritional base for juvenile fish (Collen & Gibson, 2000). Increased temperatures found above and below the impoundments may be suboptimal for salmonids, and reduce dissolved oxygen levels (Avery, 1983). The reduction of bank-side vegetation and its associated shade can result in increasing water temperatures, which could be damaging to salmonid populations. However, such an effect is particularly site dependent as increased light can also increase in-stream photosynthetic production, hence increasing invertebrate and fish biomass.

In Bavaria, beaver activity in wintering fish ponds can keep the fish moving to the extent that weight loss and higher oxygen consumption may lead to fish stock loss (Schmidbauer, 1996; Schwab & Schmidbauer, 2003). It should, however, be noted that many disturbances can cause this effect, such as the activities of predators such as the North American mink (*Neovison vison* Schreber 1777). It would require further scientific investigation to determine if this would be a legitimate concern associated with beavers. It has been suggested that beaver activities where water flow is slowed down could lead to the dissipation of dissolved oxygen (McRae & Edwards, 1994), with a resultant reduction in the potential stocking capacity of a fishery.

3.5.4 Infrastructure

Localised issues do arise where beavers block major culverts, or burrow under service roads. Beaver can also use artificial structures such as roads functions as a pre-existing dam, adding further material so that water builds up behind this main structure. If unchecked, this process can result in structural damage and impact upon upstream properties or land use (Jensen *et al*., 1999; Boyles & Savitzky, 2009). There has been an example in Bavaria of beaver burrows resulting in the limited collapse of 3-4m section of a minor road immediately adjacent to a stream bend.

In recent years there has been a rapid growth in the restoration and use of canals for recreation. Beavers readily use large, canalised water bodies in mainland Europe. Where the bank sides of these canals are reinforced with rocks, sheet metal, concrete or heavy wooden piling there are few conflicts with beaver activity unless there are outflows or weirs that can be dammed (Deutscher Verband für Wasserwirtschaft und Kulturbau 1997). Beavers can create lodges on artificially reinforced banksides where building materials are available and will readily feed on adjacent vegetation. In Holland, during the early 2000's when the reintroduced beaver population was still small, nature conservation bodies removed sections of hard reinforcements on some canals to create shallow bays to allow beavers to access adjacent woodland (V. Dijkstra, pers comm., 2014). It is likely that where canals contain bay type features set back into the surrounding landscape with riparian vegetation and soil banks that these would be attractive habitats for beavers. If these are additionally connected to wider wetland, river, ditch or other riparian networks, then the immigration of beavers into a canal system would be inevitable. The principal concern regarding the existence of beavers in canals in Scotland would be their ability to potentially exploit any missing or lose stones and create burrows which may cause structural damage to canal retaining banks. Although mitigation is possible, it tends to be expensive to install, especially given the length of bankside that would need to be reinforced. As beaver populations increase their regular removal from these environments or their exclusion could become necessary.

Although beavers may be killed on roads, beaver families can live in close proximity to major road systems for many years without regular casualties or disturbance. While most dispersing beavers readily follow water-courses they will sporadically travel overland particularly in the early spring. It is possible that some of the fencing designs which have been developed to effectively mitigate against otter road casualties (e.g. fencing to prevent access to roads, under road passages, weir ladders, Chanin, 2006), could be adapted for beavers as appropriate.

Where fresh water bodies are near to roads there is the potential for beavers to fell trees which may result in disruption or hazards to road users. Potential solutions include the coppicing or protection of any trees within felling distance. Felled trees may also have the potential to cause incidental damage to fences, power lines, buildings, for example. Although the frequency of these events is very rare, when they do occur they can cause significant disruption and cost.

In areas where water, gas or sewage pipes and electricity or telephone cables are installed next to water-courses these can be occasionally damaged by gnawing, burrowing, flooding, or exposed through digging or water flow diversion. Such areas may require protective measures such as sunken or exclusion fencing or the regular removal of beavers. Settlement beds for sewage in close proximity to a water-course can be accessed by beavers. These habitats contain a reliable water supply and are commonly surrounded by lush vegetation. There is no indication that sewage odour is a deterrent for beavers. Water treatment plants can overflow due to obstacles created by beavers (Schwab & Schmidbauer, 2003).

3.5.5 Water storage and flood alleviation

During dry summers beaver dams and canals have been shown to hold more than 60% more water (including ground table water), than comparable environments without beaver activity (Hood, 2012). On the Keriou River in Brittany, the channel capacity prior to beaver presence was estimated at 535m3 over a distance of 120m. This rose to 3250m3 after a series of beaver dams were constructed (Coles, 2006). Studies in Belgium suggest that a series of beaver dams in the upper catchment of the Ardennes have played a significant role in the reduction of discharge peaks and hence flood events in villages lower down in the catchment (Nyssen *et al.*, 2011). The ecological value of the wetlands created by beaver activities are considered to be high but undervalued, in terms of water storage, water purification and their ability to regenerate degraded aquatic ecosystems (Czech & Lisle, 2003).

4. EXAMPLES OF DIFFERENT APPROACHES AND ISSUES ACROSS EUROPE

4.1 Norway

(H. Parker, Telemark University College, pers comm., 2015)

In Norway annual harvest quotas are issued to either individual landowners (if their estates are large enough) or to conglomerates of smaller landowners. The municipal quota is divided among individual landowners or conglomerates based on the relative area of beaver habitat found on their estates or conglomerates. The right to hunt belongs to the landowners, who are expected to control the beaver population on their land at their own expense by either hunting or trapping themselves, or letting others do so. This must initially be done during the normal open season and within the limits of their quota. Beavers can be controlled outside of the open season if significant damage is demonstrated and an application is made to the municipal authorities. Permission is almost always given, and it is not uncommon for landowners to solve the problem without applying for permission, as they are rarely indicted for breaking the law in this way. Beaver lodges and dams are initially protected in Norway and landowners must apply for permission to remove them. This is usually given, and undertaken by the landowners themselves. Thus the cost of beaver damage control in Norway is covered almost completely by the landowner.

This quota-regulated harvest has been in operation since 1855, and has in time resulted in a large beaver population across most of the country. Currently new beaver management by-laws are being considered by the central authorities, and one major revision suggests the replacement of this quota system with a landowner regulated harvest, by which landowners can determine the size of the harvest themselves. Many wildlife managers and conservationists have contested this radical change in beaver management policy, on the proviso that many land owners wish to implement significant population reductions.

In one detailed study within a Norwegian commercial forest, it was calculated that beaver management (including staff time and equipment), cost ~60,000 Norwegian crowns (approx. £5150), whilst ~20,000 crowns (approx. £1720) were earned from the sale of beaver hunting (21 animals shot) (Parker *et al*., 2001a). Although the authors conclude that a greater number of animals could have been hunted sustainably.

At present the main issues in Norwegian beaver management are considered as:

- Landowner acceptance of beaver presence.
- Animal welfare challenges of spring culling, including public and hunter resistance to the shooting of beavers in the late stages of pregnancy.
- Establishing methods of non-lethal beaver generated income.
- Declining hunting effort, for example the recruitment of young hunters, or lack of access to hunting opportunities due to landowner organisation.

4.2 Bavaria

(Schwab & Schmidbauer, 2003; Schwab, 2014; G. Schwab, pers comm., 2015)

The Eurasian beaver was successfully reintroduced to Bavaria from 1966 to the early eighties, and conducted by the Bund Naturschutz in Bayern e.V. Beaver population growth was accompanied in the late eighties by growing conflicts particularly in the intensively used landscape, with crop feeding, damming of forest and agricultural land, felling of garden trees and burrowing under roads, field and dikes. Part of the history of beaver reintroduction in Bavaria has seen great conflict between land owners / managers and conservation organisations. Frustration generated by an underestimation of the conflicts experienced by land managers (and often exaggeration of the conflicts) and a refusal to permit beaver trapping by the nature organisations, led to those experiencing negative impacts to react strongly against beavers and to an exaggeration (often inflamed by media reports and politicians) of actual damage. This escalated in the mid-nineties to the point that some farming organisations wanted complete removal of beavers from Bavaria.

Given the escalation of beaver-human conflict ~30 years after beavers were first reintroduced, a beaver management program was established in 1996, and was in the initial years funded by the European Community (LEADER II), and local authorities. Beaver managers consider the key to the future of beavers in Bavaria are the landowners who have to live alongside them. Although not every conflict could be resolved, there was a willingness of landowners to accept beavers providing advice, assistance and financial support was available. This is achieved through consultation with landowners over conflict sites, assistance with applying for funding for protective measures, and encouragement of the leasing or selling of vulnerable land to the state agencies or nature conservation organisations. These beaver managers and volunteers also implement a public relations programme which focuses on educating the general public about the benefits of beavers for other wildlife and habitats, and conflict resolution. At the same time conservation organisations had to accept that beavers can cause intolerable damage in some cases that warrant removal and as population densities increase, lethal measures is a likely management solution. A key consideration in the beaver management programme is long-term landscape planning for beavers and their habitat, through the creation of buffer zones around fresh water bodies to reduce future conflict. Another point of growing interest is flood control, as many of the actual and potential beaver conflict areas will have to be set aside for flooding protection anyway.

Beaver management is jointly operated between NGO operated beaver managers, county state agencies and volunteer beaver consultants. There is a voluntary state compensation for beaver damage (~450, 000 euros per year), and beavers are strictly protected under EU and Germany law. Part of the key to success is the ability to react quickly and assist people in implementing preventative solutions (e.g. tree protection). Beaver managers also train personnel in various agencies and companies, including planners. This work is supported by a network of volunteers which help in problem solutions, are responsible for monitoring beaver populations and distribution, public relations including education about beaver biology and ecology to discourage misinformation (e.g. fish eating, rapid breeding). Given the local distribution of these volunteers (whom are a mix of hunters, farmers, nature conservationists etc.), they are a first point of contact in any conflict, have local knowledge about the beaver populations in their area and are trained to assist in implementing solutions. In more complex cases, the beaver managers become directly involved.

Beaver managers (currently two individuals for the whole of Bavaria), also monitor national beaver population data. Given that beaver translocation is no longer an employed management technique, ~1000 beavers are now culled annually. This is undertaken under direction of the county's nature agency representative who give the permits. Removal of beavers is only done if they are causing (or might cause) severe damage, and no reasonable and payable preventative measures are available. Removal is, however, not a permanent solution, as the free territories are re-occupied by migrating juveniles.

At present the main issues in Bavarian beaver management are considered as:

- Continual education of people, especially landowners, and the disparity between actual beaver conflicts and people's perceptions, particularly how this is presented in the media.
- 'Political' interest – common misconception that if there are 'too many' beavers then increasing cull numbers will solve the problem – given the territorial nature of beavers

it is more cost-effective to employ management techniques that control activities whilst leaving the family structure in place.
- The use of beavers as scape goats for many other problems, from illegal use of public land along streams to developing industrial estates in flood plains.

4.3 Denmark

(T.B. Svendsen, Danish Ministry of the Environment, pers comm., 2014)

Eurasian beaver reintroduction to Denmark is managed through a steering group consisting of Nature Agency and Danish Centre for Environment and Energy representatives. Whilst actual beaver management is conducted by the Nature Agency, currently there are no specific positions allocated to beaver management alone with daily management conducted by local NA staff (North Zealand and Westjutland), with strategic management and legal issues managed by central office staff (Copenhagen).

To date actual mitigation has been generally low, with equipment costs (e.g. fencing, piping etc.) ranging from 1000-3000 euro per year. The cost of field staff specifically dealing with beaver conflicts has grown from zero to ~70,000 euros per year (1999 to 2014). Experience demonstrates that this expense tends to stabilise when all possible territories become inhabited. Over 100 volunteers participate in yearly beaver count estimates (both regions), with yearly expenses for this monitoring work estimated at approximately 40,000 euros per year. In addition, approximately 100-400 hours per year have been employed for nature interpretation, for example, guided beaver tours, with half of these expenses recovered through fees.

At present the main issues in Danish beaver management are considered as:

- Damming of smaller streams and ditches and the effects on nearby agricultural land.
- Public relations associated with beaver impacts on some private gardens.

4.4 Czech Republic

(J. Uhlikova & A. Vorel, Nature Conservation Agency of the Czech Republic, and Czech University of Life Science, pers comm., 2014)

Eurasian beaver numbers in Czech Republic have been significantly increasing over the last 30 years, and their management plan seeks to balance the protection of the species with the economic interest of various rural land practices, within a European legal framework. The Ministry of the Environment and Nature Conservation Agency of the Czech Republic are responsible for beaver management. In 2013 a management plan for beavers was adopted by the state authorities. This 10-15 year management plan aims to sustainably preserve beavers across various catchments, provide the administrative and legislative structures to deal with beaver conflicts, a public awareness programme particularly targeting land managers, and a monitoring/research programme to address population development and distribution.

Currently only one person is employed specifically for beaver management. This role co-ordinates with regional state authority staff. Beaver populations are monitored every two years within the seven Natura 2000 sites, with this work paid for by the state authorities. A state funded beaver compensation system has been in place from 2000 (under Act 115/2000), which allows compensation of damages caused by specifically listed endangered species (e.g. wolf, lynx, bear etc). Most compensation to date has been awarded for damages to crops and forestry. A total of approximately 72,283,427 million Czech koruna

(~£2,029,456) has been paid out since 2000, however, the majority of this compensation was paid to state owned forests.

Table 2. Total amount of compensation given based on the Czech law (Act.No. 155/2000 Coll) since it came into use in 2000 due to beaver damage to trees and crops, in Czech koruna.

Year	Total annual compensation (Czech koruna)	Approx. equivalent in British sterling (nearest £)
2001	9,345	262
2003	826,641	23,210
2004	1,726,521	48,474
2005	4,168,184	117,027
2006	7,213,323	202,523
2007	4,742,352	133,148
2008	6,775,301	190,226
2009	4,444,602	124,788
2010	7,469,800	209,724
2011	10,888,479	305,709
2012	9,857,237	276,755
2013	13,585,433	381,430
2014	576,211	16,178

The beaver (burrows, lodges and dams) is protected by law so lethal control or removal can only occur under licence. To date only four separate permissions have been granted for lethal control, mainly due to damage to fish ponds and flood banks. As the current beaver population is still growing, they mainly exist on the larger river systems so impacts on migratory fish are not yet considered to be an issue.

One of the most significant aspects of the beaver management plan is the creation of differential protection zones across the Czech Republic. Areas have been divided into one of three zones (A, B or C).

Zone A – represents areas of lowest risk of serious beaver impacts, with beavers fully protected in these zones which mainly represent the seven Natura 2000 sites. The main function of Zone A is to guarantee enough suitable area (size, hydrology, food resources and migration opportunities), to sustain a long-term viable population. Any interventions are individually assessed, but favour beaver protection with minimal management interventions. This covers ~0.9% of the Czech Republic.
Zone B – represents areas where generally beavers cannot cause serious conflicts or damage, with beaver presence generally supported but can be managed and removed if necessary. The aim is to permit the species but create balanced conditions for dealing with serious impacts on economic activity. Practical management combines a range of technical measures (e.g. fencing) and the elimination of animals where such measures cannot be applied or animals are causing significant damage. This covers ~86% of Czech Republic, and facilities beaver migration between Zone A areas.

Zone C – represents areas where beavers could potentially cause significant impact and damage, with beaver presence undesirable and prevented. These regions have many fish ponds and/or human infrastructure. This covers ~13% of Czech Republic.

At present the main issues in Czech Republic beaver management are considered as:

- A delay in the adoption and implementation of a beaver management plan.
- Lack of staff employed to adequately implement the beaver management programme. Preventative beaver mitigation are currently only sporadically implemented, which is perceived as a growing issue as beaver populations spread.
- Lack of an advisory service to promote the importance of beavers, for mitigation of beaver conflicts and public relations. Creation of a beaver management manual with technical advice specifically highlighted.
- A complicated legislative system with large administrative demands, and conflicts between legal protection status and hunting by laws.
- Financial resources to support the beaver management plan. Change to the current compensation system so that money is directed towards individual landowners, as supposed to state funded organisations.
- Repeated mass media coverage of beaver conflicts and associated negative public attitudes.

4.5 Finland

(J. Sundell, University of Helsinki, pers comm., 2015)

The Finnish Wildlife Agency is responsible for beaver management in Finland, with the Finnish Game and Fisheries Research Institute undertaking the monitoring of beavers in the country. Hunting volunteers assist this process by counting the number of active beaver lodges in their area, from which whole country populations are estimated. Hunting is controlled by the Finnish Wildlife Agency through local officers. Recent estimates for Eurasian beavers are 2363-3207 and for the North American beaver 3854-7155, through these are admitted to not being very accurate. More recently the threatened status of the Eurasian beaver has been recognised.

In general, public attitudes towards beavers tend to be positive, with their importance on biodiversity recognised by most. However, locally some landowners have issues with damage caused to forestry, roads and agricultural fields, but these don't seem to be a common occurrence. Beaver management does not constitute much beyond beaver hunting. There are future plans to reintroduce Eurasian beavers to various locations.

Currently there is no management plan for beavers in Finland, and no figures are available for management costs, though these are expected to be low. Beavers can be hunted for recreation and to remove 'problem' individuals. Hunting of North American beavers is quite straightforward under a general hunting licence and with land owner permission. There are no specific beaver trappers or hunters, with any culls undertaken by normal hunters. For Eurasian beavers a special permit is required, and this is only given for real problem animals. In 2013 ~4200 +/- 1500 beavers were hunted, with 214 of these being Eurasian. There is no Government compensation for beaver damage, although some landowners have insurance to cover losses. Locally dams can prevent migration of trout but again this is not considered a common problem.

The main management issue in Finland is considered to be the introduction and spread of the North American beaver, especially as they are more numerous and competitive than the native Eurasian. Future management plans are in preparation to prevent these two species overlapping their ranges, it is hoped this will be the first step towards an official national beaver management plan.

4.6 North American beaver introduction

The Eurasian and North American (*C. canadensis* Kuhl 1820*)* beaver are the only surviving members of the once larger family of Castoridae. They are now believed to have diverged about 7.5 million years ago when beavers first colonised North America from Eurasia across the Bering Strait land bridge (Horn *et al*., 2011). Both species are physically very similar making them hard to distinguish in the field. They have comparable ecological and behavioural patterns to such an extent they were once considered to be a single species. Modern chromosome analysis has identified differences (Eurasian beavers possess 48 pairs of chromosomes while North American beavers have 40, Lavrov & Orlov, 1973). Specific attempts to cross breed these species in captivity in Poland and Russia in the 1920's and 1930's were unsuccessful (Zurowski, 1983).

In 1937, seven North American beavers were introduced to Finland to supplement an ongoing reintroduction of the nearly extinct Eurasian beaver before the two separate beaver species were recognized (Lahti & Helminen, 1974). Since then they have spread throughout southwest and central Finland and into Karelian Russia, and now represent a sizeable population. In more recent times North American beavers have established a presence in parts of Belgium, mid-west Germany and Luxembourg, as a result of escapes from zoos and game parks (Dewas *et al*., 2012). A small population also exists in northern Finland near the Swedish and Norwegian borders and several small groups, which could develop into populations, are presently found in continental Europe (Parker *et al*., 2012). Recently, expanding populations of both species have converged on two fronts in Finland and northwest Russia (Parker *et al*., 2012). The body size of both species is similar, though litter size of the North American beaver is slightly larger. Only minor differences in life history, ecology and behavior exist, suggesting a nearly complete niche overlap (Parker *et al*., 2012). There is a distinct risk and concern that without robust management, the North American species could eventually competitively exclude the Eurasian beaver at all landscape scales. Due to the significant biological and ecological similarities of these two species, identification and removal of the non-native North American beaver is of serious concern, requiring active management and resource investment (Parker *et al*., 2012).

Given this experience and the documented ability of beavers to escape from captivity it would be prudent to mitigate against the potential introduction of North American beavers to Britain. Preventative measures incorporated in the beaver management plan for the Czech Republic including a database of all the captive collections holding North American beavers, the establishment of cooperation to ensure prompt attempts to recapture any escaped animals, the elimination of any identified wild living North American beaver as a non-native species and the promotion to captive collections of the replacement of North American individuals with Eurasian beavers. This has been implemented in Germany, were Eurasian beavers were provided to zoological collections, after any captive North American specimens had died.

Very few captive facilities in Britain currently hold North American beavers, though they are present in small numbers and have even been released historically (e.g. Isle of Bute). North American beavers can be readily imported, so greater consideration should be given to the purpose of such animal movements, their sterilisation or replacement with Eurasian beavers. The registration and permanent individual identification of all captive North American beavers in Britain would be pragmatic.

5. POTENTIAL FUTURE SCENARIOS FOR SCOTTISH BEAVERS

At a practical level, there are a number of possible scenarios for the future of beavers in Scotland, from complete removal to full reintroduction. The options below were initially presented by SNH to a range of stakeholders at the beaver forum held at Battleby, 21st November 2014, then revised on the 8th April 2015 and sent to various stakeholders for further feedback. Here we briefly discuss each of the revised scenarios presented, solely in relation to some beaver management and animal welfare considerations.

1. *Full removal* – The full removal of all beavers living in the wild in Scotland.

   The removal of beavers from the Scottish landscape has historically proven possible. If a full removal programme is implemented then it is likely to require a co-ordinated effort in order to ensure adequate standards of animal welfare are consistently applied, reduce resource requirement and ensure all individuals are removed. Specific removal teams could be employed, which could result in more rapid elimination. Alternatively incentives to encourage land managers to remove beavers could be awarded. Either process would require a sustained effort over a number of seasons, including long-term monitoring and reactive deployment of resources to ensure their full removal. Consideration would need to be given to appropriate trapping and dispatch methods, impact on incidental species, beaver breeding season, particularly the removal of adults whilst dependent young are present. There would be no alternative to this option other than the culling and removal of the extant beaver populations in Scotland, as translocation to other countries or into captivity are non-viable.

2. *Restricted range* – beavers allowed to expand from their current range but specific catchments would be managed to keep free from beavers.

   Any removal or restriction of beavers to specific sites would require similar considerations as full removal. The removal of dispersing animals or prevention of settlement in specific catchments could potentially occur outside of any management restrictions made relating to breeding seasons, if it could be demonstrated these were dispersing individuals without dependent young. This scenario is likely to require constant management effort and resources to ensure specific catchments remain beaver free. Unless this is undertaken by staff dedicated to this task, then disproportionate costs and efforts may be afforded by a smaller number of landowners. Beaver densities in permitted catchments are likely to be high, which may also result in increased human-beaver conflicts. The welfare of dispersing individuals into high density beaver territories and/or catchments were they are likely to be dispatched should be considered. Any natural colonisation without any further reinforcement of current populations would need to consider the long-term genetic health and viability of the present populations.

3. *Widespread recolonisation* – current beaver population would be allowed to expand to its natural limits.

   This scenario would have similar management and welfare considerations as stated for other scenarios. A range of management techniques, potentially including future population and lethal control, would be envisioned if this scenario was implemented. A national, co-ordinated programme of beaver management including access to pragmatic information would be required. Animal welfare considerations around breeding seasons, lodges and rehabilitation of injured/orphaned individuals are likely to be a priority. This scenario may also involve translocation of 'problem' individuals as densities rise, the management and welfare considerations of such are discussed below.

4. *Accelerated widespread recolonisation* – current beaver populations allowed to expand to natural limits and be assisted using proactive further releases

   Any larger scale programme of beaver translocation and release would need a greater level of coordination of trapping, animal holding and transportation, screening and release planning on a national scale. Any translocation programme would require suitable resources and experienced personnel, to ensure trapping and transportation were appropriate, or followed agreed protocols. It would be expected that release plans would be submitted in advance. These would include information on the sourcing and screening of animals; the registering of suitable facilities with associated equipment, and a release site assessment or plan. Best practice would see the translocation of wild beavers of unknown origin being screened to determine they were the correct species and free from any disease or parasites of concern, to ensure human health and protect indigenous wildlife in the release area. To ensure appropriate management and animal welfare standards it would be vital that any releases are co-ordinated with an adherence to appropriate protocols. Release sites should be identified and assessed in advance to reduce risk of injury and mortality through for example territorial disputes and human persecution.

6. FURTHER CONSIDERATIONS AND CONCLUSIONS

It is highly likely that any future programme of beaver management in Scotland would be an evolving process as established populations expand and as and when applications for further releases are approved. This position is subject to the decision of the Scottish Government regarding the future of beavers in Scotland. This decision may also include clarification on which beaver management techniques would be permitted and under what circumstances. Regardless of this decision, the current presence of beavers already in Scotland means there is already a management need. Any future management strategy should adopt a pragmatic approach, which is flexible and open to revision as appropriate. This is likely to be a more successful approach in the long-term than any inflexible, overly-bureaucratic system. Any beaver management plan should be adapted to the social and economic situation prevalent in the Scottish context. It should provide a range of management options and tools, so that tailored, site-specific actions can be implemented. Such management must be demonstrably acceptable to both landowners and the wider public (Hartman, 1999). Drawing on the established experiences of the best management systems already in place in Europe will be key to attaining this goal, although it is not thought that any single one of these approaches could be simply translated to a Scottish context. European experience of beaver reintroduction has suggested that the early development and implementation of appropriate management plans can help alleviate land manager and public concerns.

Government compensation schemes are common in some European countries; these pay landowners for accepting the presence of reintroduced species on their land. These schemes can be quite successful, especially in enabling the establishment of a reintroduced species or the protection of small / threatened populations, and are generally popular with the public (Cope *et al*., 2003; Naughton–Treves *et al*., 2003). However, opponents of such schemes question the long-term cost implications and the ethics of potentially encouraging landowners only to adapt their activities to a more wildlife-friendly approach with financial motivation (Bulte & Rondeau, 2005). In Bavaria the purchase of land to either enable a resident beaver population to establish or expand a wetland environment is a developed part of beaver management. Although there are examples of this process where local authority or central state funds have been used, the application of agreements whereby developers fund the creation of wildlife habitats to compensate for their activities elsewhere has also resulted in the creation of beaver-generated wetlands on the edges of urban areas, e.g. the village of Auerbach, Deggendorf.

Whilst there is clear potential for the statutory nature conservation organisations in partnership with the water management authorities to incorporate beaver habitats in the landscape and biodiversity targets of the Water Framework Directive, further opportunities could be explored to support beaver-created environments where they credibly contribute to the sustainable provision of flood attenuation.

Any considered process of long-term beaver management is best focused on the establishment of buffer zones (10-20m) around freshwater features. The provision of these riparian buffer zones is a target under the Water Framework Directive in many European countries due to the wider social, economic and environmental benefits which accrue from their presence. As appropriate, this habitat could be restored through planting (with native tree and shrub species) or natural regeneration. The availability of riparian woodland in the immediate vicinity of a freshwater body will reduce the need for more distant beaver foraging. This option will not always be practicable, for example where essential infrastructure is protected by raised flood banks, heavily modified or managed waterbodies are common or the associated land-use is too commercially important for the creation of buffer zones.

Public and landowner opinions are critical to any successful beaver management programme. Most beaver reintroduction projects (in Europe and North America) report a majority of public support initially, whilst landowners tend to be more opposed, and that the acceptability of lethal control increases over time and experience of living with this species (Jonker *et al*., 2006; Siemer *et al*. 2013). Others, such as Perryman (2013), found lethal control to be unacceptable and non-lethal mitigation was sought by communities, even amongst those with direct experience of beaver damage (Needham & Morzillo, 2011). Whether culling will be an accepted beaver management option in Britain, with often greater public resistance towards these techniques, will need to be seen. Hunting is only likely to be tolerated in certain areas, so is unlikely to function as a viable management option for population control on a national scale,. The overriding response from those living with beaver damage is the need for prompt action and an ability to react without overly-administrative requirements. Support through advice, appropriate equipment and funding is also sought.

6.1 Development of a management plan for Scotland

While various management techniques have been described in this report, the range of permitted options is still to be established. Landowners are likely to want clear guidance as to what management options are available to them (and which are not permitted), when they can be implemented, and they will want to be able to act quickly without a complicated and / or lengthy permission-granting process. To facilitate this process we suggest that that an advisory resource should be established to assist landowners with beaver-related issues. This group should possess the ability to assist practically with the deployment of effective management techniques, maintain a database of issues arising and their solutions. This process would allow for periodic management reviews, provide the co-ordination for the translocation of 'problem' animals and their relocation to suitable areas, assess the population size / distribution and report back on the status of beavers in Scotland to the National Species Reintroduction Forum. Any future beaver management should be accompanied by a thorough education programme addressing control methods and potential issues, methods to enable co-existence, beaver ecology and the potential benefits of their presence.

Beaver populations in Scotland are still small, with restricted range and low densities from what could be supported in the future. Non-lethal management methods including translocation could be employed while suitable, unoccupied habitat exists. Options for the translocation of problem animals and families will not be limitless so as the population rises and extends along with the other described solutions, culling is likely to become an essential beaver management tool. Initially culling could be operated by the wildlife authorities to ensure a clear, transparent and sentient rationale for this response. Any beaver removal would balance the options available and justify the need to cull as opposed to non-lethal management options. Ultimately the future management of beavers could become the responsibility of landowners once a clear understanding of an established process of this type, with established guidelines, was in place.

The use of beavers in riparian restoration and flood alleviation programmes should be seriously considered, along with a long-term management solution for conflict resolution with this species. Land use in Scotland requires strategic planning in which habitat restoration is incorporated in a multi-functional landscape.

Key implementation requirements:

- Public education on general beaver biology and ecology, and effective management options, to dispel misinformation, encourage acceptance and increase tolerance, including increased knowledge of the ecological importance of beavers for other wildlife and habitats. Balance perceptions with actual impacts (positive and negative).

- Widely accessible and practical information on the application of a wide range of management techniques, including good quality demonstration material, site specific advice, material specifications and detailed instructions. This could include an information network to provide appropriate advice to resolve conflict and be proactive in preventative solutions.
- An ability to offer on-site assistance without the need for an overly-complex and prolonged licensing system to manage animals suitably.
- Beaver management should be science-led, involving research and monitoring of the effects of beavers and development of flexible management strategies.
- A comprehensive management plan should be put in place, in advance of beaver population spread and increasing densities, incorporating stakeholder engagement and support.
- Ongoing, proactive and site-specific management strategies are required, including the ability of land managers to remove dams, particularly in artificial drainage systems, without a lengthy, licenced procedure.
- Advance identification of 'no beaver' areas and potential relocation sites. Any areas identified as too sensitive to beaver presence (e.g. important infrastructure), can be maintained as 'beaver free' through a co-ordinated trapping and relocation, or culling process, as appropriate.
- Development of trapping protocols, system of trappers (central agency or system of local approved volunteer individuals) and equipment, identification of relocation sites (development of habitat suitability survey).
- Long-term land-use planning to incorporate buffer zones into freshwater bodies and allow the natural regeneration of these areas. In particular the potential role in flood alleviation planning.
- Central database to monitor population numbers and distribution, monitor conflict sites, review and revise management programme as required.

6.2 Conclusions

Scotland has a modern, multi-use landscape much changed from when the Eurasian beaver was last present. However, there are no indications that this species cannot be successfully restored to a modern Scottish landscape and will adapt accordingly, as demonstrated across Europe. There is no doubt that this species, which possesses such ability to modify its environment and regulate watercourses, will generate conflicts and costs to the land managers affected. Such impacts should not be underestimated, though they do tend to be localised, and therefore have variable costs to different landowners. Management techniques that have been developed and regularly employed exist from experiences in Europe and North America, and there are no apparent reasons why these could not be implemented successfully in a Scottish context. However, longer-term, landscape scale planning, incorporating the restoration of riparian zones for biodiversity would reduce the majority of beaver-generated conflicts and provide greater ecological benefits. Such buffer zones will not be possible throughout Scotland, so pragmatic management solutions for landowners, without over-bureaucratic licensing requirements are key to encourage those who will ultimately shoulder the negative impacts of beaver reintroduction, to tolerate them within manageable limits. In time this is likely to involve lethal control, though various non-lethal solutions are likely to offer longer-term solutions, requiring less repeated resource expenditure.

The ecological benefits and services often attributed to beavers and their activities may be less tangible to realise, especially when compared to more readily identified and quantifiable negative impacts. Such positive effects or ‘ecological services’ will only be apparent on a landscape scale if beavers are restored to typical densities and allowed to modify their environments. Therefore a pragmatic management plan for Scotland should make provisions for both reactive, short-term solutions, but ultimately develop proactive, and longer-term solutions, to enable co-existence.

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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