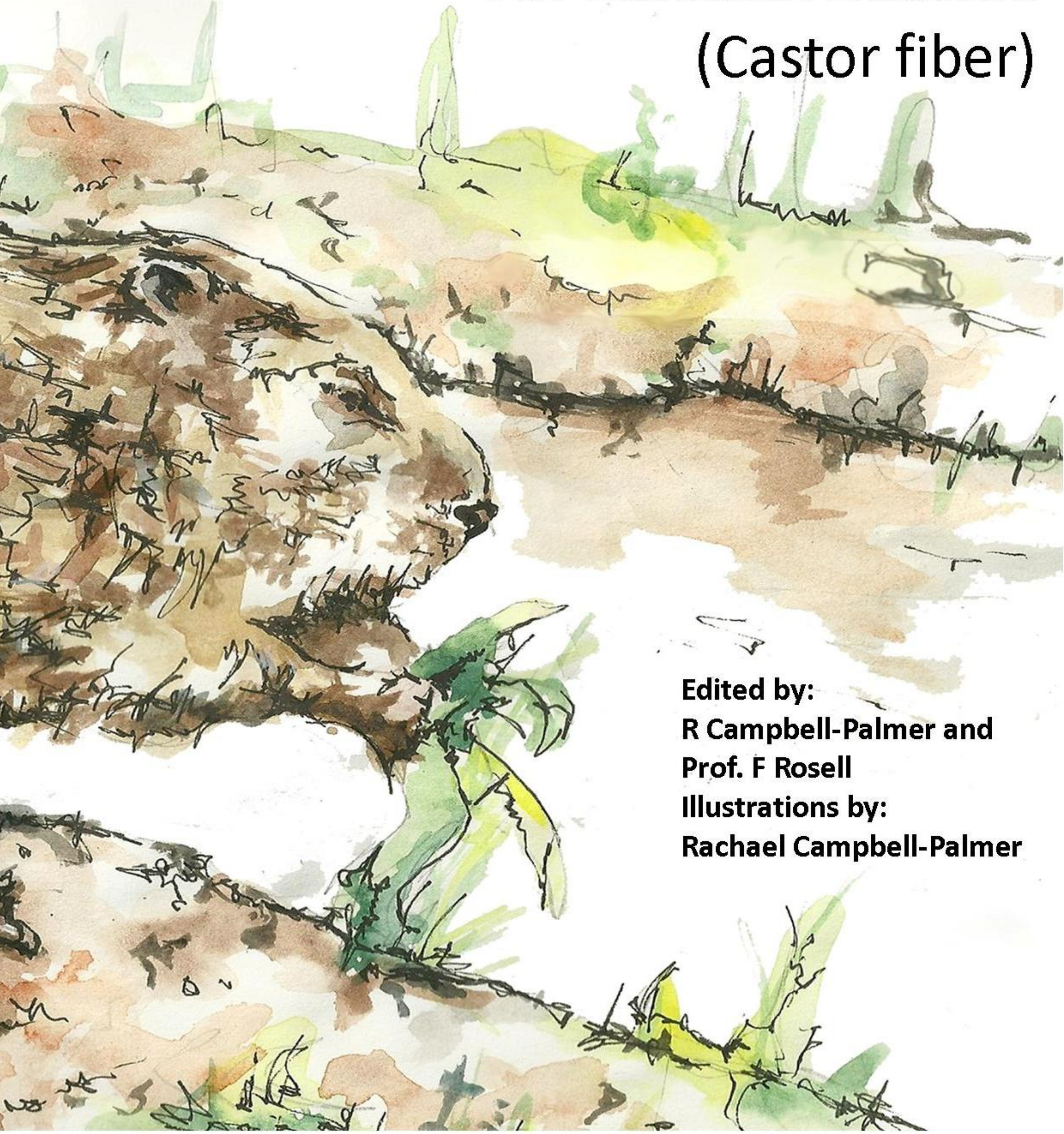
Captive Management Guidelines For Eurasian Beavers

(Castor fiber)



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SCOTTISH BEAVER TRIAL

Captive Management Guidelines for Eurasian Beavers (*Castor fiber*)

Eds. Roisin Campbell-Palmer and Prof. Frank Rosell
Illustrations Rachael Campbell-Palmer

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PREFACE by Professor Frank Rosell

To date, no complete captive management guidelines for Eurasian beavers (*Castor fiber*) have been published. The following guidelines are based on experience gained by the contributors from the capture, containment and transport of numerous beavers within Europe over the last 20 years. We have also gained extensive experience from the study of wild beavers, especially in Norway. I started my beaver work at Telemark University College (TUC) back in 1994, and since then approximately 70 scientific beaver papers have been written by the TUC group. During the summer of 2007 Iain Valentine, the Director of Animals and Conservation at the Royal Zoological Society of Scotland (RZSS), contacted me and wanted help to reintroduce beavers into the wild in Scotland as part of the Scottish Beaver Trial (SBT). In May 2009 four beaver families were released in Knapdale and seven kits have been born since. This collaboration has led to an increase in the knowledge necessary for the development of good beaver husbandry.

This is a European collaboration, aimed at providing advice to zoological and private collections, and those involved in reintroduction and translocation projects following EAZA husbandry guideline protocols. Thanks to all the contributors, including, among others, animal keepers, ecologists, nutritionists, students and veterinary surgeons, these first beaver captive management guidelines have become a reality. Special thanks to the SBT Field Operations Manager Roisin Campbell-Palmer whom I have had the pleasure to work with in Norway studying wild beaver, in Knapdale, at Edinburgh Zoo and the Highland Wildlife Park in Scotland. Without Roisin's enthusiasm, spirit and "eager beaver" work ethic these guidelines would probably not have been written for many years to come. Special thanks also to the RZSS, SBT and TUC staff who have been involved in the reintroduction process, including Frode Bergan, Frid Berge, Jo Elliot, Bjørnar Hovde, Rob Needham, Pia Paulsen, Howard Parker, Sarah Robinson, Rob Thomas and Iain Valentine, and to Rachael Campbell-Palmer for her many wonderful drawings. We are also very grateful to Phoebe Carter from Lower Mill Estate, Emma Hutchins from Wildfowl & Wetland Trust and Helmut Maegdefrau from Tiergarten Nürnberg for their valuable information on beaver enclosures within their respective organisations. We also thank James Scott (SNH) for information on the legal context of beavers in Britain. Last but not least many thanks go to Alan Finlay for proof reading and Tracy Lambert for all her time and hard work in making the printed version possible.

We hope these guidelines will increase the welfare of beavers in captivity and in reintroduction projects, and encourage further research on this incredible species. Those interested in more detailed information should browse the list of references. Finally, we would appreciate hearing the experiences of others (please send your comments to one of the editors) so that the next version can be even better.

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1. TAXONOMY & CONSERVATION STATUS

1.1 Taxonomy

There are two living species of beaver; the Eurasian (*Castor fiber,* table 1) and the North American or Canadian (*C. canadensis*) beaver, which are the only two extant members of the family Castoridae. Beavers are the second largest rodent in the world. Externally both species are morphological similar and have comparable ecology and behaviours (Novak 1987, Busher 2007, Rosell *et al.* 2005). They were once classified as one species (Lavrov & Orlov 1973, Hill 1982). However, the two species have different numbers of chromosomes (Eurasian 2n=48; North American 2n=40, Lavrov & Orlov 1973), and even though copulations between the two species have been observed (Lavrov & Orlov 1973), no hybrids have ever resulted (Lavrov 1996), even after deliberate attempts to create them in captivity (Zurowski 1983). A recent molecular study has estimated that the two species diverged about 7.5 million years ago, when beavers colonised North America from Eurasia (Horn *et al*. 2011).

Table 1. Taxonomic classification.

ORDER	**Rodentia**
FAMILY	Castoridae
GENUS	*Castor*
SPECIES	*fiber (and canadensis)*
ESU	Western, Eastern
PREVIOUSLY DESCRIBED SUB-SPECIES/POPULATIONS (for *Castor fiber*)	*C.f.albicus, C.f.belorussicus, C.f.birulai, C.f.galliae C.f.fiber, C.f.orientoeuropaeus, C.f.pohlei, C.f.tuvinicus*
COMMON NAMES	Eurasian beaver, European beaver

1.2 Protection & Conservation Status

The Eurasian beaver appears on the International Union for Conservation of Nature (IUCN) Red List of threatened species. It is currently categorised as "*Least Concern*", but conservation efforts are recommended to ensure this species does not become endangered again (Batbold *et al.* 2008), as a result of continuing threats (section 1.4). Although beaver populations in Europe are expanding, populations in Asia are small and under threat (Durka *et al*. 2005). Asian populations consist of three subspecies/populations (*C. f. tuvinicus*, *C. f. pohlei* and *C. f. birulai*) (Durka *et al*. 2005). It is estimated that <700 individuals of *C. f. birulai* exist (Chu & Jiang 2009) and hence this subspecies is classified as "*Endangered*" in the Chinese Red List (Batbold *et al.* 2008). Current population size and geographical separation of these Asian subspecies have led to calls for them to be managed as evolutionary significant units (ESU), thus requiring special conservation efforts to stabilise numbers and protection from expanding European populations (Stubbe *et al*. 1991, Durka *et al*. 2005). Based on mitochondrial DNA, Eurasian beaver may be separated into two management units (MU), eastern and western (Durka *et al*. 2005).

The Eurasian beaver is listed as a protected species on Annex IV of the EC 'Habitats Directive'. This makes it illegal to capture, injure, kill and even disturb at sensitive times during its life cycle. The possession, transportation and trading in this species is also an offence, but it is possible to carry these actions out under an appropriate licence from the relevant statutory authority, subject to strict conditions (http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm).

The Eurasian beaver is also protected under the Bern Convention, which specifically recommends the recovery of missing keystone species. As a listed Appendix III species any exploitation must be regulated in order to keep populations out of danger, e.g. closed seasons, temporary or local prohibitions of particular exploitation, and the regulation of trade in live and dead specimens.
(http://conventions.coe.int/Treaty/EN/Treaties/Html/104.htm).

N.B. These guidelines offer practical advice and management techniques employed for this species. Given its protected status and legal variations between European countries, the legal implications of undertaking any of these techniques should be investigated beforehand and the appropriate licences and permission sought before implementation.

1.3 Past & Current Status in Wild

Although numbers have recovered significantly throughout most of their former range (figure 1), Eurasian beaver populations still require active conservation management to ensure their long-term survival.

Figure 1. Current (as of 2011) distribution of Eurasian beaver (light grey) and North American beaver (dark grey), across Europe (Halley, Rosell & Saveljev 2012).

Presently the only areas within the beaver's natural range where reintroductions have not occurred are Albania, Bulgaria, England, Greece, Italy, Kosovo, Macedonia, Montenegro, Portugal, Turkey and Wales (Halley 2011). The current minimum estimated world population of Eurasian beavers is ~1.04 million (Halley *et al*. 2012). Beavers are naturally restricted to the northern hemisphere, with the northern limit determined by permafrost and the southern limit determined by temperature and moisture.

1.4 Threats to Survival

By the end of the 19th century the Eurasian beaver had almost become extinct, owing to sustained over-hunting for fur, meat and castoreum (Nolet 1996, Nolet & Rosell 1998). The current numbers have recovered from approximately 1,200 individuals left in eight isolated populations (Nolet & Rosell 1998). Translocation and reintroduction programmes were widely used (for both conservation purposes and the fur trade industry), so that today the beaver occupies much of its former range (Halley & Rosell 2002, 2003, Halley *et al*. 2012). Over 200 translocations have been recorded across 25 European countries (Halley & Rosell 2003, Halley 2011).

The main threats currently facing the Eurasian beaver are from human-wildlife conflicts, habitat loss and degradation, and the spread of the introduced North American beaver in certain areas of Europe (Nolet & Rosell 1998, Parker *et al*. in press). Although they are protected in a number of countries, beavers are easy to locate, especially during the autumn months, and so can still be targeted by humans.

2. BIOLOGY & FIELD DATA

2.1 Morphology

The Eurasian beaver is a large (adults >20 kg), herbivorous, group-living, semi-aquatic rodent. Beavers are socially monogamous and exhibit little sexual dimorphism. Adults of both sexes (3 years or older) have similar head and body lengths, although females are on average 1-1.5kg heavier (Wilsson 1971, Campbell 2010). On average, adult beavers have a head and body length of 75-100cm and tail length of 30-40cm (Zurowski & Kasperczyk 1988). Coat colour is usually brown, but ranges from golden-brown in Scandinavia to black-brown in Poland. Beavers have distinctive tails, which are large, dorso-ventrally flattened and covered with fine scales. The hind limbs are well developed and provide much of the power for locomotion on land and in water. The fore limbs and paws are relatively small, but very dexterous. Most lifting is done by grasping and dragging objects by the mouth, though beavers will also carry mud and vegetative materials for short distance by their forepaws (Wilsson 1971, Műller-Schwarze & Sun 2003). Beavers have small ears, but their hearing tends to be quite good, their eyesight is quite poor, so that beavers mainly see and respond to movements. The eyes are small with a small optic nerve and the retina lacks a light-reflecting layer, the tapetum *lucidum*, which is present in most mammals and aids vision under low light conditions (Walls 1967, Hartman & Rice 1963). Hence, beavers' eyes do not display eye-shine, when lights are shone upon them. Their olfactory sense is excellent (Campbell-Palmer & Rosell 2011). The skull is relatively large to provide attachment for the powerful musculature required to fell trees and process wood with their large incisors (section 7.8).

Kits weigh on average 0.525kg at birth (Wilsson 1971, Parker & Rosell 2001). Yearling weights in Rhone beavers have been recorded as 11-12kg and two-year old weights as 14-17kg (Pilleri *et al*. 1985). In Norway and Sweden mean weights of 7-8kg for yearlings and 13-14kg for two-year olds have been recorded (Hartman 1992, Parker *et al*. 2001); however weights can vary depending on time of year. Mean spring (March-May) weights of adults in Norway (3 years or older) average 19.7kg for females and 17.8kg for males (Parker *et al*. unpublished). Individuals of all age-classes tend to lose weight over the winter period (Campbell 2010).

2.1.1 Aquatic adaptations

Beavers spend large amounts of time in the water foraging and maintaining their territory. They are able swimmers, reaching a maximum swimming speed of 2.1 metres/second and can move large distances (Kitchener 2001). Beavers' ears, eyes and nose are set high on the head so these senses can still be used whilst swimming along at the water's surface. They have an additional eyelid, the nictitating membrane, which protects the eye and enables them to keep their eyes open under water (Wilsson 1971, Lancia & Hodgdon 1984). Beavers breathe through their noses and their nostrils automatically constrict when in contact with water (Warren 1927). The ear flaps can be folded and hair inside the ears traps air to reduce water entry. The epiglottis is located inside the nasal cavity, preventing water from entering the larynx and trachea; this also means beavers cannot breathe through their mouths (Coles 1970). They can close off the oral cavity using the raised tongue base and closing the lips behind the incisors at the diastema, thereby preventing unwanted material or water being swallowed while gnawing or foraging under water (Coles 1970). Beavers have no external reproductive organs and small extremities.

Their large webbed hind feet (figure 2) provide most of the thrust during swimming, with the tail mostly being used as a rudder, although in rapid swimming, tail movements are synchronised with the hind-leg movements, so that the tail makes a powerful downward movement as the hind legs are brought forward (Wilsson 1971). To change direction when swimming, beavers make powerful strokes with one leg, whilst angling their lower back and tail towards the desired direction. Whilst swimming, beavers hold their forefeet up under their chins.

Figure 2. Hind paw showing specialised (split) grooming claw (second inner toe), replicated from Ruth Pollitts' illustration (in Kitchener 2001).

Beaver fur consists of two different hair types – long, coarse guard hairs and shorter, dense, soft under-fur. The under-fur is very dense, so that when a beaver submerges in water, a layer of air is trapped next to the skin which helps repel water and improve insulation (Scholander *et al*. 1950). Therefore beaver fur does not become saturated and it dries very quickly once out of the water. Beaver fur has good insulating properties, especially in water, with the fur on the belly (23,000 under-fur hairs/cm^2) almost twice as dense as the fur on the back (12,000 hairs/cm^2) (Novak 1987). They undergo two moults a year in spring (April-May) and autumn (August-September). Beavers spend a lot of time grooming to maintain fur quality and have a specifically adapted grooming claw (split nail, figure 2), which they use to comb their fur and which is located on the second toe of the hind foot (Hamilton & Whitaker 1979). The incisors are also used during grooming and frequent grooming is essential to ensure insulation and buoyancy (Fish *et al*. 2002). Beaver whiskers are used as sensory tools, particularly in dark or murky water, to avoid objects and can give a sense of the strength of water currents.

Beavers can submerge for up to 15 minutes (most dives are much shorter foraging dives of 5-6 minutes or less) (figure 3), owing to physiological adaptations which enable them to exchange about 75% of the air in their lungs when they breathe (Irving & Orr 1935, McKean & Carlton 1977). Adaptations during diving include reducing heart rate (bradycardia) to around half the normal rate, increased brain blood flow with reduced flow to other organs, except the heart, lungs and adrenal glands (McKean 1982). Beavers can tolerate high concentrations of carbon dioxide in their tissues (Irving 1937).

Figure 3. Diving beaver.

2.1.2 Land adaptations

Whilst on land beavers walk on all fours and are generally slow and cumbersome. They often rise onto their hind legs when felling trees or gnawing branches, using their tail to stabilise themselves (Carlson & Welker 1976). The forearms are mainly used for walking, digging, carrying and manipulating earth and vegetation; they are not used for swimming apart from in very young animals. The front paws (figure 4) are quite dexterous and can grasp and manipulate objects. Beavers are strong and capable diggers, forming burrows, chambers and canals as well as gathering earth and mud for various constructions.

Figure 4. Beaver forepaw, replicated from Ruth Pollitts' illustration (in Kitchener 2001).

The tail of a beaver consists mainly of thick fatty tissue, which acts as an important fat store (Aleksiuk 1970). The tail is used to aid balance when gnawing trees (Rue 1964) and to signal alarm by slapping it on the water surface, a behaviour known as tail slapping (Curry-Lindahl 1967, Schramm 1968). Cutright & McKean (1979) assert that the tail serves in heat exchange though a counter-current arrangement of blood vessels, although recent evidence from thermal imaging suggests this is not the case (Zahner & Müller 2006), with most heat being lost through the less dense fur coverage on the back. Tail dimensions can reflect body condition (section 7.2.2). Tails are often damaged during territorial disputes between non-family members, but tend to heal quickly. Patterns of scaring and notching on the tail can be unique and may be used to identify individuals (figure5).

Figure 5. Beaver tail with a unique tail scarring pattern that can be used for individual identification. These healed scars were caused by tail tagging (mid-two scars) and fighting (notches near end)

2.2 Longevity

In a wild-living reintroduced population beavers lived on average 14 years (Nolet & Baveco 1996), though wild animals up to 20 years old have been recorded in a study population in Norway. The record for captive individuals is ~28 years. Beavers senesce; body condition (both sexes) and reproductive output (females) initially rises until at least 4-6 years of age, but declines after this (Campbell 2010).

2.3 Ecology

Eurasian beavers are found across most of northern Eurasia between 35°N and 70°N (Halley & Rosell 2002, Műller-Schwarze & Sun 2003). They live in and around fresh water, using water as a refuge from predators, to transport larger food items and to store food over winter (Wilsson 1971). Slow-moving mature rivers are preferred over faster-flowing mountain streams (Hartman 1996, John *et al*. 2010). They also inhabit ponds and lakes. However, water bodies with shores that experience significant wave action and/or large fluctuations in water levels are less suitable (Smith & Peterson 1991, Hartman 1996, Parker *et al*. 2000, Pinto *et al*. 2009). Beavers require a water depth of at least 0.7 – 1m to build their lodges and may dam the watercourse if the depth is less than this (Hartman & Törnlöv 2006). They may also dam to flood areas of suitable food and building materials, so that they can forage within the safety of water.

Beaver territories are used by the family group and can range from 0.5 – 20km (mean 3km) of shore or river bank length, but this is largely dependent on beaver population density and habitat quality (Macdonald *et al*. 1995, Herr & Rosell 2004, Campbell *et al*. 2005). The settlement pattern of immigrants into a previously unsettled area may also play a role in territory size whereby, if settlement is gradual, early settlers claim much larger territories with higher habitat quality, which later settlers may find difficult to compress, leading to disparities in territory size (Nolet & Rosell 1994). Settlement pattern can have an impact on territory size that may last several years (Nolet & Rosell 1994). Beavers share their freshwater habitat with several mammals, including otter (*Lutra lutra*), mink (*Mustela lutreola* and *Neovison vison*) and water vole (*Arvicola amphibius*); these and many more species of invertebrate, fish, amphibian and even reptile may also make use of active or abandoned beaver lodges (Rosell *et al*. 2005).

2.4 Behaviour

2.4.1 Activity

Beavers are most active from dusk to dawn, largely emerging from lodges around 20:00hrs during the summer months and usually being active for 12-14 hours a day, although this can be highly variable (Sharpe & Rosell 2003). Time budgets between the sexes do not tend to differ for most activities, but males tend to exhibit longer daily activity periods and travel further distances associated with territory defence (Sharpe & Rosell 2003). Beavers can travel between approximately 1 and 9km per night, with the distance moved increasing with territory size (Nolet & Rosell 1994, Herr & Rosell 2004). Time spent travelling by both sexes increases with increasing air and water temperatures (Nolet & Rosell 1994, Sharpe & Rosell 2003), although the sex difference in travel may also possibly be due to female's being more involved in care of offspring (Herr & Rosell 2004).

Beavers in a reintroduced population in the Netherlands spent on average 7.7hrs of their 12-hour active period (defined as time not in a lodge) foraging during ice-free winters and 5hrs of their 10 active hours foraging during spring and summer (Nolet & Rosell 1994). This is proportionately similar to Norwegian populations, where 2.4hrs were spent foraging out of the 4.6hrs when beavers were active and visible (Sharpe & Rosell 2003). Thus beavers spend at least half their time budget searching for, gathering and consuming food. Time allocated to travelling, foraging or resting in lodges has not been found to vary over the course of a night (Sharpe & Rosell 2003). Less is known about nightly variation in other behaviours, though building behaviours may be more common later in the night after the animals have fed (Wilsson 1971).

Within-den behaviours consist mainly of sleeping/resting, feeding and grooming, with seasonal, diel and ontogenetic differences mainly relating to changes in frequencies of feeding and sleeping; however no sex differences have been recorded (Mott *et al*. 2011). From spring onwards sleeping time tends to decrease, whilst grooming and feeding increase. Lodge maintenance behaviours increase around autumn in preparation for winter (Hodgdon & Lancia 1983). Increased exploratory behaviours occur prior to sub-adult dispersal, along with increased sentinel behaviours in other family members around the time of the birth and emergence of kits; these are all associated protective behaviours (Mott *et al*. 2011).

2.4.2 Social behaviour

Beavers display a dominance hierarchy based on age, with adults dominant over younger animals (Campbell *et al*. 2005). In captivity female dominance over males has been observed during pair-bond formation. However, after this no sexual dominance is usually demonstrated (Wilsson 1971).

Beavers live in family groups, which consist of the breeding adult pair together with offspring from the current and previous years, with only the dominant adult parents breeding within the family territory each year (Wilsson 1971, Műller-Schwarze & Sun. 2003). Once paired, beavers tend to remain together until one is displaced by another of the same sex or until one member of the pair dies (Műller-Schwarze & Sun 2003, Campbell 2010). Both the male and yearlings help to rear any kits (Patenaude 1983). In established populations large family groups (up to 11 individuals) can build up when offspring remain philopatric beyond sexual maturity, owing to a lack of territorial vacancies in the surrounding area (Campbell *et al*. 2005).

A variety of social behaviours have been described by Wilsson (1971, see also Campbell *et al*. 2010). These include allogrooming, nose-to-nose contact, caravanning and wrestling. Allogrooming (mutual grooming) is an important aspect of social contact, reinforcing social bonds between group members; it may also be significant for kits when learning to socialise and is likely to reduce aggression. When wrestling, usually in water, two beavers grasp each other or thrust their noses together and push against each other. Whining vocalisations are usually made when wrestling. Wrestling may be an agonistic behaviour linked to dominance within the family group. However, agonistic interactions are seldom observed (Mott *et al*. 2011), with most being vocal rather than physical interactions (Hodgdon & Lancia 1983). Social behaviours are more common in younger animals and the rate of social interactions declines with age (Wallis 2007).

2.4.3 Chemical communication & scent marking behaviour

All individuals over 5 months old defend the group territory, mainly through scent marking (Wilsson 1971, Nolet & Rosell 1994, Rosell 2002, Herr & Rosell 2004, Rosell & Thomsen 2006). The two main sources of scent are castoreum from castor sacs and anal gland secretions (AGS) from the anal glands (figure 6). These two primary scent-producing structures are located in two cavities found between the pelvis and base of the tail (Walro & Svendsen 1982, Valeur 1988). The two anal glands are holocrine secretory glands, which open into the cloaca, while the two castor sacs are pockets, lined with a non-secretory epithelium (Svendsen 1978, Walro & Svendsen 1982), which open separately into the cloaca.

Figure 6. Scent structures of Eurasian beaver.

Scents are largely deposited on specially constructed piles of mud and vegetation called scent mounds, which are formed throughout the year along territory boundaries near feeding and resting sites (Aleksiuk 1968, Rosell & Nolet 1997, Rosell *et al*. 1998). Castoreum is more frequently deposited than AGS and acts as the main scent used in territorial defence (Rosell & Sunsdal 2001).Castoreum is mainly composed of dietary derivatives and does not show differences between the sexes (Müller-Schwarze 1992, Sun & Müller-Schwarze 1999). Families' over-mark and act aggressively towards conspecific scents (Rosell & Bjørkøyli 2002, Rosell & Steifetten 2004). Beavers may fight with intruders, possibly resulting in wounds and scarring, particularly on and around the tail and rump area, or even death (Piechocki 1977). The Eurasian beaver exhibits sexual dimorphism in the development of scent–producing structures (castor sacs and anal glands) and this difference is thought to have arisen because of intersexual differences in territorial scent marking (Rosell & Schulte 2004). Owing to their greater use in scent marking, males have smaller castor sacs, which allow high flushing rates, and larger anal glands, which produce more AG secretion (Rosell & Schulte 2004).

Male Eurasian beavers spend significantly more time in territorial defence at territory borders, and deposit more scent marks and over-marks during the summer than females (Rosell & Thomsen 2006). Adults of both sexes display similar use of space within their territories (Herr & Rosell 2004). Scent marking is significantly higher during April-June, when dispersal of sub-adults occurs (Rosell & Nolet 1997, Rosell *et al*. 1998). This represents the time of greatest threat to territory holders as dispersers seek feeding resources and mating opportunities. However, during the mating season (Jan-March), there is a secondary peak in scent marking around February when females are in oestrus (Rosell & Bergan 2000).

2.4.4 Habitat-manipulation behaviour

Dams

If the water depth requirements of beavers are not met by naturally-occurring riparian conditions, beavers are likely to build dams to raise water levels and reduce the flow of water. While the construction of dams is less common in Eurasian beavers living in the same habitat as North American beavers (Danilov & Kan'shiev 1983), under certain environmental conditions dam building can be common and families may construct more than one dam along a stretch of river (Hartman & Törnlöv 2006). Dams may also be constructed at the outlets of existing bodies of water. Dams can be >100m (up to 1200m) in length and up to 5m in height (maximum 3.25m in Norway), though most are much smaller (Macdonald *et al*. 1995, Rosell F, personal communication).

Dams are built by placing sticks and branches downstream against the flow of water, thereby forming supportive structures, and then pushing up sedimentary material from the river or lake bed to form the base and inner surface of the dam (Macdonald *et al*. 1995, Műller-Schwarze & Sun 2003). Other material can be used for construction, such as turf excavated from adjacent banks, plant roots and rocks. Small dams made with maize stalks have been found in Bavaria (Campbell R, personal communication). Dam-building and maintenance behaviours appear to be triggered by the sound of running water (Wilsson 1971), but such an acoustic stimulus may not be a prerequisite for initiating dam building (Żurowski 1992). Beavers begin to exhibit building behaviours as juveniles at around one year of age (Wilsson 1971).

Lodges and Burrows

Beavers will dig burrows if the bank material is suitable, but can build lodges as a supplement to, or in place of, burrows (Zurowski & Kasperczyk 1988). Both lodges and burrows contain an entrance tunnel starting underwater, a feeding chamber at water level and a sleeping chamber above water level, and may have more than one of each (Wilsson

1971). Wilsson (1971) described a gradation of constructions from burrow to lodge, depending on bank substrate and water levels, but essentially there are three main types of lodge: a bank lodge where part of the burrow is supplemented with sticks and mud; a brook lodge where most of the chambers are contained above ground within the sticks and mud; and thirdly an island lodge where the entire burrow and chamber system is contained within the sticks and mud, surrounded by water.

Trails & Canals

Where beavers regularly use the same route to forage on land, well-worn trails develop. These can fill with water and beavers may push mud from the bottom and pile it up on the banks of these channels or begin digging at the water's edge, thus creating a canal (Műller-Schwarze & Sun 2003, Wilsson 1971). Canal width is usually between 40-60cm and depth ranges from 0.2- 1.2m, whilst length can range from a couple to >100m (Zavyalov 2011). Canals facilitate movement through the beavers' habitat, including the transport of felled trees, and offer a quick escape route from actual or perceived threats.

2.4.5 Feeding Behaviour (see Chapter 4 also)

Beavers are generalist herbivores that feed on bark, shoots and leaves of woody plants, herbaceous plants and aquatic vegetation (Wilsson 1971, Svendsen 1980). Digestion of plant material is aided through hind-gut (caecum) fermentation (Vecherskii *et al*. 2009), with material given additional digestion though caecotrophy (Wilsson 1971). All beavers, except unweaned kits, exhibit caecotrophy, which involves the ingestion of specially produced green faeces to maximise uptake of nutrients. Caecotrophy occurs on land, while normal urination and defecation occurring in water (Wilsson 1971).

In the spring and summer beavers feed on a wide range of natural herbaceous vegetation, including terrestrial, emergent and aquatic plant species (Nolet *et al*. 1995), and these may account for up to 90% of their diet at this time of year (Svendsen 1980). As this vegetation dies back over the colder months, woody plant material dominates the diet. Differences in diets between geographical regions across Europe are due to the availability of foods in the habitat rather than differences in feeding preferences (Danilov *et al*. 1983). Beavers can fell quite large trees (> 1m in diameter), of which they will eat the bark and smaller branches and leaves. However, smaller saplings (diameter <10cm) are generally preferred (Haarberg & Rosell 2006, Margaletić *et al*. 2006).

Most feeding activity occurs at or close to the water's edge, with most felling activity recorded within the first 20m up to 40m away (Haarberg & Rosell 2006, Margaletić *et al*. 2006). Trees are felled and material transported back to the vicinity of water to be consumed, frequently at favoured sites on the river-bank known as feeding stations (Wilsson 1971). Once felled, larger trees may need to be cut into smaller sections before they can be transported to water (Wilsson 1971). Herbs and forbs are usually browsed *in situ* (Campbell 2010). Food selection appears to be mediated by nutrient content and digestibility of the available forage with individuals attempting to maximize energy intake over time (Doucet & Fryxell 1993, Nolet *et al*. 1995). Beavers adjust foraging intensity and preference with distance from water, following a central-place-foraging strategy (Orians & Pearson 1979, Haarberg & Rosell 2006). Foraging intensity declines while food selectivity and (within limits) tree diameter taken increase with increasing distance from the safety of water (Haarberg & Rosell 2006).

Figure 7. Foraging beaver carrying vegetation.

Beavers often feel for food in the water with their forepaws then carry vegetation in their mouths (figure 7). The forepaws are used to hold and manipulate vegetation whilst feeding (Wilsson 1971). Very fine sticks and stalks are completely ingested, being fed steadily into the mouth. With thicker sticks the bark is removed with the incisors as the beaver rotates the stick using its forepaws (figure 8). The peeled sticks are then discarded, often forming visible feeding stations. On vertical trunks bark may be stripped off in long strips, using an upward motion of the head, whilst forepaws are held against the trunk. During gnawing it is the lower incisors that do the cutting whilst the upper ones act as an anchor point (Wilsson 1971).

Figure 8. Beaver holding and rotating stick with its forepaws, removing bark with its incisors.

2.4.6 Predation

Aside from humans, the main historical predators of beavers are wolf (*Canis lupus*) and brown bear (*Ursus arctos*) (Rosell & Czech 2000), though lynx (*Lynx lynx*) may also prey on beavers (Rosell & Sanda 2006). Smaller carnivores such as fox (*Vulpes vulpes*) (Kile *et al.* 1996), possibly pine marten (*Martes martes*) (Rosell & Hovde 1998) and otter (Tyurnin 1984), may also feed on beaver kits and yearlings. However, beavers are unlikely to be predated by otter - any beaver remains recorded in spraints are most likely the result of scavenging on carcasses (Rosell & Czech 2000). Analysis of mink (*Neovison vison)* scats in beaver lodges identified no demonstrable evidence of beaver remains (Brzeziński & Żurowski 1992), although there have been occasional field reports of predation on young beavers (Recker 1997).

Beavers are less likely to forage on aspen (*Populus tremula*) branches tainted with predator odour (Rosell & Czech 2000) and are less likely to over-mark beaver scent mounds that have been contaminated with a predator scent (Rosell & Sanda 2006), indicating that the presence of predators has a deterrent effect on the behaviour of beavers. Beaver lodges, defensive behaviours and a semi-aquatic lifestyle offer protection against predation (Rosell & Parker 1995).

2.4.7 Defensive behaviour

When threatened, beavers slap their tails loudly on the water surface to communicate the threat to others. Tail slapping is a specialised alarm behaviour, which involves raising the tail out of the water and bringing it quickly down to slap the water's surface, usually followed by a dive. Tail slapping warns other family members of the presence of potential predators and may deter predators from pursuing beavers. Predator and human presence, unfamiliar noises and odours (including castoreum from unknown beavers) can all stimulate tail slapping (Müller-Schwarze & Sun 2003). Beavers can discriminate tail slaps from different individuals, with older animals tending only to react to tail slaps from other adults, particularly females (Müller-Schwarze & Sun 2003).

Beavers have defensive vocalisations, mainly in the form of hissing. Hissing can be heard in response to capture, handling and unfamiliar scents or towards other animals. In captivity beavers will often hiss, tail slap, grind their teeth, and charge and/or push objects with their forepaws when disturbed, or approached in confined spaces during capture or handling.

In a wild population of beavers in southern Norway an additional defensive behaviour has been described. The behaviour involves a beaver picking up an object (a stick if available, but occasionally other objects), rising up on its hind legs and moving its upper body rapidly up and down while holding the object in its mouth and forepaws (Thomsen *et al*. 2007). The behaviour was usually witnessed at disputed territory boundaries and may be wholly confined to individuals within this population in southern Norway, though similar behaviours have been witnessed on three occasions in North American beavers (Thomsen *et al*. 2007).

If water is not immediately accessible, beavers may 'freeze' when threatened (reports for both wild and captive beavers). Freezing is accompanied by fear bradycardia (slowing of the heart rate). This behaviour may help conceal the beaver on land and reduce likelihood of its detection by a predator (Swain *et al*. 1988). Long dive times have also been recorded in extremely frightened beavers, which have been observed pressing themselves against the bottom of a river or lake, where they remain motionless or they can swim considerable distances under water to escape (Wilsson 1971).

3. ENCLOSURE DESIGN AND HOUSING

3.1 General Features

Members of the same family should be housed together; this may include animals from a range of sexes, ages and litters, as long as they are related and currently living together. Ideally, if trapping and re-housing a family group, the trapping interval between all family members should be kept to a minimum. Individuals from the same family have been accepted even with trapping intervals of a number of weeks (Gow 2002), but this may not always be the case, so the operation should be treated with care. Also, it may be hard to ensure that members of the same family are being trapped and that different beavers have not replaced them. Studies of wild North American beavers have shown that beavers can recognise relatives, even if they have been born several years apart and never previously met (Sun & Müller-Schwarze 1997). Animals from different families must not be housed together, unless trying to establish a breeding pair. This requires a carefully controlled and staged introduction protocol to ensure that there is only one female and only one male involved, and that there is adequate room for escape, should aggression occur. It is essential that individuals to be paired together are sexed correctly (section 7.1.3); otherwise severe fighting will occur with resultant injuries. If attempting to build up beaver numbers within a single enclosure, a pair should be allowed to breed or a whole family translocated rather than trying to create a group from unrelated animals.

Beavers will readily attempt to escape from enclosures by digging and biting through fencing. Some collections have even reported beavers climbing over fences. They are adept at building ramps of material gathered from within the enclosure against areas of fencing, under bridges, etc. Such activity, if unchecked, can provide a platform for escape. Inspection of various beaver holding facilities and enclosures can provide vital information on what does and does not work, prior to designing any new facility.

Key enclosure design requirements

- Access to fresh water, deep enough for animals to submerge, that can be emptied and changed, or is fed by a natural source.
- Entire enclosure is surrounded by proven beaver-proof fencing that prevents digging, climbing and chewing.
- In- and outflows to any enclosure should be reinforced as these can act as escape points.
- Land section should enable digging and earth manipulation to occur and/or have enough resources to enable lodge construction/or provide shelter.
- Any trees or fellable materials close to the enclosure fence line should be protected or removed.
- Enclosure fences should prevent entry of predators/scavengers.
- Enclosure design should prevent instances of flooding, both naturally occurring and those created by beaver activity.

3.2 Enclosure Examples

RZSS Highland Wildlife Park, Scotland (Richardson D, personal communication)

The beaver enclosure consists of the main portion, which is approximately 640m^2, and a connected smaller enclosure of about 168m^2 (figure 9). The water to land ratio is about 30% to 70%, with the land area being tussock grass landscape. A constant trickling of fresh water is maintained by a hose and seasonal fill from a neighbouring stream. The water area is quite changeable due to canal digging and dam building by beavers. The main lodge structure has also been added to and altered by subsequent families of beavers, initially North American, but Eurasian in more recent years. Trees are protected by simple, free-standing 1m high welded mesh (~5cm^2 spaced) guards (figure 10). Much of the raised wooden visitor walkway that covers the dividing fence between the two enclosures is supported on recycled plastic posts that the beavers have never attempted to chew. To facilitate swift and easy capture of the beavers, when required, a large welded mesh trap is permanently positioned within the enclosure, near one end of the main body of water. The trap has a door at one end that is tied open and a portion of the beavers' food is placed in the trap 2-3 afternoons per week to keep them habituated to it.

Figure 9. Main beaver enclosure at HWP.

Figure 10. Tree guards used at HWP.

In addition to the main beaver area, a former otter enclosure (figure 11 & 12) has been used for temporary holding. This enclosure is about 100m^2 with a 50:50 land to water ratio. The main pond area (figure 12) is floored with concrete, fed by a constant natural stream and a couple of stone-and-log-construction dens have been built by the keepers and added to by the beavers. The perimeter barrier is a combination of 1.5m high smooth concrete wall and an area that is contained by a 1.4m high welded mesh fence with a 0.4m wide 90° mesh overhang. The weld-mesh is mounted on an exterior wooden frame with the base set in concrete.

Figure 11 & 12. Former otter enclosure used to house beavers at HWP.

Lower Mill Estate, Gloucestershire, England (Carter P, personal communication).

This beaver enclosure covers an area of 14,200m^2 with a lake of 11,800m^2 (a former gravel pit), and mixed woodland (willow, oak, aspen, alder, etc.) and peripheral scrub, grass and trees comprising 2400m^2. The average depth of the lake is 2m. Set in the woodland is a large, natural pond, from which the beavers have excavated canals in several directions. A small (4m diameter) artificial pond was dug in the woodland prior to the release of the beavers. This was initially well used with signs of a canal being created between it and the lake. However, this appears not to have been used for several summers now. Two large natural lodges have been built on the shores of the lake along with a series of large burrows in the steepest banks. The beavers have bred successfully every year since their initial release, with between 2 and 4 kits born each year. The lake is enclosed by 1m high stock-proof fencing, with 40cm laid flat at right angles to the fence and staked down. In some areas where beaver burrows have started to approach the fence line, additional fencing has been sunk into the ground to a depth of 1.5m. Running along the inside of the fence is a single strand of electric wire. The fencing is checked daily for any signs of damage. The inflow and outflow are fitted with rigid metal grills, cemented firmly into the lake bed. A wire mesh 'beaver deceiver' has been fitted around the outflow to trap debris and prevent the outflow from blocking up.

Tiergarten Nürnberg, Germany (Maegdefrau H, personal communication).

This beaver enclosure contains two pools measuring 74m x 105m and 75m x 105m, both up to 1.4m deep, with underwater viewing. These ponds are connected by a small waterfall, with dam building prevented through the use of hot wires at the top. The water is filtered with a turnover of around 14 hours. The available land is split into two areas, approximately 110m² and 170m². Dens are provided, where the beavers breed, but they dig their own burrows around the enclosure. Good breeding success has been experienced annually.

Upcott Grange, Broadwoodwidger, England (Gow D, personal communication).

This enclosure offers approximately 8 acres (3.2ha) of meadow and stream habitat, fenced with 2 inch (5.08cm) weld-mesh ~1.20m high with a "chicken" mesh collar attached along its lower edge, extending at a 90 degree angle for 2ft into the enclosure (section 3.5); this collar is pegged to the ground (figures 17&20). The fence is set well back from the ponds, ~50m from the water's edge. There are two large natural ponds - approximately 18m in diameter and <4m deep, which are spring fed and well vegetated with grass, herb and reed species. Although there was some willow woodland in the lower part of the enclosure, the beavers felled this in the first few years of occupancy and any subsequent regeneration has been limited by constant browsing. The beavers have built three dams in the stream system linking the upper and lower ponds. They generally occupy a lodge in the lower of the two ponds, which they built themselves. They have additional burrow systems throughout the riparian zone in the enclosure. Where the stream formerly exited the enclosure, it has been piped to flow underground for a distance of 20m before entering its original course. The access to the outflow pipe is grilled with a rigid bar system. This is cleared of beaver debris every couple of days in the winter to allow a smooth flow of water.

Wildfowl & Wetlands Trust, Slimbridge, England (Hutchins E, personal communication).

The entire area accessible to beavers is approximately 120m x 120m with around a quarter being water of varying depths up to 2m. The fencing on land is high-tensile horse netting (75mm mesh size), attached with fencing rings to weld-mesh (5cm). 1 metre of the weld-mesh is above ground, with 90cm buried with a 30cm return into the enclosure. The fencing at the water's edge is also horse netting, but attached to 180cm-high, heavy-duty galvanised chain link, which is laid on the bed of the pond to prevent digging. The whole perimeter is additionally protected with a seven-strand electric fence at 15cm and 45cm above ground.

The initial lodge was provided and was a simple design of straw bales with a tin roof covered with brash with one tunnel into the water. The beavers have created an additional exit tunnel to the rear and extended the wood pile 2m into the water. The lodge area has been increased at the rear by adding more straw bales on two occasions and in cooler weather this is still used by the beavers. There is a CCTV camera, which can be used for observing animals within the lodge.

At two corners of the pond there are alder trees, which the beavers have access to and a variety of willows and other shrubs towards the back of the pen. Some of the trees are protected with a simple collar of chicken wire or mesh. Diet is a selection of apples, carrot and cabbage daily, with occasional sweet corn cobs or sweet potato. Additional branches (willow, alder) are also given either directly into the water or pushed upright at the water's edge. There is no filtration of the water, but a flow is achieved by drainage from the surrounding land area and can be increased by redirection of the flow from the central "wild at heart" clean water course.

Wildfowl & Wetlands Trust, Martin Mere, England (Hutchins E, personal communication).

The main beaver enclosure is approximately 1,320m^2, housing a breeding pair and offspring from two previous years. This naturalistic enclosure includes two ponds, which the beavers have joined together with a canal, with two lodges built by the beavers (one bank lodge, one freestanding). The water to land ratio is approximately 1:3, with the water supply pumped from a nearby pond (treated sewage water) and run through a metal pipe. The outflow pipe is protected by mesh, but still requires clearing on a daily basis. Water depth varies but is approximately 1-1.5m at the deepest point. Fencing consists of weld-mesh (~5cm spaced) to a height of approximately 1.2m above and below ground level. An electric fence, consisting of four wires, surrounds the perimeter of the enclosure.

A stand of mainly birch and alder is present within this area, most of which have now been felled, but some remain protected with wire. A stand of willow and poplar has been planted and will be 'available' for beaver browsing on a rotation system once established. Beavers have access to wild browse at all times, but supplementary feeding is also required on a daily basis, consisting of apples, potatoes, carrots and sweet potato. This food is placed in the traps, which are fixed open within the enclosure to facilitate capture as required.

3.3 Water Area

Being semi-aquatic beavers should always be provided with suitable access to water for swimming. As a potential prey species beavers will often naturally enter and remain in the water to avoid capture, which should be taken into consideration before planning any catch -up procedure. It is possible to keep beavers out of water for short periods of time, for example, after surgery or whilst in temporary holdings. However, behavioural and ethical consequences must be taken into consideration. Under such circumstances a heavy metal, non-tippable water dish must be provided, as beavers will often attempt to bathe and defecate in any available water and therefore tip water dishes or move them around.

Water should be kept open during cold weather, with ice broken daily. Beavers swim readily under ice and chew or dig to make holes in it, but additional ice breaking may be required in captivity to ensure adequate access. It is usually sufficient to break the ice at the animal's normal entry and exit points to the pool.

Ideally any water pool should reach at least 1 m in depth to allow normal diving. The edges of any pool should be gently sloped so animals can enter and exit easily. If a pool has right-angled edges, a wide shelf should be added (figure 13) just below the water level to assist exit from the water and also provide a place for beavers to sit. This shelf or ramp, for obvious reasons, should not be made of wood. Beavers will often feed and groom at the water's edge, where they feel more secure. The volume of any pool should reflect the number of animals to be comfortably held by a particular enclosure size.

Figure 13. Quarantine pool (L 103cm, W 102cm, H 47cm) adapted for short-term (1 month) holding of beavers in Norway. Metal non-slip shelf to enable beavers to sit in water to groom and feed, replicating natural behaviours. Depth of water is sufficient to allow complete submersion. This size of pool should be emptied and cleaned daily, and is suitable for 1-2 animals.

3.3.1 Water quality

Beavers defecate in water, so pool hygiene is paramount as they will also drink from this. Pool size will determine the regularity of water changes, especially on non-filtered systems. Emptying and refilling pools with large volumes of water may not be viable to maintain water quality so alternative water treatment methods should be employed. Static water bodies will quickly become fouled; ideally larger pools should employ a constant input/output water system. Debris such as uneaten food and faeces should be scooped from the water every day. Water in smaller pools/tubs should also be changed on a daily basis. However, it should be noted that such cleaning and water changes can be stressful to beavers. Cleaning and refilling of smaller pools should be completed before other enclosure servicing is undertaken, for example when beavers are sleeping in their lodge. Any water treatment methods should address visual quality, and remove suspended and dissolved solids and pathogens. Regular monitoring of water chemistry and biology is recommended; especially on larger water bodies (see Boness 1996).

3.4 Substrate

The substrate within the enclosure should allow for digging and manipulation, in order to facilitate natural behaviours and provide exercise. All enclosures should ideally have areas of soil that will allow for digging and burrowing rather than a collapsible substrate, such as sawdust. This may make effective display to the public difficult as beavers will readily manipulate any movable materials to adapt their environment. Beavers will readily split any light timber into shreds to form their own bedding materials. Straw or wood chips can also be provided for bedding material. Solid concrete flooring should be avoided as abrasion causes damage to foot pads and tails. Thicker logs and branches should be provided for gnawing and building activities. Beaver constructions should be left in place as long as they do not cause a risk to any animals or keeping staff, or provide means of escape, or present a hygiene risk.

3.5 Walls & Fencing

Beavers can be hard to contain without the appropriate fencing. Access should be possible around the entire perimeter fencing, both inside and out, to ensure ease of checking and maintenance. Evidence from a number of holding facilities suggests that the containment of beavers in large areas of suitable habitat is practicable, but dependent on the topography of each site. Past escapes have generally been linked to poor perimeter fencing, flood events or a failure to cater for burrowing alongside water inflows or outflows. Perimeter fencing should be checked on a daily basis. Fencing can be solid, tall or thick enough to prevent climbing, digging or gnawing. Even where a hotwire is deployed, fencing should still extend underground by at least 0.5m to prevent beavers from digging underneath. Overhanging fencing is recommended to discourage climbing and entry of predators/scavengers, such as foxes, particularly when there is a risk of disease and parasite transfer between species.

Figures 14 & 15. Different perimeter fencing used to retain beavers at RZSS Edinburgh Zoo (left) and Highland Wildlife Park (right).

In friable soils with raised banks beavers more often build burrows rather than construct lodges (Zurowski & Kasperczyk 1988). Beavers are adept burrowers and will in time extend a mixture of canals and burrows from a central water body outwards into an enclosure. Beavers build lodges in part to be able to utilise bank-side habitats, where excavation is difficult. Facing river banks with a pitched rock surface is a standard and effective anti-burrowing mitigation. If burrow blocking is required, then filling burrows with stones can be effective. Signs of digging near the fence should be monitored and filled in, especially if beavers start to dig canals near the fencing as they tend to follow water courses. Digging can also be deterred through use of weld-mesh (figure 17), which can be sunk underground to enable digging, but prevent escape.

Figures 16. Overhanging fence with hot wire at HWP Stones have been used to prevent continuation of canal digging next to fence line.

Figure 17. Weld-mesh used to prevent digging.

Any trees within falling distance of the fence line should be removed, coppiced or protected through fencing (figure 10 & 18) wire guards or ‘game paint’ (figure 19) to ensure beavers do not fell them on to the fence line. Protection can be achieved though ringing the trunk from the base to approx 1m up the trunk with wire mesh (higher if deep snow is likely).

Figures 18 & 19. Protective fencing at RZSS to discourage tree felling in a beaver enclosure (left), game paint used to deter beaver gnawing (right).

Underground fences, which do not extend beneath the normal water table, must normally, be set well back from the water's edge to be effective. Where the fencing can be set over 30m away from any friable bank-side habitat, then a perimeter fence can be erected with a collar facing inwards at a 90-degree angle at the ground surface. This ground-level collar should be pegged to the ground and extended into the enclosure for at least 115cm (figure 18). Vegetation will grow through the collar, ensuring that it forms a secure mat.

Varying reports about beavers' ability to climb exist. Beaver fences in England have traditionally incorporated as internal components mains-, battery- or solar-powered hotwires at heights of 38cm and again at 75 - 100cm above ground level. Shortage of power from these fences, owing to encroachment by vegetation can be problematic. Low-level electric wires are particularly difficult to maintain, with regular monitoring and vegetation clearance essential. Careful use of an electrical strimmer every 2-3 weeks will keep the vegetation in check. Experience gained recently from three separate holding facilities, where beavers have died as a result of gripping low-level electric wires in their teeth, suggests that this design is hazardous and their use should be abandoned. A better solution may be to employ an anti climb strip of smooth material (metal or thick plastic) attached to the top of the fence by 'hog' rings for example.

Drainage leaving the site should ideally be piped and grilled. The grille should be a legged structure, sunk down to a depth of 1 metre into the ground below the outflow pipe. At least one escape from a beaver enclosure has been prompted by burrowing alongside an outflow pipe and exiting under the internal curtain. To negate this possibility on either side of the grille, 5cm 3.25-gauge weld mesh should be extended down into the ground to a depth of 1.2 m. This weld-mesh should be extended along the fence for at least 20 m. Where the grill sits in the stream, the sides and base of the channel should be covered with a mesh screen. It should be noted that any fencing, particularly in more naturalistic enclosures, should not impact on the movement of protected species, such as otter. It is recommended that enclosure location and design are discussed with the appropriate statutory conservation body.

Standard beaver fencing design consists of ~2m posts set on the outside of the fence (away from the beavers) and sunk 90cm into the ground with ~1.2m standing above the ground surface. High-tensile wire ($7.6cm^2$) is strained at regular intervals across the height of the posts. At ~90cm, a 30cm-broad strip of smooth heavy duty plastic or sheet tin is hog-ringed to the internal wire as an anti-climb strip. The advantage of this design is that electric 'hotwires' are not required. Along the base of the fence a 5cm weld-mesh curtain extends into the enclosure for 90cm (figure 20). This curtain extends up the perimeter fence to a height of 30cm and is hog-ringed to the fence. Where straining posts are set on the internal side of the fence, these must be protected with 2 inch weld-mesh guards. Where burrowing may be an issue, a 5cm heavy-gauge weld-mesh curtain should extend down into the ground to a depth of 1.2m.

Figure 20. Standard beaver fencing to discourage digging and gnawing.

Figure 21. Hog rings connecting fencing.

It is recommended that the fence line is walked and inspected daily.

3.6 Sleeping & Breeding Areas

Artificial lodges or sleeping dens should be provided for beavers when first entering an enclosure. These should be situated near the water's edge, with the opening facing the pool. Often the easiest form is created by using bales of straw with a weighted-down plywood or metal sheet roof. This roof must initially be supported by placing straight branches on top of the straw bales to support the roof sheets, because when these shelters are new, adults climbing on top can cause them to collapse onto other individuals inside. Once the beavers have started to adapt to them, they rapidly form a series of strong internal chambers. Further branches, browse and digging materials should be provided, as often beavers will choose to construct their own lodge or modify an artificial one. Beavers often prefer to dig and form burrows, in which they sleep. The entrance to a beaver lodge will open out under the water and beavers often cover lodges with a layer of mud. Breaking open a lodge should be avoided unless necessary. If this has to occur, beavers should return to the same lodge, but may be unsettled, so additional lodge-building materials should be provided to allow them to modify and restore their lodge. An easier way to catch beavers in larger complex enclosures is to leave a beaver trap in the enclosure and regularly place some of their feed within the trap, which should be securely tied open. This approach will habituate the beavers to the trap and facilitate a swift and relatively stress-free capture. If a permanent artificial lodge is provided (perhaps with viewing facilities as in some zoos), ideally these should have 2-3 inter-connecting chambers with each being about 1m^3 to encourage use and allow for breeding. Cameras may be placed in these areas to enable public viewing during visiting times.

3.7 Visual Barriers

Beaver pairs/families should ideally be housed out of sight of other beavers. If beavers from separate family groups are housed in adjoining pens, then the walls should be solid to prevent wounding through territorial fights. Ideally a distance of several metres should be maintained between beaver families to minimise olfactory stress. Beavers/beaver families have been separated at a distance of <10cm through use of a solid steel barrier to prevent physical injury.

3.8 Environmental Factors

If beavers are maintained in large, naturalistic enclosures, with good access to adequate shelter and fresh water, in which depth does not fluctuate widely, the main environmental concern would be access to essential environmental resources (especially food) for all individuals, especially as population numbers increase. Correct management should monitor environmental conditions to ensure they are appropriate and adequate for the number of contained animals. Additional heating and draft exclusion tends only to be required when housing very young or sick animals away from other family members.

3.9 Hygiene

Depending on pool size and number of animals, water should be changed daily due to risk of infections. It should be remembered that beavers drink from water, in which they also swim and defecate (beavers tend not to soil their lodges). Beavers should be allowed to build their own shelters and make their own beds without regular disturbance. However, these should be monitored if possible to ensure they are not damp, with fresh bedding provided regularly. In small enclosures wet bedding and substrate should be removed on a daily basis as should any uneaten food. Although lodges should also be checked for any carcasses, if individuals are unaccounted for, this is not always easily accomplished. Beaver-built structures can be extremely robust and the crepuscular nature of the species ensures that they are not easy to monitor or observe. Other techniques such as monitoring of food taken and camera traps should also be employed.

3.10 Mixed-species Exhibits

Beavers will live alongside a range of other wildlife species. The potential to include them as a component of wetland exhibits is clear. European otters have been housed with beavers at Edinburgh Zoo. Otters had access to the beaver enclosure through wide ceramic and plastic pipes, through which the beavers could not pass. Both species were often seen at dusk sharing the same pool, but rarely came into direct contact or displayed any interactions with each other. The otters moved into the lodge, which they co-habited with the beaver/s and eventually gave birth there. The otter cubs were raised without incident and no injuries to either species were ever observed. As the lodge was not opened, it is unclear whether more than one chamber existed or if they occupied different chambers within the lodge, though it is thought this is most likely. Wild otters have temporarily shared the beavers' enclosure at the Highland Wildlife Park. However, care must be taken to ensure that other large rodents cannot access the lodges as mortalities have occurred in the past as a result of capybaras (*Hydrochoerus hydrochaeris*) entering a breeding chamber and crushing small beaver kits (Gow D, personal communication). Consultation with experienced beaver keepers is advised when planning mixed exhibits.

3.11 Escape Prevention

It is fundamental to good husbandry practice that every measure is taken to prevent escape of this species and it is the responsibility of the owners of any collection to ensure this does not occur, and that every attempt is made to recapture any escaped animals. The deliberate release of beavers without legal consent, implementation of a release programme, public and legal awareness and support is irresponsible and illegal in many countries including Britain.

The first priority after any suspected escape would be to secure the enclosure, then thoroughly search the immediate vicinity, and contact neighbouring landowners and relevant authorities, particularly those that may have staff on nearby water bodies, for example. Beavers have been known to travel around 5km+ in one night and over 20km along a water course in a few days. Beavers leave distinctive field signs, but these can be harder to identify in the spring and summer months when vegetation offers significant cover, so search effort should be thorough and concentrated along freshwater bodies, in particular. If fresh field signs are identified, a trapping plan should be put into place immediately, with traps being placed along any established trails, baited and monitored regularly. Single individuals may remain unsettled and continually relocate, making them more difficult to trap, so searches should continue and be expanded accordingly. Making people aware of the situation and what field signs to report, can increase the search effort and area covered. Any escapes should be reported to the relevant authorities immediately.

Appropriate measures to minimise the risk of animal escapes

- Check fence lines on a daily basis looking for breaches or potential escape attempts.
- Protect trees near fence lines.
- Do not exceed enclosure population/resource capacity. The social behaviour of any family unit should be monitored, especially around times of sexual maturation and natural juvenile dispersal. Signs of aggression, injuries and increased escape attempts may all indicate the enclosure has reached capacity. It is likely escape attempts will increase as sub-adults attempt to leave the family unit and/or aggression can increase, if resources are limited. This may be more likely in small enclosures than large ones. At the Lower Mill Estate (enclosure area of 14,200m^2), a family of 18 beavers of different ages has lived amicably, with all individuals displaying good body condition and with no known deaths or injuries (little tail scarring) due to aggression. Only the adult pair breeds annually. However, this is within a large, natural enclosure with abundant resources.
- Monitor heights of lodge, dams and any other piles of vegetation/building materials, so that they do not enable beavers to climb out of the enclosure.
- A captive population management plan should always be in place, particularly prior to breeding beavers, in order to deal with offspring reaching dispersal age, and to ensure health and welfare of all individuals.
- Every collection should know how many animals are present in any one enclosure, approximate ages and social structure of a group. Regular monitoring and effective record keeping are required, in order to ensure there are no escapes and for planning captive management interventions, such as culling, sterilisation or re-homing as required.

3.12 Monitoring Beavers in Captivity

Given their more nocturnal and semi-aquatic lifestyle beavers may be hard to monitor in captivity. If feed is provided, checking the amount of food remaining each morning can be an important method to monitor beaver activity. If all food remains, this can be an indication that the animals are unwell or have potentially died. If all given food is repeatedly taken with no remains, this may indicate the enclosure has reached carrying capacity and either more resources should be made available, or sub-adults should be removed to be re-homed or culled as appropriate.

Camera traps in the correct location/s can offer an effective, non-invasive means to monitor beaver activity. Placement is important and ideally should be flexible as beaver enclosure use may vary between seasons, resource placement and availability, and even individual preference in habitat use. For most productive results, cameras should be placed around the freshest field signs, especially along well-worn forage trails; in particular this should include feeding stations, newly constructed dams and lodges (or during the autumn on already established lodges). Freshly and/or partially gnawed trees may prove productive in capturing beaver activity via camera traps, but it should be noted that beavers often partially gnaw trees and then ignore them until the wind brings the trees down. Well-used forage trails and/or regularly used feeding stations often prove the most productive sites, especially if individual animals can be identified from ear tags or tail-scars, this can act as a method to determine all individuals are present within an enclosure.

Camera traps that record moving footage can capture a range of behaviours, which may not often be seen during visual observations, especially given the more secretive behaviours of this species. Examples include grooming (figure 22), feeding, scent marking and social interactions. These recordings can be a valuable educational and promotional tool, particularly in a species, which may not make an especially popular exhibit. Camera traps may also offer a means to monitor health and body condition in individuals, which may not often be seen or handled. It should be noted that body condition may be mistaken when looking at a beaver's rounded stomach, so particular attention should be paid to the pelvis and tail region. Any signs of injury should also be recorded. Camera-trap images can provide a useful assessment of body condition in the absence of capture and physical health checks, particularly if a constant scale is included (figure 23).

Figure 22. Captive beaver in quarantine caught on camera trap, displaying use of water pool, feeding and normal grooming behaviours.

Figure 23. Camera trap located at a beaver feeding station with pole marked in 20cm intervals with reflective tape.

4. NUTRITION

4.1 Nutritional Requirements

In their native range beavers exhibit seasonal and spatial variations in their diet, which should be reflected in captivity as far as possible. Variation in the diet is important to provide nutrition and novelty. However, sudden changes in diet should be avoided to prevent disruption of gut microflora. Feeding on a mixed diet is a strategy displayed by generalist herbivores to avoid dietary deficiencies (Nolet *et al*. 1995). During the spring and summer wild beavers mainly feed on a range of green herbaceous vegetation, new woody growth and aquatic plants, whilst in the autumn and winter tree bark makes up the majority of their diet (Wilsson 1971, Svendson 1980). In captivity a major challenge is to provide beavers with a varied diet, which is also high in fibre.

Wild beavers taken into captivity should be fed browse similar to that found in their area of capture, as a way of settling them in and to ensure minimal disruption to the established microflora in the hind gut (Gow 2002). This is also a major consideration when a planned re-introduction is likely. No differences in dietary composition have been found between the sexes or age groups in Eurasian beaver (Krojerová-Prokešová *et al*. 2010).

Beavers will often form underwater food caches during the autumn and winter months. These caches consist of cut branches, which are stored under water near a lodge. Building caches should be allowed and encouraged in captivity as long as hygiene is not jeopardised.

4.2 Digestion of Food

Beavers possess specially adapted dentition for processing their diet (section 7.8). They have four continually growing incisor teeth with very hard outer enamel on the front surface and edge and softer, dentine on the back surface. The softer dentine erodes faster than the hard enamel, maintaining a sharp cutting edge as the beaver gnaws. Therefore, browse should be supplied for both behavioural and physiological purposes. Beavers cut plant material with their incisors and grind it up with their molars.

As is typical in members of Rodentia, beavers have a simple stomach with an enlarged hind gut to enable them to ferment cellulose (figure 24), using a large population of micro-organisms (bacteria and protozoa). The expanded caecum is the main site of cellulose digestion; the enzyme cellulase severs the glycosidic bonds between glucose molecules that comprise cellulose (e.g. Vispo & Hume 1995). In terms of efficiency of digestion, beavers digest 33% of ingested cellulose (Currier *et al*. 1960). This is to be expected where a high proportion of the diet is lignified and thus indigestible. This low rate of nutrient extraction and relatively short retention time translates into a need to eat large amounts of food. For example Red Maple (*Acer rubrum*) is less digestible and has less energy content (Fryxell & Doucet 1993), taking 30-50hrs to pass through a beaver's digestive tract compared to aspen (*Populus* spp.), which takes 10-20hr (Doucet & Fryxell 1993). Beavers also exhibit caecotrophy (section 2.4.5), to maximise uptake of nutrients.

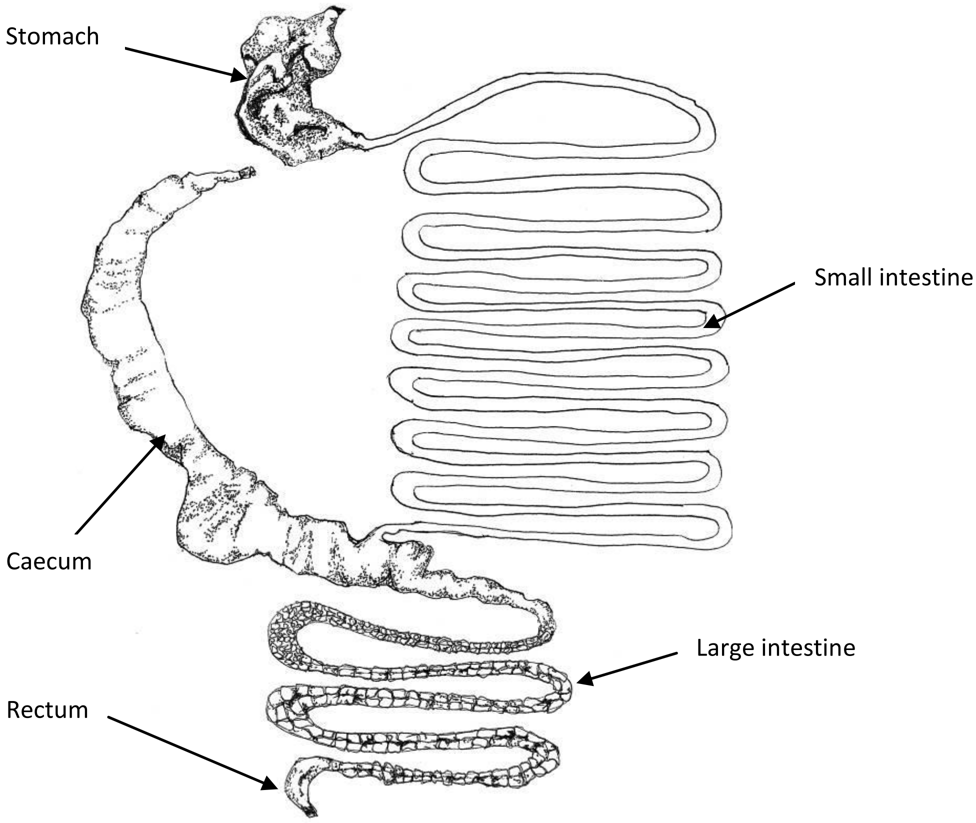


Figure 24. Digestive system of beavers. Beavers are monogastric hindgut fermentors. Diagram replicated from Vispo & Hume 1995.

4.3 Browse

Access to browse is a vital component of beaver diet, long-term provision of which should be secured prior to the keeping and breeding of captive animals. Browse (table 2) should be added *ad libitum*. This is important for beavers' nutrition, to allow animals to express a fuller behavioural repertoire and for physiological reasons such as maintaining sufficient tooth wear. Beavers tend to avoid conifers, but in the wild these trees may be felled for building purposes, or small amounts of bark may be taken (e.g. Johnston & Naiman 1990, Krojerová-Prokešová *et al*. 2010). Beavers tend to eat the bark, the cambium of twigs, young shoots and fine tips of branches. Wild Eurasian beavers have been reported to feed primarily on willow (*Salix* spp.) (Erome & Broyer 1984), perhaps as a strategy to avoid secondary compounds and high resin contents found in other species, which disrupt digestion, or which are toxic (Bryant & Kuropat 1980). Beavers from the Elbe region feed most often on aspen and willow species, followed by Elm (*Ulmus* spp.*)*, Birch (*Betula* spp.*)*, fruit trees (*Prunus* spp.*)*, Dogwood (*Cornus* spp.*)*, Hawthorn (*Crataegus* spp.*)* and Hazel (*Corylus* spp.) (Heidecke 1988). In the wild beavers are highly selective in their choice of browse (Fryxell & Doucet 1991). Leaves of *Populus*, *Betula* and *Salix* provide 22 – 24% crude protein, whereas bark provides only 5 – 8% crude protein during the leaf growth stage (May – June) (Sahulk 1998). Table 2 provides a list of species commonly eaten by beavers in their native range and which are thus suitable as browse in captivity.

Alders (*Alnus* spp.) are not commonly eaten, so alders are not recommended as browse. Indeed large and medium alders are commonly a retained feature of beaver-generated landscapes, because they are so unpalatable. Alder tends to die as a result of flood/inundation rather than by being felled/eaten by beavers. *A. incana*, though not favoured, is taken by beavers in Norway, but is probably not a good browse species for captive feeding.

Table 2. Browse species taken by beavers.

Common Name	Latin Name
Ash	*Fraxinus* spp.
Aspen	*Populus* spp.
Beech	*Fagus* spp.
Birch	*Betula* spp.
Cherry, Plum, Peach, Almond	*Prunus* spp.
Elm	*Ulmus* spp.
Hawthorn	*Crataegus spp.*
Hazel	*Corylus* spp.
Lime	*Tilia cordata*
Maple/Horse chestnut	*Acer* spp.
Oak	*Quercus* spp.
Poplar	*Populus* spp.
Rowan	*Sorbus aucuparia*
Sycamore	*Acer pseudoplatanus*
Willow	*Salix* spp.
Witch hazel	*Hammamelis virginiana*

Elder (*Sambucus nigra*) is avoided by beavers because it contains sambunigrin, a poisonous cyanogen glucoside (e.g. Kalleder 1982). This can be released as cyanide – a toxin. Beavers will also avoid foods treated with casein hydrolysate (Kimball & Perry 2008), and commercial herbivore deterrents that contain egg or blood products (DuBow 2000).

Captive North American beavers, fed on a diet consisting of only 1 or 2 tree species, lose body weight (0.1-0.6% of body mass per day), and may even die (O'Brien 1938). Therefore mixed and varied diets are vital for beavers' health and welfare (Nolet *et al*. 1994), by avoiding large quantities of specific secondary metabolites (Freeland & Janzen 1974) and to prevent sodium deficiencies (Pehrson 1983). Preference for aspen and willow species may be related to palatability, digestibility and nutritional value, with 1kg of aspen bark equal to ~604 kilocalories, which is double that of willow and triple that of birch (Sokolov 1949, Solov'jov 1973). In captivity cut willow supplies can be stored in water to prolong use and reduce the need for daily cutting (Blake E, personal communication). If offered, beavers also positively select uncommon, non-willow species, which suggests that they are seeking complementary nutrients (Nolet *et al*. 1994).

4.4 Wild Greens

Beavers will take a range of herbaceous and aquatic plants (table 3), up to 300 species have been recorded (Krojerová-Prokešová *et al*. 2010). In the wild summer diets include a substantial proportion of woody vegetation, but the increase in herbaceous and aquatic plants eaten during this time is thought to be prompted by the demand for food rich in vitamins, minerals and microelements (Lavrov 1938, Tomme *et al*. 1948). Herbaceous vegetation is reportedly favoured by pregnant and lactating females (Fomicheva 1958). Herbaceous plants have high protein contents, whilst aquatic plants are high in sodium (Doucet & Fryxell 1993, Nolet *et al*. 1994, Ganzhorn & Harthun 2000). In some areas herbaceous and aquatic plants may form up to 90% of diet during the growing season (Svendsen 1980, Doucet & Fryxell 1993).

Table 3. Examples of herbaceous plants eaten by beavers in native habitats (Kitchener 2001, RZSS, Willby *et al*. 2011).

Common Name	**Latin Name**
Angelica	*Angelica sylvestris*
Aster, sunflower	Asteraceae family
Bedstraw	*Galium* spp.
Bellflower	*Campanula* spp.
Blackberry	*Rubus fruticosus*
Buckbean/Bogbean	*Menyanthes trifoliata*
Butterbur	*Petasites* spp.
Bur-reed	*Sparganium erectum*
Canary grass	*Digraphis arundiancea*
Cattails	*Typha latifolia*
Cinquefoils	*Potentilla* spp.
Clover	*Trifolium* spp.
Common club rush	*Schoenoplectus lacustris*
Crowfoot family	Ranunculaceae
Dandelion	*Taraxacum* spp.
Downy burdock	*Arctium tomentosum*
Dropwort	*Filipendula vulgaris*
Geum	*Geum rivale*
Goldenrod	*Solidago virgaurea*
Ground elder	*Aegopodium podagraria*
Horse sorrel	*Rumex*
Iris	*Iris pseudacorus*
Mint family	Lamiaceae
Legume family	Fabaceae
Lizard’s tail	*Saururus cernuus*
Marsh cinquefoil	*Potentilla palustris*
Marsh marigolds	*Caltha palustris*
Meadowsweet	*Filipendula ulmaria*
Mugwort	*Artemisia vulgaris*
Nettles	*Urtica* spp.
Pondweed	*Potamogeton*
Raspberry	*Rubus idaeus*
Red dogwood	*Swida sanguinea*
Reeds	*Phragmites*
Reed grass	*Calamagrostis lanceolatus*
Rushes	*Juncus* spp.
Saw sedge	*Cladium mariscus*
Sedges	*Carex* spp.
Silverberry	*Elaeagnus commatata*
Sweet flag	*Acorus calamus*
Thistles	*Cirsium* spp.
Timothy	*Phleum pratense*
Velvet plants	*Verbascum*
Water avens	*Geum rivale*
Water lilies	*Nymphaea alba* & *Nuphar lutea*

Water milfoil	*Myriophyllum* spp.
Water horsetail	*Equisetum fluviatile*
Willow herb	*Epilobium angustifolium*
Yarrow	*Achillea millefolium*

4.5 Fruit & Vegetables

Captive beaver diets have traditionally consisted of small amounts of browse, supplemented with carrots, apples, parsnip, beet, turnip, sweet potato, maize, pear, celery, cabbage, cucumber, broccoli and kale.

Concerns have recently been expressed about the inclusion of fruit in the diet, because of their higher content of soluble carbohydrates (sugars), which have the potential to act as highly fermentable substrates in the hind gut, particularly when they form a significant proportion of the diet. The recommendation is thus to limit, but preferably to exclude, apples and pears, but to include celery, swedes and green brassicas (broccoli, kale, cabbage) as the main sources of non-browse material. Such a strategy will minimise the possibility of rapid fermentation in the hindgut, which could cause diarrhoea and gastro-intestinal disorders (Girling S & Beer A, personal communication). Grass hay provides a source of dietary fibre, when browse is limited, as well as being consumed, and is also used as bedding.

Figure 25. Captive beaver feeding on a carrot.

4.6 Feed Quantity & Feeding Schedule

Beavers need to eat large amounts of food daily, because their digestive efficiency is low. Quantities of approximately 2kg of woody vegetation per day (Ouderaa *et al*. 1985) or 0. 6 – 0.1kg body mass (willow bark, twigs and leaves), which is equivalent to 1.2-1.9kg of willow per day for a 20kg beaver in captivity (Nolet *et al*. 1994), have been recommended. Captive North American beavers require 0.7-1kg of digestible energy per day or 850kcal (203.07KJ) per day to maintain themselves during the summer, 2040kcal (487.36KJ) for maximal growth and 3340kcal (797.94KJ) in winter (Brenner 1962). Other published figures, based on metabolic data for North American beavers, determined the daily energy expenditure of free-living beavers to be 6,755 kJ in an ice-free winter, 5,823 kJ in spring and 5,397 kJ in summer, but only 4,141 kJ in winter when movement was restricted by ice (Nolet & Rosell 1994).

Uneaten food should be removed on a daily basis; this should be monitored as any remaining food can be a good indicator of poor health or even death in a species not often seen during the day. If all food is being taken each day, consider increasing quantities moderately.

4.7 Food Supplements

Beavers have been recorded as taking Leaf Eater pellet, Diet A, Vitamin E ungulate pellets and pellet alfalfa cubes (Swain *et al*. 1988, RZSS diet trials). While these foods could be provided as an addition to the diet, they should not form a significant proportion**.** Captive beavers have been known to develop hypervitaminosis D when fed on commercial primate pellets that contained vitamin D_3. Captive North American beavers have also died from goitre (an iodine deficiency), owing to an inadequate intake of iodine. Aquatic plants are an important source of iodine and sodium in wild beaver diets (Müller-Schwarze & Sun 2003), and they should be included in captive diets, which are known to be deficient in iodine. Alternatively iodised salt can be used as a dietary supplement. Older animals have been recorded with highly porous bones, which suggest that phosphorus deficiency occurs in beavers (Piechocki 1962, Nolet *et al*. 1994).

4.8 Drinking

Beavers need access to fresh water daily. Beavers cannot make licking motions and so do not lap water or lick fur. To drink, they hold their noses horizontally, whilst submerging their mouths and making chewing motions with their lower jaws to take in water (Wilsson 1971).

5. REPRODUCTIVE BEHAVIOUR, SOCIAL STRUCTURE & BREEDING IN CAPTIVITY

5.1 Group Size & Composition in Captivity

Beavers should be housed in pairs or family units. Being a highly social species (figure 26), they should not be housed individually for long periods of time. One male and one female should usually accept each other and form a pair. However, captive resource availability, housing limitations, population control and re-homing options for any resultant offspring should be given careful thought and consideration BEFORE setting up or enabling beaver mating and reproduction.

Figure 26. Beaver family.

5.2 Animal Introductions in Captivity

Beavers from different families should not be introduced unless the intention is to form a new breeding pair. All introductions should be monitored, with the means to intervene if needed. Beavers can inflict severe wounds and even kill each other. Fighting involves vocalisations, teeth gnashing, tail slapping, wrestling, pushing with forearms, chasing, biting (particularly around the flank and sides) and swimming after each other.

Housing a new potential pair next to each other, to allow visual and olfactory contact, improves pairing success and can reduce potential injuries. Presentation of collected scent in the form of artificial scent mounds and/or soiled bedding has been successfully used to pre-expose potential partners in a semi-wild setting before actual introduction (Campbell-Palmer & Rosell 2010, 2011).

5.3 Breeding

In a beaver family only the dominant adults male and female usually breed. Both males and females become sexually mature at around 20 months of age, although primiparity can be common (Doboszynska & Zurowski 1983). Dominant females are seasonally polyoestrous, with 2-4 oestrus cycles of 7-15 days each, during each of which she is receptive for ~ 12hours (Doboszynska & Zurowski 1983). Females come into oestrus from late December to February, with the peak occurring in mid-January. The female is only in heat for approximately 10-12 hours, though she will become receptive again after a fortnight if not pregnant (Wilsson 1971). Copulation occurs in winter (late Dec-Feb) usually in water, and lasts from 30 seconds to 3 minutes (Wilsson 1971). During copulation, the female floats in the water while the male clings on to her flank (Hediger 1970, Wilsson 1971, figure 27). Though socially monogamous, there is evidence from North American beavers that extra-pair copulations can occur (Crawford *et al*. 2009).

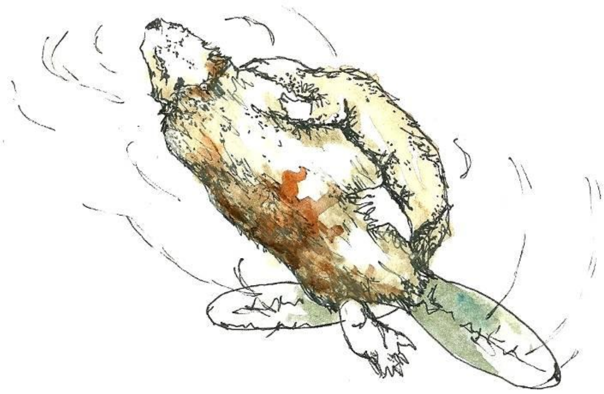


Figure 27. Copulation in water, replicated from Ruth Pollitts' illustration (in Kitchener 2001).

Fertility is lower in Eurasian compared to North American beavers: 7-8% of 1-2 year olds and 50-60% of wild adult female Eurasian beavers reproduce annually, compared to 20% of 1-2 year olds and 70-80% of adults in North American beavers (Danilov & Kan'shiev 1983, Müller-Schwarze & Sun 2003).

5.4 Gestation, Birth & Kit Raising

Pregnant and lactating females can be identified, because they have prominent nipples (figure 28). Gestation lasts 105-107 days on average and parturition occurs in the lodge or burrow around mid-May in northern latitudes (Doboszynska & Zurowski 1983). Up to five young (known as 'kits') may be born in a litter in the wild, but usually there are fewer (Wilsson 1971, Parker & Rosell 2001, Campbell *et al*. 2005). Żurowski *et al*. (1974) reported six kits being born to a captive Eurasian female, while Starikov & Anchugov (2009) quoted a maximum litter size of nine kits, suggesting that with sufficient nutrition larger litter sizes can be achieved. In the wild beavers living in poor-quality habitat produce fewer young (displaying lower ovulation and pregnancy rates, and higher embryo re-absorption rates) than those living in good-quality habitats (Gunson 1970). Each breeding pair will have only one litter per year with an average of 2-4 kits. However, various factors, including population density, altitude and habitat quality, can affect litter size and frequency.

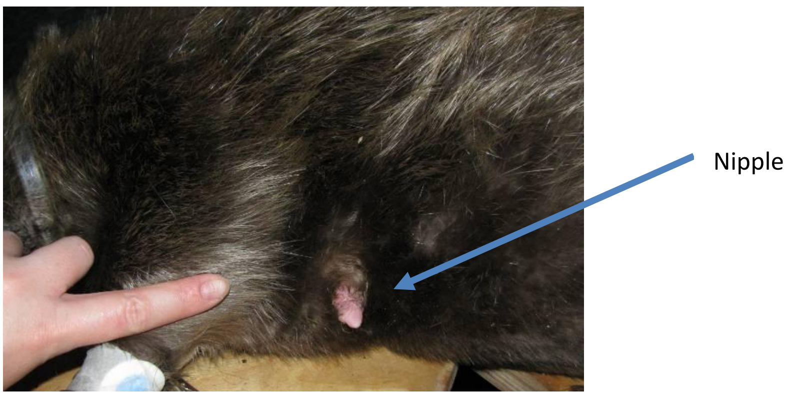


Figure 28. Prominent nipple seen in pregnant/lactating females.

Campbell (2010) found a trade-off in offspring numbers versus their weight in younger females, but not in older mothers. Reproductive output of females may initially improve with increasing age, but can decline in later life (Campbell 2010). Average birth weight is 300-700 grams, with eyes fully opened after 2-3 days (Wilsson 1971). The female groom each kit thoroughly after birth and ingests their excrement for the first 2-3 days before the kits start to defecate in the pool inside the lodge (Wilsson 1971, Müller-Schwarze & Sun 2003). Mothers lactate for two to three months, though kits can consume solid food at the age of just one week (Wilsson 1971, Żurowski *et al*. 1974). The kits remain in the lodge post-partum and do not emerge until approximately six weeks to two months of age (Wilsson 1971). Parents and older siblings bring leafy twigs and other vegetation to the kits until they are around 2-3 months, after which they forage for themselves (Müller-Schwarze & Sun 2003).

5.5 Kit Development

Kits are suckled by the female for 1-2 months, but soon after birth they will also start to take solids, being fully weaned by 2-3 months. Kits of around 14 days have been reported carrying sticks and manipulating building materials, and by 45 days they display building behaviours similar to those of adults (see table 4, Wilsson 1971).

Walking is fully coordinated a few hours after birth, whilst galloping is not fully developed until around one month (Wilsson 1971). Beavers have been observed swimming from 4-6 days of age. Diving is often attempted, but getting the whole body under the water surface may not occur at first. Full escape reactions are usually fully developed by one month, when diving and tail slapping behaviours are displayed (Wilsson 1971).

Grooming is usually attempted soon after the kits' first entry to water. However, grooming, which involves an increased number of movements, grooming with teeth and even mutual grooming are not usually performed before one month of age (Wilsson 1971).

Table 4. Development of behaviours (Wilsson 1971).

Behaviour	Age behaviour first observed
Locomotion	
Walking	Few hours
Swimming on surface	4 days
Diving/swimming underwater	12 days
Galloping	1 month
Bipedal walking	1 month
Full ability to stay under water	2 months
Feeding	
Gnawing	4 days
Eating leaves	11 days
Handling twigs and stalks	14 days
Eating mainly solids	33 days
Bark peeling	58 days
Felling small trees	2.5 months
Collection of food from underwater stores	6 months
Grooming	
With forepaws and grooming claw	4 days
With teeth and mutual grooming	6 days
Fully developed grooming	19 days
Fully developed ability to waterproof fur	60 days
Habitat modifying behaviours	
Shoving/pushing of earth	6 days
Carrying/pushing sticks	14 days
Dragging	16 days
Complete shoving/lifting/pushing/packing	45 days
Digging temporary nest	60 days
Lodge building	4-5 months
Dam building	6-7 months

Digging tunnel system	1 year
Defensive Hissing Seeking protection in water Tail slapping Full escape behaviour	 1 day 10 days 1 month 2 months
Social Exploration Movements of territorial marking Aggression/wrestling Full territorial marking	 1 day 6 days 30 days 5 months

5.5.1 Hand rearing

The costs and benefits of hand rearing should be carefully evaluated before committing to this process. The long-term implications, including available resources, social factors, individual welfare and population structure, should all be taken into consideration. Beavers are social animals and should not be kept in isolation, so that serious consideration should be given to the future provisions and prospects of each hand-reared individual, particularly given current population numbers.

Beaver milk is very rich. It is higher in fat, protein and energy, but lower in sugar, content compared to that of many other mammals (Zurowski *et al*. 1974). Calcium: phosphorus ratio equals 1.19: 1 and overall energy content is 92.46 kcal/grams (Zurowski *et al*. 1974).

Composition of beaver milk (Müller-Schwarze & Sun 2003)

Water 67%	Fat 19%	Protein 11.2%	Sugar 1.7%	Ash 1.1%

Any hand-reared kits should be fed substitute milk with a low sugar content to avoid diarrhoea (Wilsson 1971). 'Esbilac' is probably the most suitable commercial formula or others used for hand-rearing rodents should be appropriate (Pizzi R, personal communication). Kits will also take processed cereal-based baby food, which can be mixed with a little cream, and vitamin and mineral supplements (Schwab G, personal communication). Food should be presented approximately every 2 hours until the kit starts to take food for itself; solid food can be offered after the first week. Whilst feeding on formula milk, the anogenital region should be stimulated after each feed to induce urination and defecation (Sainsbury 2003). After around 3 days after birth kits should have access to water at all times for drinking and swimming, in order to encourage urination and defecation. Solids should be offered from 1 week of age, such as wild herbaceous plants and dark green leafy vegetables. Kits should also have access to a heat lamp whilst they are very young.

5.6 Dispersing Juveniles

Beavers remain in their natal territory until they reach sexual maturity at around 20 months, after which they may disperse (Hartman 1997). There is no consistent sex difference in dispersal. Saveljev *et al*. (2002) found that males dispersed further than females, while in North American beavers Sun *et al*. (2000) found females dispersed further than males, and McNew & Woolf (2005) found no sex difference in dispersal. Prior to dispersal, sexually-mature individuals commonly make exploratory excursions outside their territory (Hartman 1997, Campbell *et al*. 2005). Full adult size is not attained until the age of three (Pilleri *et al*. 1985, Campbell 2010).

In wild populations offspring of 3-4 years old (even up to 7-8 years) have been found still living within the family group (R. Campbell and F. Rosell, personal communication). Dispersal can be naturally delayed, if surrounding population densities are high or habitat is poor. On occasion dispersal may be encouraged by parents, but mainly it seems to be determined by the juvenile itself (Müller-Schwarze & Sun 2003). Few agonistic interactions have been witnessed prior to dispersal, suggesting this is instinctive rather than encouraged through aggression (Mott *et al*. 2011). In captivity the size and social composition of a family and the resources available to them should be evaluated when considering removal of sub-adults. It is vital to monitor family interactions and social behaviours when any offspring approach dispersal age. Signs of family breakdown, or the need for juvenile dispersal, may include signs of aggression, increased escape attempts, more time spent alone, or not sleeping in the lodge with other family members. It has been suggested that older offspring should be removed in their second autumn to prevent aggressive behaviour, especially if resources and space are limited (Sainsbury 2003). However, sub-adults have an important role in providing, care for their younger siblings. Breeding in sub-adults tends to be suppressed in family units, because normally only the dominant male and female breed each year, so there is no sexual competition. Sexually-mature offspring may replace one of the parents, if they die or disperse; the degree of inbreeding in wild populations is largely unknown. In large enclosures several generations of the same family have lived together amicably, e.g. Lower Mill Estate beaver collection. Careful consideration should be given if and when sub-adults are to be removed. Identification using PITs ensures that correct individuals are removed.

6. CAPTURE, HANDLING, TRANSPORTATION & QUARANTINE

Permission to trap, hold and transport beavers varies greatly between countries, and may have legal implications. This chapter describes the practicalities of these activities, but BEFORE any of these are undertaken the correct permissions and licences must be sought from the appropriate statutory body. Undertaking certain activities could be illegal without the necessary permission (statutory and landowner) and documentation.

6.1 Capture

In order to increase capture success and reduce capture effort, good knowledge of beaver behaviour and habitats is vital. Appropriate capture methods should be used according to enclosure type, habitat, season and experience of the personnel involved. Often a combination of capture techniques may be needed (see Rosell & Kvinlaug 1998, Rosell & Hovde 2001), especially if habitat and water conditions do not permit boat- or hand-capture methods.

Capture using chemical immobilisation is possible as a capture method, but never in the presence of open water, owing to the risk of beavers drowning. Instead physical capture is recommended using nets or traps, before transfer of the animal to a hessian sack for processing when chemical immobilisation (if required) may be undertaken safely. It is advised that these processes should occur away from the water for precautionary reasons, but within the individuals' territory/enclosure, as far as possible.

6.1.1 Netting on land

Netting beavers, particularly those that can be identified individually, makes it possible to target specific individuals and avoid multiple recaptures of untargeted animals, thereby reducing both stress on the animals, and trapping time and effort (Rosell & Hovde 2001).

Artificial pools should be drained or entry to water prevented, if possible, as beavers will naturally enter water when they feel threatened. This is not recommended in larger, naturalistic enclosures where draining of water may impact on other species and habitats. Specially-designed landing nets (figure 29 & 30) or standard long-handled nets (figure 31) can be placed over the entire beaver, making sure that the net frame makes contact with the ground thereby preventing escape. Care should be taken, so that the net frame does not injure the beaver.

Figures 29 & 30. A specially-designed beaver landing net (SBT). Net frame should be around 100 x 85cm and attached to a ~200cm long iron/aluminium tube. The frame can rectangular or more oval/circle shaped. Joints should be strengthened for durability.

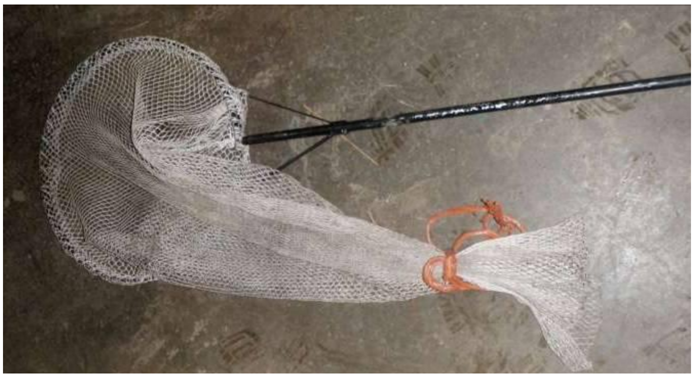


Figure 31. Long-handed (scoop) net (SBT), with a diameter of ~60cm and attached long handle of ~200cm to catch beaver on land or in water. This net can also be used to remove beavers from crates or traps for handling. To reduce handling time and stress, a frame can be fabricated to fit a hessian sack, thereby eliminating the need for a transfer from a net to a hessian sack.

Once within the net, a beaver should be manoeuvred into the closed end of net, so that the mouth of the net can be tied closed behind the animal. Using an open-ended net (tied with a buckle tie-down) makes removal of a beaver from the net easier and is less stressful on the animal. This method allows the beaver to be moved in the net, or transferred to a hessian sack for processing/sample collection, or into a crate for transportation. Ensure the hessian sack is not too small or short, a heavy sack with the dimensions of ~85cm x 50 cm should be sufficient, otherwise handling of a beaver will be difficult and its escape more likely.
N.B. Heavy, coffee-bean-type hessian sacks are not ideal for this procedure. If a landing net is not available, it is recommended that beavers are trapped with a robust, long-handled net with a netting length of around 1.5m, which should be open ended and tied with non-slip rope (figure 32), or fastened with a quick-release buckle tie-down (figure 33).

Beavers may be carried in a hessian sack for short distances. Make sure your hands and other body parts are well away from the beaver's mouth. Place one arm just under/behind the beaver's forelimbs and the other arm over its back and under the hind feet.

Netting on land in the wild or in large, naturalistic enclosures can be used in combination with the boat method, if water conditions permit. If a beaver is spotted on land, using spot lamps, then the boat should be quickly manoeuvred into the shore. If the beaver remains on land (probably unlikely), the trapper should go ashore so that the net can be used to trap the beaver, although a scoop-net can be easier to carry and use in dense vegetation. The beaver may try to enter the water, so the boat driver should be ready to try and deter the beaver from doing so. Beavers may also try to hide or may freeze in position.

In some circumstances permit netting on land or trapping from a boat may not be possible, so that alternative approaches should be taken, such as the use of beaver traps (section 6.1.3). Another way is to sit silently close to known beaver hotspots (e.g. feeding stations, dams, small canals) and wait for the beaver to appear. An area may also be baited with food or scent from other beavers. Select an area that allows easy trapping with a net, if a beaver appears. Potential exit routes may be blocked or barriers arranged so that animal is funnelled into a particular area. Note this may take time and care must be taken to limit human scent.

6.1.2 Netting from a boat

Beavers can be trapped from a boat, using spotlights and a specifically-designed landing net to capture adults or long-handled scoop nets for kits (see Rosell & Hovde 2001). Nets with a mesh gauge of ~0.5cm are used to ensure claws and ear tags are not snagged, which could cause injuries to the animals. Beavers are spot-lamped from a boat, which is then manoeuvred, so that they can be captured with a net on land or in water of <1m deep. Beavers often dive and swim underneath the water surface, when approached closely by boat. When appropriate, the trapper at the bow of the boat jumps over the side, directing the landing net over the animal. The landing net must be pushed downwards and contact made with the river bed/bottom of enclosure to ensure the beaver does not escape. If contact is incomplete, the beaver will often squeeze or dig its way under the net and escape. Care should be taken not to strike the beaver with the net frame in the process. Once secured, the tied end of the net should be let out to allow the beaver to swim to the end, where it often comes to the surface. The open end of the net (mouth end) can then be tied behind the beaver to prevent escape. Care should be taken to avoid possible bite or claw injuries, particularly to legs and hands. The netted beaver can then be carefully carried to shore or placed in the boat. The beaver's eyes should be covered with a hessian sack, until handling begins, to keep it calmer.

Kits and small individuals (<10kgs) can be captured from a boat using a long-handled, scoop net. Once a beaver has been captured by this method, it can be brought into the boat, and the open end of net can be twisted or tied behind it to prevent escape. Again the beavers' eyes should be covered.

An important modification of these beaver nets is that the bottom end is open. During capture this tied shut with non-slip rope (figure 32), or fastened with a quick-release buckle tie-down (figure 33), which can easily be released, enabling the net to be opened to allow the beaver to be transferred to travel crates or hessian sacks for processing.

Figures 32 & 33. Rope ties or hold clasps used to secure open bottom ends of nets.

6.1.3 Bavarian beaver traps

Boat capture is an inappropriate technique in small water bodies and muddy water. Instead, specifically-designed beaver traps should be used and set along forage trails, near dams or canals, or in a regularly-used part of an enclosure. Beavers may also be tempted to traps by repeated baiting with appropriate food or scent. Sweet plant foods such as apples, carrots and sweet potatoes, have successfully attracted beavers to traps (SBT), as have cut branches of aspen or birch (Koenen *et al*. 2005). As a highly territorial species, which relies heavily on chemical communication, castoreum has been used as a beaver attractant for centuries. Across Europe beavers are traditionally trapped in Bailey, Hancock or Bavarian traps (figure 34; Rosell & Kvinlaug 1998). Permitted trap types vary across European countries, so always consult the relevant authorities and ensure appropriate licences are in place prior to any trapping.

Figure 34. Bavarian beaver trap (L 175cm, H 60cm, W 60cm)

It is advised that latex gloves are worn when handling and setting traps or the traps should be left in the elements, unset for a few days to minimise human odours. The mesh floor of a trap should be covered with mud and vegetation, to try and blend it into the surrounding vegetation as much as possible and provide a more natural footing (Koenen *et al*. 2005). Make sure a trap is stable, and cannot fall over into the water. Traps which are not set on a level surface may not lock closed properly. Once in position traps should be set and checked several times before they are finally primed for capture. Remove any sticks or debris around the door that may prevent the trap latching. To increase trapping efficiency, a funnel made from vegetation or wire mesh can be formed to try and guide any beaver into the trap. Trap mechanisms and joints can freeze or become stiff, and should be lubricated regularly with vegetable oil. Bavarian traps (figure 34) have the capacity for an internal isolation slide which can confine a captured beaver to one half of the trap. This allows the door at the other end to be opened safely and a capture crate to be inserted, ensuring the easy and safe transport of a captured beaver.

A few accidental injuries and deaths have been recorded using Bavarian traps, most caused by the door falling down on the beavers back/neck. Some animals have received nose and teeth injuries whilst trying to escape from the trap, and on two occasions family members have been seen trying to free a trapped individual by gnawing parts of the trap. Overall injuries through this trapping method are very low, and no deaths have been reported in > 3,000 trappings in Bavaria (G Schwab, personal communication). To reduce risk of injuries or death, food, scent or lure must be placed only on the trap treadle (figure 35), to prevent beavers reaching in for bait rather than having to enter the trap completely. Animals should not be moved whilst in a trap, because body parts may become trapped when setting down the trap. Koenen *et al*. (2005) report 58 beaver captures via box traps, with no injuries or mortalities, except for a few minor scratches on 4-5 occasions.

Figure 35. Set Bavarian trap with food in the centre; apples and sweet potatoes prove popular bait foods.

Potential issues

- Trap placed in inappropriate place.
- Traps tripping but not latching.
- Traps placed on uneven ground or at an angle so that more pressure is required to set off trap.
- Treadle set too high so that trap is not set off.
- Mesh on trap is too wide or gauge of wire too light, causing teeth and claw injuries.
- Vegetation, especially on trap floor or side of trap, preventing complete latching.
- Trap-shy animals.
- Carnivores e.g. pine martens, scenting near trap may discourage beavers entering.

6.2 Handling

These large rodents, with their strong digging claws and sharp teeth, can present a danger to any handler unless restrained properly. Beavers may inflict deep bite wounds with incisor teeth and possibly transmit zoonotic agents. Take appropriate health-and-safety precautions and wear appropriate protective equipment.

Recommended equipment

- Hessian sacks.
- Long-handled net.
- Scissors/sharp knife.
- Rope ties/quick-release clasp.
- Transponder reader.
- Travel crate.

A trapped beaver should be transferred from the net to a hessian sack for handling and processing. Placing a beaver in a sack prevents forward movement and the animal is usually more relaxed, if its head is covered. Covering the eyes has been demonstrated to maintain normal heart rate and alleviate signs of stress during handling in rodents (e.g. Koprowski 2002), and is recommended during the restraint of both wild and captive animals (e.g. Fowler & Miller 1998).

To transfer the beaver from the capture net to the hessian sack, one person should manoeuvre the beaver so that its head faces the clasped end of the net, while an additional person takes the hessian sack to the clasped end of net and ensures the sack opening is under the beaver's forelegs before releasing the clasp and pulling the sack over the rest of the animal. The beaver can be encouraged to move forward by applying gentle pressure to its hind region, allowing the animal to walk forward of its own accord. Ensure claws are not caught in the net. The beaver can be safely restrained by placing downward pressure along the back and reducing head movements behind the jaws and neck with your hands.

A beaver should not be lifted by the tail, because its heavy body may cause spinal injuries. If a beaver needs to be lifted, we advise lifting it in a sack or net and restraining it around the neck and hind region with a firm grip before lifting. By constantly ensuring that the head of the beaver remains pushed into one corner of the sack, with the sack pulled tight preventing head movements, processing can occur with little danger of the handler being bitten. Once this is achieved two methods of restraint are acceptable;

a) One person straddles the beaver without sitting on the animal, but applying some pressure, so the beaver cannot move its head out of the corner of the sack, or raise its back upwards. The handler should face the tail, whilst the sampler is working on the back end, and face the front of the beaver, holding behind the head, when ear tagging (figure 36).

Figure 36. Restraint position 'a' whilst working on head end of beaver.

b) One person may also sit alongside the beaver (figure 37), or lift it on to a raised surface (figure 38) and facing the back end of the beaver with your arm across the animal, so that its shoulders are under your arm and the beaver's head is facing outwards. This method is perhaps the most secure and allows you to manoeuvre the animal more easily, but only if the person has the strength to hold the animal.

Figure 37 & 38. Restraint position 'b', in the field and in captivity.

With either method the hands should be behind the beaver's hind region and slight pressure applied, so the animal does not try to reverse out of the sack. You should also ensure the head remains in the corner of the sack at all times. During scent or faecal sample collection the person holding the beaver should gently lift the hind region of the animal upwards, without lifting its legs off the ground, but by holding the region under the tail with thumbs across the base of the tail. Do not bend a beaver's tail too far back from the normal horizontal position. In a darkened sack secured in this manner, many beavers will mostly remain still for most of the processing period.

Figure 39. Veterinary health check; abdominal palpation.

However, any animal that repeatedly struggles during sample collection should be allowed to rest within the sack for a few minutes, so that it settles down and sample collection can be attempted again. It is important to remember that rodents do not possess specialised thermoregulatory mechanisms, so excitation and a long handling period may lead to hyperthermia (Fowler & Miller 1998). Equally, processing beavers on snow or ice may lead to hypothermia. Therefore, a captured beaver should be placed upon a blanket or camping mat, so it is not in direct contact with ice or snow, and you should regularly feel its body temperature to ensure that it is comfortable and check that its breathing is normal. Animals should be processed out of the water in as dry an area as possible. Beaver processing and restraint time should be kept to a minimum and animals should be processed within <30 minutes of capture, unless specific veterinary procedures are required.

6.2.1 Castoreum collection

Collection of castoreum may be necessary for research purposes, or scent baiting of traps, artificial lodges, etc. Castoreum should be collected after the rectum has been evacuated of faeces. Latex gloves should be worn, because both castoreum and anal-gland secretions have a strong odour and can remain on the skin even after washing. The sampler should feel for two large internal lumps (castoreum sacs), behind the cloaca. By applying a gentle rolling motion downward from the bladder towards and over the cloaca, the castor sacs should release their castoreum (Schulte 1998, Rosell & Bjørkøyli 2002). Castoreum can be stored frozen.

6.2.2 Anal-gland secretions (AGS) collection

To collect anal-gland secretions, the beaver's tail should be gently lifted, so that the cloacal area can be seen clearly. To expose the papillae from within the body's cavity, press the area just above the cloaca and in front of the castor sacs (figure 42). One papilla should be gently, but firmly, squeezed at a time and this pressure should be held until secretions appear (figure 41) (Rosell & Bjørkøyli 2002). Note that this can take practice, particularly with the right amount of required pressure, and also the papillae may be difficult to grasp. Owing to the difference in viscosity, AGS can be more difficult to collect in females than in males (section 7.1.3 for sexing, figure 40). AGS can be collected and stored in glass or plastic vials, and frozen for long-term storage.

Figures 40, 41 & 42. Sex differences in colouration of AGS from male and female Eurasian beaver and exposure of anal papilla for AGS collection.

6.2.3 Sample collection for DNA analysis

DNA for genetic analysis can be extracted most easily from blood, tissue samples (e.g. from tail or ear tagging) and hair samples. Note any hair samples for genetic work must be plucked so that hair root bulb is present. A minimum of at least 20 plucked hairs should be collected or 0.5ml of blood. Muscle tissue from dead animals can also provide DNA. Subsequent storage of collected samples is important (section 7.14.3).

6.3 Individual Identification

6.3.1 Passive integrated transponder (PIT) tagging

Each individual should be uniquely marked with a PIT tag (Sharpe & Rosell 2003). The skin along the dorsal midline around the shoulders and lower neck region can be lifted up and a PIT tag can be inserted with a 12-gauge needle. Note that beaver skin is very tough, so make sure that correct pressure is applied, but avoid excessive force as this may cause injury.

6.3.2 Ear tagging

Ear tagging is a useful management tool for identification of individuals (Sharpe & Rosell 2003). There are several different types of ear tags, so it is important to select a tag appropriate to the size of beaver and subsequent method of observation. Plastic (Dalton) rotatags (approx. 35mm x 10mm) have been employed on beavers from 2 years old upwards (figure 43). For smaller animals, particularly kits or animals with split ears, a smaller metal tag (e.g. BARR no. 3 INOX Chasse MQN, from Chevillot SAS) can be used (figure 44). Visibility of tags can be enhanced by using bright, contrasting colours, adding reflective tape or fluorescent spray paint. However, it should be noted that the addition of glue, tape or spray paint to tags may interfere with correct tag closure or hinder their fit into applicators. Always check ear tags and applicator before catching up an animal. Mini rotatags are not recommended, even for kits or beavers with split ears, as these tags tend to come out more easily and can also split the ear.

Figure 43. Brightly-coloured Dalton rotatag (adult beaver).

Figure 44. Inspection of beaver ear for reflective-tape metal tag.

Before ear tagging an animal, make sure each ear tag, the applicator and ear flaps are clean and antiseptic is used to prevent any infections. Position the beaver's head in one corner of the hessian sack. Feeling for each ear in turn, carefully use scissors to make a small hole in the sack big enough for the beaver's ear to be exposed through it. In this way each ear can be inspected to determine suitability for tagging and presence of any previous tags (figure 45).

One person should restrain the beaver with a firm grip around the head by holding behind the jaws with thumbs, or using one palm and applying slight downward pressure. Beavers may flinch when a tag is inserted, but excessive reaction or bleeding should not occur. Each ear tag should be inserted with the sharp end pointing upwards and away from the beaver's head and not into the head, because this may affect the closing of the ears during diving. If using plastic tags, the sharp end should be rounded off with scissors (figure 45). Metal tags should be flush with the edge of the ear; any gaps may result in ear tags becoming snagged and being pulled from the ear. Plastic tags may appear more invasive, but if they are bitten off, an intact hole is often left in the ear flap, enabling new tags to be inserted. Metal tags often result in less reaction when inserted, but may cause splitting of the ear flap, if they catch on other objects; they are less likely to be groomed out, but require closer observation to identify individuals in free-ranging animals. Ears should be checked for infections or tearing, and any wounds cleaned as required. Tags should not be used on infected, cut or ears with multiple splits.

Figure 45. Rounding off of sharp edges of plastic tag.

6.3.3 Biotelemetry/biologging device attachment methods

Different studies and reintroduction programmes have required the attachment of various devices (e.g. Dataloggers, Global position system tags) for animal management, ecological and behavioural research purposes (e.g. Graf *et al*. 2011). Attachment of these tags can present various problems, owing to the behaviour, habitat and body shape of these animals. Because beavers have little obvious neck, radio collars readily slip off. Harnesses may prove more reliable, but could cause drowning if they get snagged on submerged vegetation, or straps could be gnawed through by the beaver. Because they are highly sociable animals and diligent groomers, external devices are often subject to increased attention by the animal itself or by other family members. Therefore, it is difficult to make an external tag 'beaver proof', but tags can be made more robust if encased in metal (figure 46), hardened plastic (figure 47) or covered with epoxy or araldite, especially around any weak or delicate points. Beavers' semi-aquatic lifestyle also requires tags to be waterproof and any connections on the tag should be sealed to avoid corrosion. Tags may catch on branches, debris, or rocks, etc., so it is important to make any tag as small and as streamlined as possible to try to avoid the tag being damaged or ripped off.

Biotelemetry/biologging devices may be lost inside burrows, in vegetation and water, so the attachment of a small VHF (very high frequency) transmitter can help with their retrieval. Although beavers are large and strong animals, best practice suggests the weight of any tag and its attachment mechanism should be no more than 1 % of an individual's total body weight. Heavier tags can be supported, but it should be noted that recommendations differ according to animal ethical guidelines for various scientific journals and between countries.

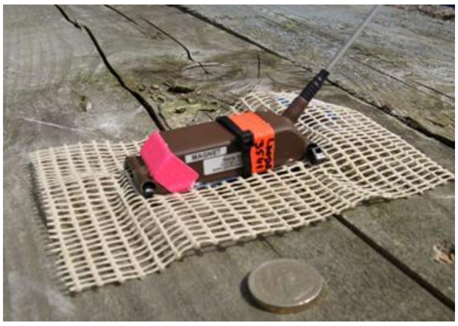


Figure 46. Metal-encased ARGOS satellite tag.

Figure 47. Reinforced plastic-encased RF tag on mesh (SBT).

Gluing

Gluing of tags is a recognised, short-term attachment method in beavers (Robstad *et al*. 2012). Tag units should be attached on the fur of the lower back, approximately 15cm from base of tail, using a two-component epoxy resin (e.g. 5min Quick –cure epoxy) or high-tech araldite (figure 49). Ensure that any glue is not toxic, does not cause damage to the skin, or is harmful on ingestion. Coarse-meshed polyester, or any light-weight, flexible material should be used as a base and cover to secure the units, thus reducing the possibility of the glue making contact with skin and increasing the area of the point of attachment. The guard hairs can be drawn around the mesh. The antennae of any tag should face backwards towards the tail. Additional glue should be applied around the edge of tag so that a seal is formed, but avoid excessive amounts of glue and pressing too hard, which could cause the fur to become saturated and sink into the skin, where chemical burns may occur.

Figure 49. GPS and VHF tag on mesh, glued to adult beaver's back (SBT).

Tips

- Always use gloves when using epoxy or araldite.
- Bring a coolant or water to reduce the heat of the chemical reaction created by the epoxy.
- If ambient temperatures are low, the glue should be kept warm so that it is easier to work with.
- Make sure the area is well ventilated when applying the glue.
- Do not used on highly stressed or injured animals.
- Do not saturate fur with glue and ensure it is hardened before releasing animal.

Tail tagging

Tail tagging has been used widely for beavers as a way of attaching external tags (figure 49) (Arjo *et al*. 2008, Baker 2006, Rothmeyer *et al*. 2002). Belt pliers are often used to make a hole in the tail, through which a short length of plastic tubing is inserted. The transmitter can then be attached using a bolt, washer and nut (Sharpe & Rosell 2003, Campbell *et al*. 2005, Rosell & Thomsen 2006). Tail tags can fall off or rip out, with possible secondary infections and their use should be carefully considered. Veterinary supervision is highly recommended.

Figure 49. RF tail tag.

Implantation

Radio transmitters have been implanted intraperitoneally in wild beavers through ventro-lateral (Wheatley 1997), paralumbar (Guynn *et al*. 1987) and midline-ventral surgical incisions (Ranheim *et al*. 2004). Behaviour and movements are reportedly unaffected by these procedures or implants, apart from the first few days after implantation when the animals tend to spend more time within their lodges. Haemorrhage, post-operative infections and damage caused by free-floating tags are all possible complications of implanting intraperitoneal transmitters. Deaths have been recorded in beavers with abdominally-implanted transmitters (Davis *et al*. 1984, Ranheim *et al*. 2004), so this technique is not recommended for this species; current veterinary standards advise the use of subcutaneous implants.

6.4 Transportation

Generally, like most mammals, beavers can be crated for journeys of up to 24hrs with few problems, provided sufficient absorbent bedding, ventilation, food and water are provided. Bedding should include a deep layer of sawdust and clean, dry, non-dusty straw. By including used bedding from an individual being transported in a crate, stress may be reduced during transportation (Campbell-Palmer & Rosell 2010). Inspection during transportation should occur regularly, if possible, but it should be noted that beavers tend to exhibit reduced movement, often remaining in a crouching position, or huddled with other animals, if present, so visual signs of distress may be more difficult to discern (Gow 2002).

6.4.1 Air transportation

Please consult the latest edition of the International Air Transport Association (IATA) Live Animals Regulations before importing beavers by air. In order to import beavers the freight carrier must be a member of IATA and animals must be transported in containers that conform to IATA Live Animal Regulations (figure 50).

IATA-approved beaver crates should be constructed from wood or plywood, which is lined interiorly with sheet metal and/or fine weld-mesh. Ventilation holes must also be meshed. The floor must be waterproof (to prevent leakage) and covered with a thick layer of sawdust and straw. Water dishes must be accessible from the outside. Animals should be crated with enough food for the duration of their journey. Browse should be avoided unless cut into very short sections (~20cm pieces with side branches removed), in case of potential injuries if a crate moves suddenly. Moisture-rich foods, such as apples, have traditionally been included, because water often spills or is emptied by the animal. These crates are often heavy, so good, solid handles are recommended for ease of carrying. Crates must be clearly labelled with appropriate documentation and signage.

Figure 50. IATA-approved beaver transport crate (H 57cm, L117cm, W56cm).

All individuals must be in good health and fit to travel. Sexually mature females that have had access to males may potentially be pregnant between February and June, so extra care should be taken during transportation, or this period should be avoided if possible. Individuals should be transported separately apart from kits and yearlings, which should be crated with either parent. However, it is not recommended that lactating females and very young kits are transported.

6.4.2 Road transportation

Only an approved rabies quarantine carrier, operating an approved quarantine vehicle, can move imported animals in the UK, unless special dispensation has been given by DEFRA. It is illegal to open any rabies-quarantine crates in the UK, unless at an approved quarantine centre, or at a rabies-approved facility.

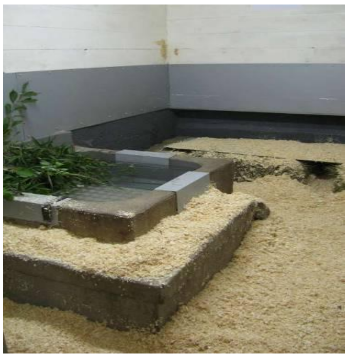
For short journeys beavers have been transported in medium dog-sized vari-kennels (figures 51 & 52) but, it should be noted that beavers can gnaw their way out of these, if left unsupervised for any length of time. The front should be covered with hessian or blankets to keep the animals in the dark. Specially-designed beaver crates have been developed for transporting beavers in England and these have been used without any problems for many years, e.g. sometimes to transport beavers from Germany to the UK (10hours+ road journey) with no fatalities to date. They are approximately 80 x 58 x 58cm, constructed from ¾ inch marine ply, and are open at both ends. These sides are lined internally with sheet tin or half inch weld-mesh. The sliding doors at either end are constructed from heavy-gauge 2inch weld-mesh set in runners. The crates have carrying handles fixed onto the tops of the frames at both ends.

Figures 51 & 52. Vari-kennels used to transport beavers short distances.

6.5 Quarantine

To avoid contravening animal health and disease-control legislation, strict policies must be adhered to when importing beavers. These will vary between countries and should be fully investigated prior to importation. Beavers are required to undergo 6–months' rabies quarantine on entering the UK.

Two examples of beaver quarantine facilities can be seen in figures 53 & 54. Walls are lined to just over 1m with sheer sheet metal to prevent gnawing and reduce injuries to beaver paws, if they attempt to dig out of the enclosure. Some individuals in quarantine have been observed to spend a good deal of time standing on their hind limbs, repeatedly digging at the walls of the quarantine facility. Concrete floors are often recommended for hygiene reasons, to prevent entry of vermin and beaver escape. However, concrete can be very abrasive on beaver paws and tails, and therefore a potential source of pain and infection. Concrete should be skimmed off as smoothly as possible and covered in plenty of substrate to act as a soft barrier and provide bedding. Beavers will spend quite a bit of time in captivity manipulating substrate. Each holding pen should have a water pool (section 3.3).



Figures 53 & 54. Two different beaver quarantine facilities, both with access to water.

In 2010 RZSS received permission to import Norwegian beavers, which did not have to undergo rabies quarantine. This special dispensation was granted after fulfilling specific criteria.

- Beavers had to be wild-caught Norwegian stock, trapped in an area declared free of rabies and *Echinococcus multilocularis*.
- Each individual had to undergo four weeks' quarantine in Norway under veterinary supervision and in isolation from all other (non-beaver) animals.
- Each individual had to show no clinical signs of rabies during the quarantine period and no reports made of suspected rabies in the surrounding area during the quarantine period.
- Each individual had NOT to be vaccinated against rabies using a live vaccine.
- Each individual had to be PIT tagged.
- Each individual had to be certified fit to travel by a veterinary surgeon.
- A veterinary certificate from the Norwegian Food Safety Authority had to be received by the Scottish Government, Rural and Environment Directorate, which had to sign each individual out of rabies quarantine.

To increase likelihood of reducing length of quarantine period, ensure good health status of imported animals and minimise possibility of disease transmission to other wildlife, all imported beavers should also be tested for:

- Leptospirosis.
- Enteric bacterial pathogens such as *Salmonella*.
- *Giardia*.
- Tularaemia.
- *Cryptosporidium*.
- Faecal worm burdens.
- *Echinococcus multilocularis.*

E. multilocularis (tapeworm) will not be revealed by faecal testing of beavers and is currently only detected at post mortem (PM) examinations of liver or through minimally invasive exploratory laparoscopy (Pizzi *et al*. submitted). This parasite is present in wildlife across central Europe, although currently Norway and Great Britain are deemed free from this parasite (Davidson *et al*. 2009). However, *E. multilocularis* has been recently found in Sweden, less than 65km from the Norwegian border (Osterman *et al*. 2011) and it is possible that in time the Norwegian population may become infected with this parasite. It is vital that any imported beavers from European regions, where this parasite is present, are screened via laparoscopic investigation, or are born in captivity, or come from areas free from *E. multilocularis* (Kosmider *et al*. 2012). It is recommended that any dead beavers are submitted for full post mortem examinations. It is particularly important to recover any escaped beavers that are potentially infected with *E. multilocularis* from areas currently free from this parasite and to inform the appropriate authorities immediately. A serological blood test, modified from one used in domestic dogs (*Canis familiaris*), is currently being developed to test for this parasite, but presently this requires further testing and verification (A Barlow, personal communication).

7. HEALTH & VETERINARY CARE

7.1 Physical Examination & Clinical Techniques

Physical examination of beavers (table 5 and figure 55) is similar to that of other mammalian species. However, to allow for a detailed clinical examination, including for example the teeth, a general anaesthetic is recommended.

Prior to handling and anaesthetising the beaver, observe it in the pen or enclosure for:

- Symmetry of eyes, ears and limbs.
- Ocular and nasal discharge.
- Locomotion.
- Breathing pattern and frequency.
- Normal behaviours and feeding.

Once the animal has been anaesthetised, it should be weighed so that accurate dose rates of medication can be administered, if required.

Table 5. Clinical examination of individual beavers.

Organ	Examination
Eyes	Check the symmetry of the head and eyes for ocular discharge. Mydriatics would be required for more in-depth examination, owing to small pupil size
Ears	Check for parasites
Nose	Check for nasal discharge
Teeth	Check for malocclusion and other signs of dental disease (section 7.8)
Integument	Check for wounds, ectoparasites and dermatitis, including on tail and feet
Tail	Check for wounds
Abdomen	Abdominal palpation for organ enlargement and abdominal masses

Beaver health check sheet

Date: **ID Number:**

Clinical examination:

- Eyes____________________
- Ears____________________
- Skin____________________
- Dentition____________________
- Skeleton____________________
- Abdominal palpation____________________
- Auscultation____________________
- Other____________________

Samples: ***A. Faecal sample:***

- Bacteriology: enteric pathogens including Clostridium and Yersinia
- Parasitology: helminths (including beaver fluke), protozoa (including Giardia antigen and cryptosporidium)

B. Blood samples:

- General health profile (FBC and Biochemistry EDTA, serum and sodium fluoride, two blood smears)
- Serum: minimum 3x2.5ml sample but more if surplus blood (leptospirosis serology and remainder stored)
- DNA sample (Whatman FTA card, EDTA and fur with follicles):
- Heparin: 1x1ml sample (only if surplus blood as it tends to clot)

Figure 55. RZSS beaver health check sheet.

7.1.1 Blood collection

There are various accessible blood vessels in the beaver, which allow for blood sampling. The choice of blood sample site depends on the required sample size and whether the beaver is conscious or anaesthetised. Beaver blood tends to clot extremely rapidly and even clots in heparinised blood-sample tubes. It is recommended to use plain tubes for clotted blood and potassium EDTA tubes for haematology. Handlers should note that blood samples in potassium EDTA need to be rolled carefully for 1-2 minutes to avoid clotting.

The ventral tail vein (ventral coccygeal vein) can be accessed in conscious as well as anaesthetised beavers. Larger blood samples can be taken from this vein. Introduce a needle (21G in older animals, but finer needles for kits) with a 2.5 to 10ml syringe attached at a 45 degree angle as shown in figures 56. The medial saphenous vein (hind leg) can be used for catheter placement or for smaller blood samples (figure 57). The vein on the plantar side of the webbed hind feet can be used for emergency venous access (figure 58).

Figure 56. Blood sample collection from the ventral tail vein (anaesthetised animal).

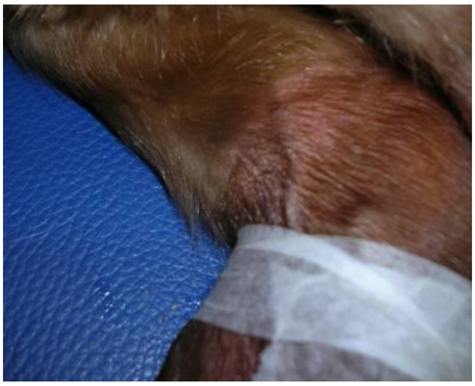


Figure 57. Medial saphenous vein.

Figure 58. Arrow pointing to a vein on the plantar side of the webbed feet.

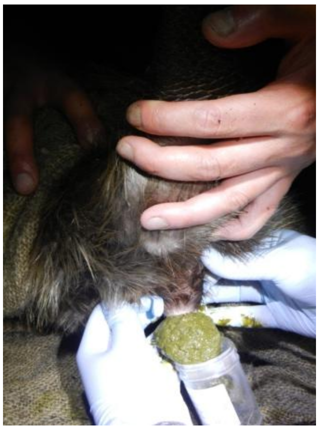


Figure 59. Faecal collection.

7.1.2 Faecal sample collection

Beavers tend to defecate in water, so faecal samples should be collected directly from the animal (figure 59). To do so, the sampler should feel just behind the anus for internal lumps, which indicate the presence of faeces in the colon. The sampler should gently apply pressure on either side of the anus, and at the same time pull gently forwards (towards themselves), until faeces can be seen exiting the anus. It is recommended that a plastic bag or collection vial is placed beneath the anus for faecal collection. This process should be repeated, moving fingers slightly backwards each time until an adequate faecal sample has been collected.

7.1.3 Sex determination

Beavers do not have external genitalia, varying coloration or size differences that enable them to be sexed easily. In both sexes the urino-genital and anal tracts open into a common cloaca. Both sexes also possess anal glands and castor sacs, which should not be confused with testes. Sexing can be done by palpation of the os penis or baculum, by inserting a finger into the cloacal opening or across the lower part of the abdominal region, if the beaver is anesthetised and placed in a lateral position (Osborn 1955).

Sex can also be determined through the sexual dimorphism of blood neutrophils (Larson & Knapp 1971, Patenaude & Genest 1977).

Sexing can most readily be done by looking at the coloration and viscosity of the anal-gland secretions (figure 41) (Rosell & Sun 1999).

Male = yellow/brown, liquid

Female = grey/white, thick liquid/paste

In North American beavers anal gland secretion is brown and viscous in males and whitish or light yellow and runny in females (Schulte *et al*. 1995).

7.2 Body Measurements & Body Condition Scoring

7.2.1 Tail measurements

Beaver tails store fat and so tail dimensions vary annually, depending on seasonal deposition and mobilisation of fat (Aleksiuk 1970, Smith & Jenkins 1997). The ratio of tail size to body length can be used as an index of tail-fat content and body condition (Parker *et al*. 2007). The tail-fat index equals tail length (from tail tip to hair line) multiplied by tail width (at tail length midpoint) divided by body length (nose tip to hair line at base of tail) (Parker *et al*. unpublished).

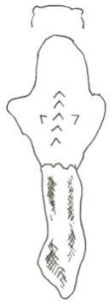
$$\text{Tail-Fat Index} = \frac{\text{Tail Length x Tail width}}{\text{Body length}}$$

Higher tail-fat index (I) values represent higher tail-fat reserves and, therefore, presumably better body conditions. The mean tail-fat index for adult (3 years+) Norwegian beavers weighed from March-May was 37.3 for pregnant females, 33.6 for non-breeding females and 39.1 for males (Parker *et al*. unpublished).

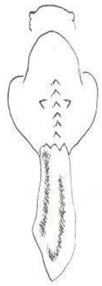
Figure 60. Measurement of various tail dimensions, including mid-point tail thickness with callipers.

7.2.2 Body condition scoring

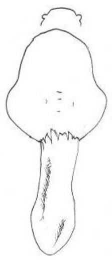
Standard rodent body scoring systems can be used to determine body condition in beavers (figure 61). Particular attention should be paid to the pelvic region, backbone and tail. Beavers in poorer body condition have a prominent backbone and pelvis. These will also be more visible when a beaver is on land, with the pelvis more 'M' shaped. Tails are also more concave on both sides of the mid vein. Lack of proper grooming may also be seen, so that beavers in poorer body condition may also look ‘scruffy’ or unkempt.



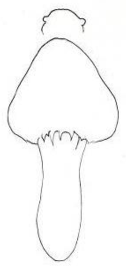
Body Condition Score 1
Beaver is emaciated: skeletal structure extremely prominent, little flesh cover. Vertebrae distinctly segmented. Tail arch very prominent, with tail sunken on either side of midline, owing to low fat reserves.



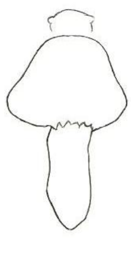
Body Condition Score 2
Beaver is in poor condition: segmentation of vertebral column evident. Dorsal pelvic bones are readily palpated. Tail arch prominent, tail sunken, low fat reserves.



Body Condition Score 3
Beaver is in normal condition: vertebrae and dorsal pelvis not prominent, but palpated with slight pressure. Tail arch is visible, but tail is thick with good healthy fat reserves.



Body Condition Score 4
Beaver is overweight: spine is a continuous column. Vertebrae palpated only with firm pressure. Tail arch not really visible, tail thick and more rounded.



Body Condition Score 5
Beaver is obese: body is bulky. Bones disappear under flesh and subcutaneous fat layer. Tail is thick and rounded.

Figure 61. Beaver body condition scoring (dorsal view).

In the wild beavers’ weight and body condition varies seasonally by as much as several kilogrammes annually. This variation is determined by food availability. Consequently, captive animals should not show significant seasonal variation in body weight and condition. Therefore, sudden or gradual long-term weight loss in captive animals is probably the result of an underlying medical condition, which should be investigated. It should be noted that even in poor body condition, beavers may still have large, rounded stomachs, and especially from a distance may appear ‘fat’. It is only by feeling along the spine and pelvis, and careful observation of the tail that body condition can be assessed accurately.

7.2.3 Weighing

Anaesthetised animals can easily be placed on digital scales. Conscious animals should be weighed in the hessian sack after all other procedures and sample collection has occurred. Two holes should be made in the mouth of the hessian sack, on opposite sides, leaving enough material to ensure the sack does not split with the weight of the beaver when lifted off the ground. The scale hook should be inserted into both holes before attaching to scales. One person should lift the animal, using the scales, off the ground, whilst another takes a reading (figure 62). Ensure that the animal is completely lifted off the ground to obtain an accurate reading, and also ensure that ear tags are completely within the sack and not caught on material to prevent ripping of ears. This procedure should be carried out by two people in a calm, quick manner, because a beaver may attempt to climb out of the sack once lifted off the ground. Care should be taken to keep the beaver away from the legs of the lifter to avoid potential bites. The weight of the empty sack should be deducted from the total weight to establish the weight of the beaver.

Figure 62. Weighing a live beaver in the field. Note mouth of sack is closed and is therefore darker thereby reducing escape attempts.

7.3 Haematology & Blood Serum Biochemistry

Normal blood values for wild Eurasian beaver are to be published soon, but early evidence suggests that they are broadly similar to those already published for North American beavers as published by the International Species Information System (ISIS) http://www.isis.org 2002.

7.4 Anaesthesia/Sedation & Analgesia

Various anaesthetic regimes have been described for North American beavers with a few described for the Eurasian beaver. Despite being different species, the use of those for North American beaver has been successful on Eurasian beavers.

Selection of a suitable anaesthetic regime should include consideration of the aims of the procedure, the duration of the procedure, the depth of anaesthesia required, the location (field versus clinic), availability of supporting equipment and, most importantly, whether the animal will be returned directly to water or recover in a dry dock.

Where rapid release back into water is not required after chemical immobilisation, injectable anaesthetics can be used. Recovery times to safe release near water with injectable agents vary, but are often 2-3 hours after antagonists are given. Injectable regimes have the advantage of minimising handling and subsequent stress, but the recovery time is often long and prohibits their use in field situations, where animals must be returned quickly to the water. It is recommended that animals are housed until full recovery has occurred prior to returning them to the water. Protocols adopted by Greene *et al*. (1991) for North American beavers have been adapted by vets at the RZSS to find a suitable sedative to use prior to induction and which will not interfere with other diagnostic testing, such as cardiac ultrasound studies. RZSS uses:

- Ketamine 12.5mg/kg and diazepam 0.2mg/kg. Sedation generally occurs within 15-20 minutes, after which the beaver can then be relatively easily induced using 100% oxygen and isoflurane gas via a face mask. Maintenance with 1.5-2% isoflurane plus 100% oxygen can then be carried out, either via face mask or after intubation.

Other published injectable anaesthetic regimes include:

- **Eurasian beavers** - Ketamine 5mg/kg, butorphanol and 0.1mg/kg medetomidine 0.05mg/kg have been used by Ranheim *et al*. (2004) for implantation of intraperitoneal transmitters. Mean induction time was 7.8 minutes, with surgical time of 15.6 minutes.
- Face-mask induction with isoflurane gas (Wenger *et al*. 2010).
- **North American beavers** - Ketamine 10mg/kg was used for sedation of a single beaver that underwent skull radiography as part of a dental work up; few comments (Kim *et al*. 2005).
- Face-mask induction, using either sevoflurane or isoflurane, with little difference between the two (except cost) (Breck & Gaynor 2003).
- Ketamine 10-12mg/kg premedication followed by face-mask isoflurane used for the implantation of intraperitoneal radio-transmitters (Eisele *et al*. 1997). Intubation was only achieved following a period of isoflurane anaesthesia. Procedures lasted from 65-117 minutes.
- Ketamine 25mg/kg, diazepam 0.1mg/kg and halothane (Greene *et al*. 1991). Tracheal intubation possible under injectable anaesthesia alone.

Recovery from injectable anaesthesia can be prolonged, even with the administration of an anatagonist. Hypothermia also prolongs recovery times.

Where rapid release after chemical immobilisation is intended, it is recommended that individuals are induced and maintained using a volatile anaesthetic, such as isoflurane or sevoflurane. Beavers can be netted or transferred into a hessian sack (which acts as a visual barrier), restrained and the animal induced using a large, small-animal face mask, which is placed over the nose and mouth (figure 63). The beaver should be manipulated into the corner of the sack/net and then the mask put into place when the handler is confident that the beaver is adequately restrained. Care must be taken when putting the mask over the mouth, because there is a potential risk of being bitten or damaging the mask. It should be noted that beavers often hold their breath when handled, especially when a mask is placed over the muzzle. Induction with 5% isoflurane in 100% oxygen takes on average 1.5 minutes, after which the beaver may be removed from the sack and maintained, using a facemask (or intubated), with 1-2% isoflurane with 100% oxygen. Recovery times from isoflurane anaesthesia vary, but should be seen 4-5 minutes after volatile administration has ceased. Recovery time until the beaver is fit to release safely back into the water varies and can be prolonged in animals that become hypothermic. Once isoflurane administration has ceased recovery to sternal? Recumbency tends to occur in 5-6 minutes and to full recovery for release near to water is possible in healthy animals after 30-40 minutes. Recovery time is slightly longer if sevoflurane is used (Breck & Gaynor 2003).

Figure 63. A netted beaver is induced through the net with a volatile anaesthetic agent.

Figure 64. The tongue is large and fleshy and can make visualisation of the larynx difficult.

Once anaesthesia has been induced, beavers may be maintained on either a facemask or they can be intubated. Intubation is relatively straightforward, but requires the use of a laryngoscope. A miller blade is particularly useful, with 7-15cm being used for juveniles through to adults. The tongue is large and fleshy, and should be gently pulled through the diastema. The laryngoscope blade tip is then used to gently push the long soft palate dorsally, so visualisation of the larynx is possible (figure 64 & 65). In some cases only the tip of the epiglottis can be seen and intubation requires a partially blind technique, but with the beaver in sternal recumbency and the head extended, it is often possible to see the larynx (figure 65). Endotracheal tube sizes vary from 2.5mm external diameter for kits through to 7.0mm for larger adults. Capnography is a useful tool to confirm intubation has been successful; an alternative is to use clear portex tubes and to monitor condensation of expired gases within the lumen of the tube (figure 66).

Figure 65. Extending the tongue and the use of a laryngoscope is essential to be able to visualise the larynx. Here the tip of the epiglottis can be made out.

Figure 66. The use of clear protex tubes allows visualisation of successful intubation. Here expired gases from the lungs can be seen as condensation on the sides of the clear endotracheal tube.

Positioning is important in beavers, because they have a relatively small lung field and a large gastrointestinal tract. Beavers should be maintained in sternal recumbency wherever possible to ensure adequate ventilation. When in dorsal recumbency, the gastrointestinal tract can press on the diaphragm and reduce gas exchange. Gas exchange is further compromised by the use of volatile anaesthetics, which can often cause hypoventilation in beavers (Breck & Gaynor 2003, Greene *et al*. 1991). Capnography is recommended for any procedures where a beaver will be maintained under gaseous anaesthesia (figure 67). Arterial blood gases are also useful. The veterinarian should be prepared for controlled ventilation to ensure adequate gas exchange. Beavers are extremely tolerant of high pulmonary CO_2 levels for short procedures, but this should not be considered an acceptable alternative to suitable maintenance of respiratory blood gases. Clausen & Ersland (1970) recorded $PaCO_2$as high as 150mmHg, with an arterial pH of 6.8 within 10 minutes of diving. Similar arterial blood gases have been seen in Eurasian beavers under volatile anaesthesia that have not been ventilated. These animals showed no apparent adverse clinical signs during recovery. Arterial blood gases are expected to be similar to those of other mammals, but reported values from North American beavers are probably indicative of hypoventilation rather than a normal hypercapnic state.

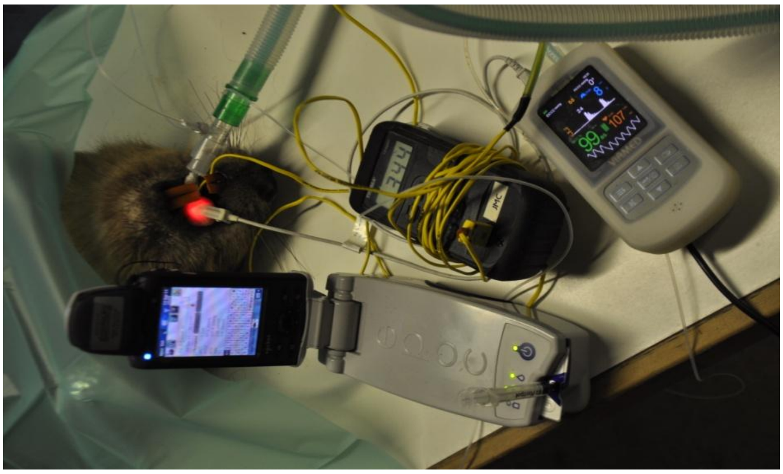


Figure 67. Arterial blood gases, oesophageal thermometry, pulse oximetery and capnography are all easily applied modalities to support beaver monitoring under anaesthesia.

Thermoregulation is an important consideration during beaver anaesthesia. Body temperature (rectal or oesophageal) should be monitored continually throughout anaesthesia. Anaesthesia can disrupt the normal thermoregulatory systems, such as the counter-current systems in the tail and distal limbs (Cutright & McKean 1979), through alteration of cardiovascular tone. In a cold environment this can result in rapid loss of body heat. Various methods can be used to minimise heat loss. A simple method for field or clinical anaesthesia is the use of aluminium tin foil: the “burrito technique” (figure 68). Tin foil should be wrapped around the paws, distal limbs and tail. This is a very effective method for minimising heat loss in beavers (J Cracknell, personal communication).

Figure 68. The "burrito technique"; aluminium tin foil is used to cover the extremities and minimise heat loss under anaesthesia.

Figure 69. Doppler is a useful monitoring tool. It is placed quickly and easily over the ventral tail artery, which is also the site for arterial blood sampling as seen here.

Pulse oximetery can be a useful monitoring tool; sites include the webbing of the hind limbs or the tongue. The Doppler method utilises the artery located on the ventral side of the tail (figure 69). This location can also be used for arterial blood collection (as well as blood sampling for biochemistry, haematology and serology).

Analgesia can be provided with 0.3-0.5mg/kg meloxicam (although care should be taken to ensure that there is no underlying renal disease or stomach ulceration) and/or 0.03 -0.05mg/kg buprenorphine. No pharmacological studies have been carried out in beavers to determine the efficacy or safety of these drugs, but anecdotal evidence at the RZSS has suggested these doses are safe.

7.5 Cardiology

Beaver have quite small hearts, which is a characteristic of slow-moving animals that do not experience high rates of prolonged energy expenditure (McKean & Carlton 1977). Preliminary studies undertaken on beavers have found a high incidence of heart murmurs, ranging in intensities from grade I/VI to grade IV/VI in 26 out of 27 examined animals (Devine *et al*. 2011). The point of maximum intensity of these murmurs was on the left side of the thorax and in the cranial parasternal region. Frequently these murmurs were also audible on the right. In one animal the murmur was heard loudest over the right heart base. In the majority of the examined beavers no evidence of haemodynamically significant structural heart disease was found. The murmurs heard in these animals were attributed to turbulence in the main vessels exiting the heart (flow murmurs). It is concluded that flow murmurs are common in isoflurane-anaesthetised Eurasian beavers. Significant structural heart disease was not common in the examined animals.

Table 6. Heart rates in captive, free-ranging North American beavers.

Activity	Beats/min
Resting on land	100[a], 116[b]
Grooming	121[b]
Swimming	125[b]
Sleeping	75[a]
Diving	61[a], 67[b]

Swain *et al*. (1988)[a], Gilbert & Gofton (1982)[b].

7.6 Parasites

7.6.1 Ectoparasites

Beaver beetle (*Platypsyllus castoris*)

This is a small wingless, ectoparasitic beetle (figure 70) that lives on the skin and fur of both species of beavers (see Peck 2006). Larvae and adult beetles feed on the epidermal tissue and possibly on skin secretions and wound exudates (Wood 1965). Infestation rates in beavers have been recorded of between 0-192 adult beetles per beaver (Janzen 1963). Beavers are the primary host for this species, with only one record of an accidental host switch in an otter (Belfiore 2006), which possibly occurred when the otter was present inside the beaver lodge (Peck 2006). Only the pupal stage does not live on the beaver, but is found in the earth of lodges/burrows (Peck 2006). Beavers do not appear to be bothered by the feeding of these beetles and the grooming claw does not appear to remove them (Wood 1965). Beetles can be hard to locate, but are often found around the neck/head region and can be collected by combing fur with a fine comb, or they move to an alternative heat source (e.g. human hand) under cold conditions, such as the death of their host (e.g. refrigerated carcass). They do not survive long off the beaver, owing to desiccation or extremes in temperature (Janzen 1963). These beetles may be mistaken for fleas, but do not jump and are rusty orange/brown in coloration.

Figure 70. Adult beaver beetles are visible through careful examination of fur, especially around the neck and shoulder region. Orange-rusty brown in coloration.

Mite (genus *Schizocarpus*)

45 species of *Schizocarpus* are known from the Eurasian beaver (Saveljev & Bochkov 2012). 15 beavers examined from various parts of Sweden all had ears infected with mites, with the mean number of mites per individual's ear varying from 27 to 309 (Åhlén 2001). Mites are usually spread through direct contact. Infected animals often shake, scratch or rub their ears and head, and their ears may be particularly waxy and may smell. Skin mites can cause itching, which in turn can lead to injuries to the skin and secondary infections (Stocker 2000). More than 10 species may live on an individual beaver at any one time, and they are often restricted to particular areas of the body (Saveljev & Bochkov 2012).

Tick

Eurasian beavers do not seem to be significant hosts to ticks. *Ixodes banksi* has been recorded in North American beavers and bedding material from their lodges (infestation rates of 30% and 34% respectively, Lawrence *et al*. 1956). As with other animals, ticks can transfer haemoparasites and heavy infection may lead to anaemia. When removing ticks ensure mouthparts (hypostome) are removed, otherwise infections may occur. Note ticks can transmit Lyme disease and there is a risk of infection when crushing ticks, so that they should be killed with surgical spirit (Stocker 2000).

7.6.2. Endoparasites

Beaver nematode (*Travassosius rufus*)

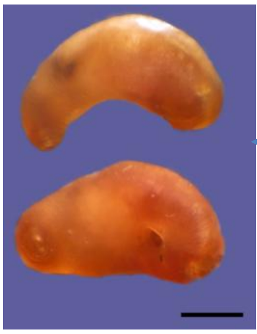
This species-specific nematode is found in the mucosal layer of beaver stomachs. It has a direct life cycle, with eggs expelled with beaver faeces. The infectious larval stage is ingested by the beavers while feeding (Åhlén 2001). These thin worms are seen on the stomach walls and within its contents. They are pink/red in coloration.

Beaver fluke (*Stichorchis subtriquetrus*)

This is a specialised trematode (figure 72) that is a strict parasite of the genus *Castor* and lives in the caecum of beavers. Its life cycle includes an aquatic snail as the intermediate host and beavers become infected when they ingest submerged plants (Bush & Samuel, 1981). Prevalence rates of more than 90% have been recorded (Drozdz *et al*. 2004), whilst 100% of Swedish beavers (n=25) were infected (Åhlén 2001).

During post mortem examinations these fluke are clearly visible as pale, rounded bodies (figure 71), mainly in the caecum, but they may also be present in the large intestines. Eggs are revealed through faecal testing. Heavy burdens are suggested to cause mortality.

Figure 71. Adult beaver fluke visible in contents of caecum.



Adult fluke

Figure 72. Adult beaver fluke.

Cryptosporidium spp. (Protozoa)

Cryptosporidium is an intestinal protozoan parasite. This parasite causes disease in the small intestine, particularly in immuno-compromised and immunologically naïve animals. The transmission route is faeco-oral. Infections are difficult to treat. It is currently widely present within wildlife and domestic animals therefore, whilst it is desirable that released beavers are free from this disease, they may actually become infected once released from native wildlife and domestic animals.

Giardia spp. (Protozoa)

Giardia is an intestinal protozoan parasite. Many cases of infection show no evidence of disease, but beavers have been implicated in human outbreaks, though it should be noted *Giardia* occurs naturally in the environment and within other wildlife and human populations (Morrison 2004). This parasite is transmitted via the faeco-oral route and beavers may contaminate human water supplies. It lives in the small intestine and can cause diarrhoea and abdominal pain in all mammals. *Giardia* spp. are present in Europe.

Haemoparasites

Blood parasites have not yet been recorded in Eurasian beavers (Cross *et al*. 2012) and further investigations are encouraged.

Liver fluke (*Fasciola* spp.)

Beavers become infected after ingesting vegetation, on which the flukes encyst. Flukes travel from the gut to the liver, where adult flukes shed eggs into bile, which then pass to the intestines. Eggs can be detected in faeces. Infected animals may display anaemia and reduced growth.

Echinococcus multilocularis

This is also known as the fox tapeworm and is a pathogenic parasitic zoonoses present in Central Europe. It has been suggested that there is a likelihood this could be introduced to the UK via imported beavers (Simpson & Hartley 2011). This tapeworm only becomes sexually mature and sheds eggs once inside a fox, but under certain circumstances cats and dogs can also act as the final host (Eckert & Deplazes 1999). Various rodents, including beavers, can act as intermediate hosts (Janovsky *et al*. 2002), in which an intermediate stage of the tapeworm can develop and then be passed on, if a fox ingests the infected rodent. Humans can act as an accidental intermediate host, in which case this tapeworm infests the liver, lungs and, on occasions, the brain resulting in alveolar, cerebral and hepatic echincoccosis, all of which can be fatal and all of which require lifelong treatment as the condition is not curable in humans.

Infection can either be determined through post mortem inspection of the beaver's liver and/or via minimally invasive exploratory laparoscopy in the live animal (Pizzi *et al*. submitted). Infection by this tapeworm has been observed in a dead Bavarian beaver from a captive population in England. Captive collections should particularly ensure that any escaped animal originating from areas with this parasite are recaptured or accounted for, and ensure any beaver carcasses are recovered and removed to prevent scavenging by other mammals, such as foxes, as soon as possible. Post mortem examinations should include investigations for this parasite, particularly through examination of the liver for cysts (see Barlow *et al*. 2011).

7.7 Diseases

Beavers may harbour rodent pathogens. Common European rodent pathogens have been highlighted (table 7). Not all have been reported in beavers* and some do not occur in the UK. Beavers from outside the UK should be screened for these pathogens, especially as some of them have zoonotic potential.

Table 7. Diseases of Eurasian Beaver *Castor fiber*

Infectious						
Disease	**Aetiology**	**Epizootology**	**Signs**	**Diagnosis**	**Management**	**References**
Hantavirus*	Hantaviruses Bunyaviridae	Rodents act as reservoir. Aerosol, horizontal transmission in host animal	Rare	Serology	Zoonotic Euthanasia	
Tularemia	*Francisella tularensis*	Vector, aerosols, ingestion contaminated water	Lethargy followed by death	Serology Culture	Zoonotic	Morner *et al.* 1988
Yersinia	*Yersinia enterocolitica pseudotuberculosis*	Contaminated food or water	Gastroenteritis	Culture Serology	Antibiotics	Gaydos *et al.* 2009 Hacking & Sileo 1974
Leptospirosis	*Leptospira sp.*	Contact with infected urine	Disease often subclinical in rodents	Serology	Zoonotic	Dollinger *et al.*1999
Salmonella	*Salmonella spp.*	Ingestion contaminated food and water		Culture	Zoonotic	Dollinger *et al.* 1999 Rosell *et al.* 2001
Campylobacter	*Campylobacter jejuni*	Ingestion of contaminated food and water (faeco-oral route of infection)	Uncommon but could include diarrhoea	Culture of faeces	Zoonotic	Rosell *et al.* 2001
Dermatophytosis	*Trichophyon* spp. *Microsporum* spp.	Contact with infected animal or spores from scurf/hair of an infected animal	Uncommon but include scaling, scurf and alopecia	Culture of scurf and coat brushings	Zoonotic but often self-limiting although oral griseofulvin and topical antifungal agents such as clotrimazole, miconazole and enilconazole effective	
Toxoplasma	*Toxoplasma gondii*	Contaminated food (shed by domestic cats in faeces and potentially by sheep in aborted foetal/placental tissues)	Uncommon but beaver may act as intermediate host for large felids in Europe	Serology	Rarely requires treatment and difficult to eradicate in herbivores	

Table 7. Diseases of Eurasian Beaver *Castor fiber continued…*

Disease	Aetiology	Epizootology	Signs	Diagnosis	Management	References
Echinococcus	*Echinococcus multilocularis*	Not currently present in the UK or Norway. Has two host life cycle using beavers (and humans) as occasional intermediate hosts. Definitive host for this tapeworm is the Red fox (*Vulpes vulpes*) but could also be domestic dogs, jackals and wolves.	No clinical signs in beavers	Post mortem evidence that serological tests used in humans may be possible in beavers	Zoonotic Euthanasia (not treatable in beavers)	
Fasciola hepatica	Trematode	Ingestion of infected aquatic snails on herbage (parasite has 2 stage life-cycle)	Rare unless severe infestation when liver failure may occur with jaundice, ascites and death may be seen	Difficult in live animal	Unknown treatment in beavers but clorsulon etc. used in domestic livestock	
Stichorchis subtriquetrus	Trematode	Its life cycle includes an aquatic snail as the intermediate host, beavers become infected when they ingest submerged plants	Heavy burdens are suggested to cause mortality	Faecal sedimentation technique	Endemic in some beaver populations	
Giardia	*Giardia lamblia*	Ingestion of contaminated water/food (faeco-oral route of infection)	Diarrhoea/enteritis	Faecal shedding of typical motile organisms	Zoonotic Metronidazole or tinidazole	Rosell *et al.* 2001
Cryptosporidium	*Cryptosporidium parvum*	Ingestion of contaminated food/water (faeco-oral route of infection)	Rare clinical signs but enteritis possible in immuno-suppressed individuals	Faecal shedding of oocysts	Zoonotic Not currently treatable	Rosell *et al.* 2001
Travassosius rufus	Nematode	Direct life cycle				Åhlén 2001
Schizocarpus	Mite		Shake, scratch or rub their ears and head, ears may be particularly waxy and may smell	Examination of the ear canal		
Rabies	Terrestrial rabies virus	Rare but may produce 'dumb' rabies in rodents	Mental depression and death	Post mortem demonstration of virus	Zoonotic Euthanasia	

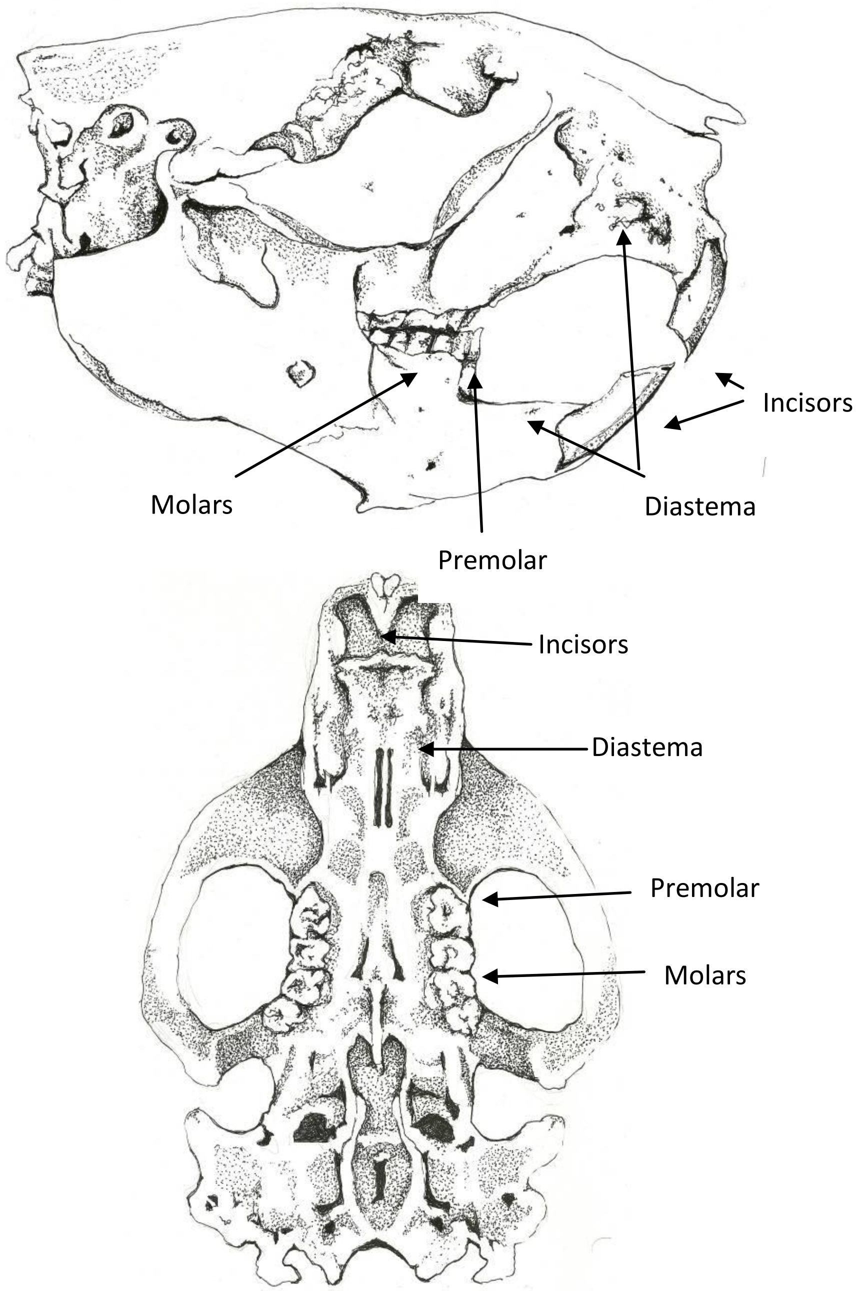
Table 7. Diseases of Eurasian Beaver *Castor fiber continued…*

Non Infectious

Disease	**Aetiology**	**Epizootology**	**Signs**	**Diagnosis**	**Management**	**References**
Metabolic	Hypervitaminosis D	Fed on a commercial primate feed that contained vitamin D_3	Cardiovascular failure and renal failure	Radiographs and ultrasonography	Not manageable	Sainsbury 2003
Neoplasia	1. Thyroid follicular carcinoma with pulmonary metastasis 2. Fibroma of the gall bladder		Presented with intermittent diarrhoea, lethargy and anorexia			Anderson *et al.* 1989 Dollinger *et al.* 1999

7.8 Skull & Dentistry

Beavers have large skulls to accommodate the powerful masseter muscles required to provide the forces needed for chewing through wood. Their dental formula is similar to that of other rodents (Incisor 1/1 Canine 0/0 Premolar 1/1 Molar 3/3 (figure 73 & 74). The front teeth or incisors are necessary for gnawing and grow continuously throughout the lifetime of the animal. They are coated on the outer side with thick orange enamel that provides a hard-wearing cutting surface (figure 79). Beavers have a diastema between the incisor teeth and molars to allow their lips to seal off their mouth while gnawing trees. Beavers grind their upper and lower incisors together regularly to sharpen them.



Figures 73 & 74. Beaver skull and dentition.

Malocclusion and hypertrophy of incisors has been reported in captive and wild beavers of both species (Żurowski & Krzywiński 1974, Cave 1984). Wild beavers have been recorded as surviving, breeding and feeding with abnormal incisor growth (Rosell & Kile 1998). However, in captivity these abnormalities should be treated as for any other rodents.

Figures 75, 76, 77 & 78. Dental abnormalities in beavers. From left to right, top infected lower incisor, non-growth of lower incisors leading to curling of top incisor back into skull, lower left. Uneven incisor wearing.

For example a female beaver in quarantine with overgrown incisors received treatment in which teeth were cut back to the gums. The teeth re-grew rapidly and this individual went on to live for many years, reproducing annually (D Gow, personal communication). If the underlying cause is congenital, the animal should not be used for breeding purposes. If the animal requires repeated investigation and treatment, the long-term welfare of the animal should be taken in to consideration and it will not be suitable for any release programme.

Fractures of the incisor teeth also appear to be common, but rarely seem to cause long-term debility, owing to the rapid growth of these teeth. Beavers are normally born with pointed incisors (Dzieciolowski 1996). Birth defects or damage to teeth or jaw shortly after birth may lead to deformities (Rosell & Kile 1998).

Figure 79. Beaver lying on its back with damage to its right upper incisor.

7.9 Vaccination

The decision to vaccinate (for example against leptospirosis), or to treat internal and external parasites, depends on the findings of health screens, the clinical impact on the hosts, and what pathogens already exist in indigenous rodents, with which the beavers may be in contact.

Vaccinations against pseudotuberculosis have been recorded as not being totally effective in beavers (Nolet *et al.* 1997). Yersiniosis and leptospirosis have been significant causes of mortality in reintroduced beavers in central Europe and vaccinations against these prior to release are recommended (Nolet *et al*. 1997).

7.10 Common Clinical Problems

In the RZSS's experience the prevalence of clinical problems is relatively uncommon in wild beavers (Girling S, personal communication). The most commonly observed clinical problems relate to intraspecific fight wounds, which may develop into abscesses, often with thick pus similar to those observed in lagomorphs and from which bacteria may be recovered, such as *Pasteurella* spp., *Aeromonas hydrophila* and *Pseudomonas* spp.

Tail wounds from fighting are also common and may provide sites for infection by bacteria, such as *Aeromonas hydrophila* and *Pseudomonas* spp. In some instances this has resulted in a bacteraemic/septicaemic state, resulting in the diagnosis of diseases, such as pneumonia and bacterial endocarditis. Severe debilitation of the affected beaver, as would be expected, has been observed in these cases with cardiovascular compromise, tachypnoea, hyperpnoea and dyspnoea coupled with dramatic weight loss and, in some cases, fatalities.

7.11 Diagnostic Imaging

7.11.1 Radiography

The body plan of the beaver is similar to that of other herbivorous hind-gut fermenting rodents. The chest is small in relation to the body size overall (as in most rodents) with the heart lying almost transversely when viewed dorso-ventrally.

The liver is a flattened organ, normally well hidden underneath the ribcage. The caecum and large intestine are the most prominent sections of the intestines and occupy the ventral portion of the abdominal cavity, which is relatively large in proportion to overall body size.

The stomach should always have ingesta present and may have a small crescentic gas pocket. Excessive gas accumulation in the stomach and intestines has been observed in cases of enteritis/gastritis and could be caused by an obstruction. Small areas of gas bubbles are normal in the caecum and large intestine, which should also always be full of ingesta.

The kidneys are located in the usual retroperitoneal space and are clearly visible on most radiographs, with the right kidney being close to the caudal liver and cranial to the left one, which adopts a more mid-dorsal abdominal position.

7.11.2 Ultrasound

Echocardiography (figure 80) is possible in the beaver, but can be difficult to interpret, owing to the transverse orientation of the heart and the presence of unique structures such as a septum which divides the right atrium into two halves. Further information on echocardiography should become available in the near future as a result of research at RZSS.

Figure 80. Ultrasound examination.

Abdominal ultrasound is also possible with the liver being easily imaged. The large intestines do cause some problems, owing to the presence of small gas bubbles in the lumen, which can cause reflection of sound waves and poor imaging of deeper structures.

7.12 Therapeutics

Owing to the high prevalence of Gram negative bacterial infections, such as *Pseudomonas* spp. and *Aeromonas* spp., the use of antibiotics, such as the fluoroquinolone family, has been shown to be effective. Enrofloxacin at 10mg/kg once-twice daily, or marbofloxacin at 10mg/kg once daily, or the use of a long-acting fluoroquinolone (e.g. Baytril Max® Bayer) at 7.5-10mg/kg every 2-4 days have all been used successfully by the RZSS veterinary team. Where anaerobic infections are found, the use of parenteral penicillin's or oral metronidazole has been found to be effective.

Ivermectin (at 0.2mg/kg) appears to be effective against intestinal nematodes, but is not effective against intestinal flukes. There is some anecdotal evidence from the

RZSS veterinary team to suggest that the use of clorsulon-containing compounds (e.g. Ivomec super injection for cattle® Merial which also contains ivermectin and dosed at 1ml/50kg bodyweight) do have some effect against intestinal flukes in beavers. Theoretically niclosamide-containing compounds may also have an effect against intestinal fluke, but these are not currently available in the UK.

<u>7.13 Surgery</u>

7.13.1 Wounds & traumatic injuries

Wounds appear to become easily infected with environmental bacteria, such as *Pseudomonas* spp. and *Aeromonas* spp. as is expected in semi-aquatic animals. Abscesses in beavers can produce caseous pus similar to that seen in lagomorphs. However, many deep penetrating bite wounds appear not to become rapidly septic and healthy beavers appear to be able to recover from moderately serious fight wounds without complications. In the case of debilitated beavers though, fight wounds can turn rapidly septic and septicaemia with multiple organ infection, particularly pneumonia and endocarditis, seem common.

Large abscesses should be lanced and flushed with dilute povidone iodine at a 0.5-1% solution. They may then be treated as open wounds. Alternatively if the abscess is resectable, then it should be surgically removed in its entirety.

7.13.2 Sterilisation & laparoscopy

Beavers, of both sexes, can be permanently sterilised by minimally invasive surgery, or laparoscopy (also referred to as "keyhole" surgery) (Pizzi *et al*. submitted). This method has numerous advantages over traditional open surgery. Animals experience less pain, have a lower risk of post-operative wound infections or complications, and can be returned to water and normal activity levels 2-3 days post-operatively. They also require less pain relief and for a shorter period than in open abdominal surgery. As the incisions are limited to three small 3-5mm wounds at the cannula sites, there is no risk of major dehiscence or evisceration post-operatively. The use of paediatric 3mm diameter 20cm shaft length instruments is advisable. Only a very small fur clip is needed for surgical skin preparation as there is minimal risk of hair entering wounds. This reduces the impact of the operation on the animals after their rapid reintroduction to their normal habitat soon after surgery. Owing to the voluminous gastrointestinal tract, an open-access approach to placement of the primary sub-umbilical optical port is recommended, as a blind approach, using a verress needle, carries an elevated risk of bowel trauma and subsequent peritonitis. All 3 cannula incisions are placed in the midline, overlying the *linea alba*. An additional benefit of laparoscopic neutering is it allows a visual examination of the abdominal organs for other undetected pathologies, including the presence of any *Echinococcus* cysts in the liver. Insufflation is at a standard intrabdominal pressure of 10-12mmHg. The use of biopolar radiosurgery (3.8-4.0MHz) is recommended. Use of standard monopolar electrocautery is not advisable, as this carries a risk of skin burns due to poor contact with the ground plate, owing to the thick, insulating fur. If this is to be used, a region of fur would need to be clipped and moist swabs applied to ensure adequate ground-plate contact. In males a laparoscopic intra-abdominal vasectomy is performed by cautery, sectioning and separation of the ends of the vasa deferentia. A sample should be taken for histological confirmation. This is in preference to

orchidectomy (removal of the abdominal testicle), which requires a larger incision and may also result in altered behaviour and hence group dynamics. In young females, laparoscopic ovariectomy, or tubal ligation, is indicated. Tubal ligation has been described in beavers for the reduction of breeding (Brooks *et al*. 1980) and has not been found to change group dynamics or behaviour. There are no reports of tubal ligation resulting in later uterine pathology (these were not monitored, Pizzi *et al.* submitted). Tubal ligation should be performed in the fallopian tube and not in the uterine horn, to prevent the risk of hydrometra. A partial salpingectomy, bipolar electrosurgery, or endoloop ligation are all applicable methods of tubal ligation. Ovariectomy could be performed instead, but may alter the female's behaviour and group dynamics. However, it may be appropriate for captive beavers living in pairs.
In older multiparous females, or those demonstrating gross uterine changes or abnormalities, a laparoscopic or laparoscopic-assisted ovariohysterectomy may need to be performed. The uterus in these cases is exteriorised from the caudal-most cannula site, which is slightly enlarged. Rapidly–absorbable, monofilament suture closure is recommended at the intradermal and intramuscular (muscle/linea alba) layer. Additional cyanoacrylate tissue adhesive application to cannula insertion sites helps with early return to water post-operatively.


Figure 81. Laparoscopic view of beaver ovary.

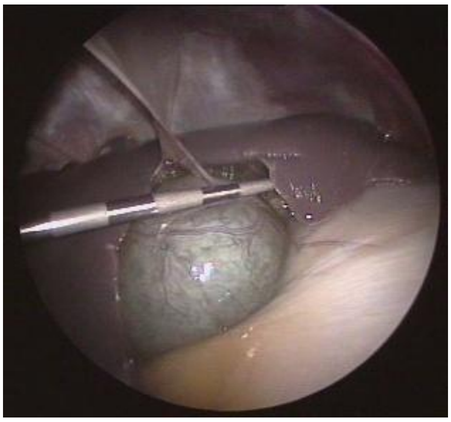


Figure 82. Beaver liver and gall bladder.

If only the male or female from the adult breeding pair are sterilised, this generally does not lead to other family members reproducing, as long as those individuals remain within the colony (Brooks *et al*. 1980).

7.13.3 Euthanasia

Humane euthanasia may be carried out using sodium pentobarbital as with other mammals (80-160mg/kg intravenously). The beaver is usually sedated first and the fatal dose may then be administered either via the ventral tail, cephalic or saphenous veins. It should be noted that the Eurasian beaver is a protected species in many European countries and such a procedure must be undertaken by a fully qualified veterinary surgeon.

7.14 Post Mortems

Any captive beavers or those found involved in the initial stages of a reintroduction that die should have a full post-mortem (PM) examination by an accredited pathologist and tissues should be stored. Dead wild rodents from the release sites can also be submitted for routine post-mortem.

7.14.1 Handling of cadavers

Cadavers should be sent for post mortem unfrozen, unless a body has been discovered in a badly decomposed state. Gloves should be worn and the body should be double bagged for transportation. The individual ID of the animal should be determined through transponder number, ear tag, etc., which should be recorded along with age and sex, if known. The cadaver should be weighed and given a body score using the standard body scoring system (section 7.2.2). Tail length, width at mid-length point and thickness at the midpoint of the base of the tail should be recorded, so tail fat index can be calculated. This will aid in scoring the condition of the cadaver.

7.14.2 Sample collection

See PM request (figure 83) for recommended sample collection. External and internal parasites should be preserved in 70% ethanol. A cube of muscle tissue, 2cm x 2cm x 2cm, taken from anywhere in the body, should be preserved in 70% ethanol for genetic analysis. Skulls and skeletons are useful for morphometric analysis. This is particularly important for released beavers and their progeny in order to study the adaptation of reintroduced beavers to their new habitats. After post mortem, carcasses should be frozen with clear labelling to retain data prior to subsequent processing. Sampling of brain tissue is to be avoided unless there is a clear neurological problem. Premolar teeth required for ageing can be removed through warm-water maceration, in order to prevent avoidable damage to the skull.

Detailed medical records, laboratory results, protocols and risk analyses should be collated and retained centrally, so that they are readily accessible to those who may require them. The disease and PM surveillance programme should be under constant review and continued for a minimum of one year post release.

7.14.3 Sample storage

- Hair – small paper envelopes in a dry environment or sterile plastic tubes, frozen.
- Tissue (such as muscle or tail) – frozen or ≥70% ethanol (for DNA samples) or formalin.
- Blood – EDTA tubes, frozen (whole, serum) or blood smear slides or Whatman DNA cards.
- AGS/Castoruem – sterile plastic vials or Teflon capped, glass vials if using samples for gas chromatography-mass spectrometry analysis, frozen.
- Faeces – plastic vials or sample bags, frozen or ≥70% ethanol.
- Parasites – ≥70% ethanol.
- Teeth – premolar for ageing.
- Skeletons – see 7.14.2. For UK beavers contact Dr Andrew Kitchener, National Museums Scotland, Tel. 0131 247 4240 a.kitchener@nms.ac.uk to make arrangements for transport to the National Museum of Scotland, which retains a large skeletal collection for research.

Beaver Necropsy Request Form

ANIMAL DATA
Owner:

Clinician:

Animal ID: Transponder :

Sex: Male / Female

Age: Adult / Juvenile / Kit

Weight: Body Score:

Tail length: Tail width: Tail thickness: Body Length:

Date received:

Cadaver / Died / Euthanasia

HISTORY / CLINICAL DATA / CLINICAL DIAGNOSIS

SAMPLE STORAGE
Please collect and store the following samples:

- Heart blood, urine, castoreum, anal gland secretions, faeces , stomach contents (Frozen)
- Heart (10% formal saline), Liver, Kidney, Lung, Brain tissue sample, Spleen (formalin)
- Parasites (70% ethanol)
- Tissue sample: 2x2cm muscle (70% ethanol)
- Any gross abnormal tissues (formalin)

Please take images of any abnormal pathology

Figure 83. RZSS beaver PM check sheet.

8. POPULATION MANAGEMENT

8.1 Species Identification

The North American beaver was introduced to various European countries at different times during the 20th century, starting in Finland in 1935-1937 (Nolet & Rosell 1998). At present it is uncertain which species has the competitive advantage (Danilov *et al*. 2011), though due to their extreme physical and ecological similarity it is likely that one species will competitively exclude the other (Gause 1934). This could eventually lead to the local extirpation of Eurasian beavers and in time its extinction in Eurasia. However, very recent studies suggest comparison of various life history traits, using data from both beaver species within Europe, reveal very few differences (Parker *et al*. in press). There are extermination programmes in Finland (Nummi 1996), but the spread of North American beavers continues. These two species cannot be readily and reliably be distinguished through external morphological, ecological or behavioural characteristics in the field. Chromosome numbers (section 1.1) can be determined from fresh biological samples, although this method can be slow, expensive and requires specialised expertise and equipment. On horizontal starch gel electrophoresis Eurasian beavers have alleles that migrate faster (esterase D locus) compared to those of North American beavers (Sieber *et al*. 1999). The AGS of North American beavers are brown and viscous in males, whitish to light yellow and runny in females (Schulte *et al*. 1995), and the opposite consistency to those of Eurasian beavers (Rosell & Sun 1999). Therefore, if the sex of an individual is known for certain, species identification can be made reliably in the field through the colour and viscosity of the AGS (Rosell & Sun 1999).

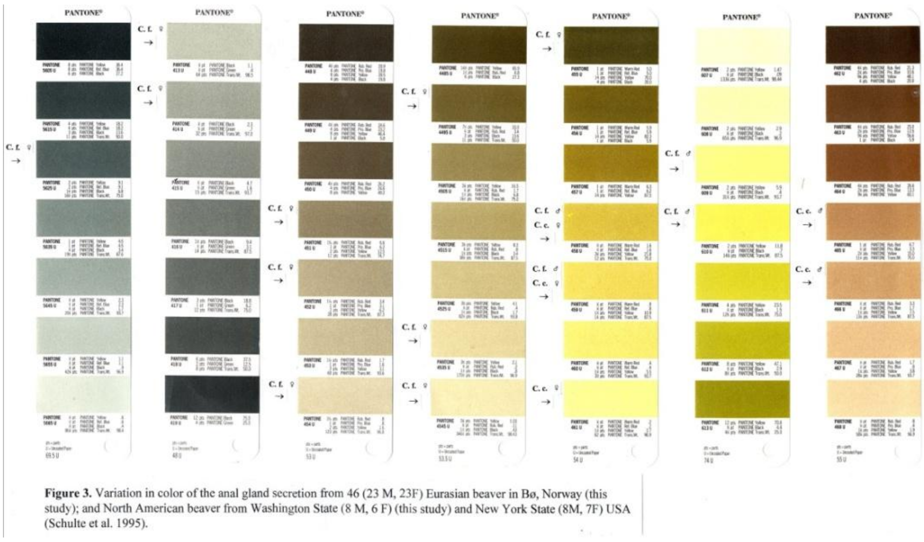


Figure 84. Colour variation of AGS in Eurasian (*C .fiber*) and North American (*C. canadensis*) beaver AGS, (cited in Shultz *et al*. 1995).

Given the current distribution of North American beavers in Finland and reports of escaped individuals from captive collections in various countries, including France and Germany (Dewas *et al*. 2011), it is recommended that this species is not kept in the UK or Europe. The keeping and breeding of American beavers presents an escape risk for an invasive species and any offspring must also be housed taking up further space and resources. Given the limited resources available in European collections, especially when implementing reintroduction and captive breeding programmes, captive resources need to be prioritised. It should be noted that given the availability of wild stock across Europe for translocations the need for captive breeding programmes is not a major requirement. If the species of beaver held in captivity is unknown or unconfirmed, then genetic screening to determine species is recommended.

8.2 Population Growth & Control Strategies

In the wild, population density is usually measured as the number of occupied territories along a unit length of water body, or as the number per unit area (Novak 1987, Müller-Schwarze & Sun 2003). The number of beavers in each territory is often more difficult and time-consuming to measure (Rosell *et al*. 2006), and mean values are, therefore, often employed when estimating the number of individuals in a population (Parker *et al*. 2002). Population growth depends on many factors, including population density and competition levels, habitat availability and quality, water resources, food availability, disease, predation, hunting pressure and territorial behaviours (Novak 1987, Hartman 1999). Decline in population growth has been determined to occur at population densities of ~0.2-0.25 per km^2 (Kichener 2001). Population growth, in a non-hunted population, is mainly regulated though the availability of suitable habitat (Novak 1987, Müller-Schwarze & Sun 2003).

8.2.1 Estimating population growth

Fecundity can be estimated through field observations of kits in late summer (Rosell *et al*. 2006) or through repeated live-trapping (Campbell 2010). Ovaries of trapped dead females can be examined for incidence of ovulation by counting *corpora lutea* during the breeding season (Provost 1962, Hartman 1999). Uteri can be examined for presence of embryos, or placental scars following parturition (Harder 2005). Uteri and ovaries of kits and non-breeding yearlings are small, thin and light in colour, whilst in older females these are darker, thicker and heavier (Hartman 1999).

Foetal implantation rate can be determined by comparing corpora *lutea* and embryo counts, so that embryo mortality rate can be calculated from the difference between them (Provost 1962, Harder 2005). Estimates of age-specific reproduction and age-specific mortality can be calculated from hunted and trapped specimens.

Population growth of reintroduced beavers to Sweden saw the first pairs released in 1922 and by 1999 the country's beaver population was estimated at 100,000. The population growth rate fell to around 0 about 50 years after reintroduction as population density increased (Hartman 1994). In Norway the population has risen from ~100 in 1899 to around 70,000 in 2005, the equivalent of 5-6% population growth rate per year (measured from 1880-1965) (Rosell & Parker 2011).

8.2.2 Captive social grouping

Beavers can be kept in single-sex groups, if they are related. It should be noted that same-sex individuals introduced to each other from different families are very likely to attack each other, resulting in injury and potentially death. Movement of single-sex groups into new enclosures has also reportedly caused fighting as a dominant individual asserted itself (Gow D, personal communication). Individuals injured in these fights are often seen above ground during the day and experience suggests they cannot be successfully reintroduced into the group after treatment. As only the dominant pair reproduce in a family group, it is recommended that their sterilisation will result in a stable social grouping and breeding will be suppressed in other family members. However, confirmation of this is needed for the long term, so that sterilisation of all family members is recommended to prevent any chance of reproduction (section 7.13.2).

8.3 Captive Population Management Planning

Under the right circumstances, beavers breed readily in captivity. Once a breeding pair is established, they continue to produce offspring each year (on average 2-4 offspring/year). Only the dominant pair reproduces within a family group. Offspring remain naturally with their parents for at least two years and should not be removed before this period, although yearlings can survive independently of parents (Hartman 1997). However, the problem of surplus animals may develop and such issues should be both planned for and handled responsibly.

Before undertaking any sort of breeding programme, a population-control strategy should be put in place, so that any offspring that cannot be accommodated are responsibly managed. Collections should not allow indiscriminate breeding and particular pairs to become genetically over-represented. Beavers are often described as a poor exhibit species within zoological collections, but can make excellent educational models, if displayed appropriately. However, available places within zoological or private collections are limited, so that culling (7.13.3 and 8.5) and sterilisation (7.13.2) are viable population-management options that should be considered. All individuals should be micro-chipped/genetically tagged for identification. It is recommended that all individuals receive some level of health screening (chapter 7), with biological samples collected and stored for veterinary and genetic analysis. Genetic screening and good record keeping are vital management tools for encouraging responsible breeding.

8.3.1 Record keeping

Responsible husbandry should involve the keeping of precise records on the animals within collections, particularly if breeding and translocating animals. Those responsible for any collection should know how many beavers they have, approximate ages, establish a record-keeping and monitoring programme, determine carrying capacity of available resources and determine options for dealing with expanding numbers. A beaver studbook is particularly recommended, if establishing a population for potential use in reintroduction programmes, where provenance and procurement of F_1 animals may be of particular importance.

The minimum data to be recorded for each individual held in captivity are:

- Local ID: A unique institutional identifying number.
- Correct scientific name: if subspecies uncertain, then just use species or geographical origin of founders.
- Accurate information on any distinguishing identifiers: transponder numbers, tags (numbers, colours, location), identifying marks, scars and notches (descriptions, location), including dates of application and loss or removal.
- Sex.

- Age: date of birth or estimate.
- Location of birth.
- Birth type: wild, captive, unknown.
- Provenance: if born at another collection/institution the date of arrival, where arrived from vendor ID number (vendor). If born in the wild then date of arrival, place of capture (as accurate as possible).
- Sire ID: their local ID and location.
- Dam ID: their local ID and location.
- Veterinary: dates of treatment, types of intervention received.
- Behavioural and life history data: breeding events, unusual behaviours.
- Diet: can include standard diet sheet, note anything of interest.
- Enclosure: details of enclosure, enclosure mates.
- Transfers: dates and location ID.
- Disposition/Death: date. For disposition recipient, and their local ID. For death, death circumstances and post mortem information.

8.4 Surplus Animals

Surplus animals should be avoided through responsible management and control of breeding. If resources allow and welfare of individuals is not compromised, sub-adults should remain within family units and not used to create new breeding pairs. Sterilisation should also be implemented and careful consideration should be given before deciding to hand-rear individuals (Graham 1996). Re-homing surplus animals may be an option, but in time places will become limited. Ethical consideration should be given to where individuals are placed. Although there may be other options, which are not acceptable or accredited by EAZA or AZA, these should not be used as a quick fix.

Reintroductions and translocations have been used widely in beaver conservation and these can provide an option for the disposal of surplus animals. However, these are often expensive, involve various legalities, may not be supported by the public, captive-bred animals may not be suitable for release, and appropriate habitat may be limiting.

Euthanasia is a legitimate management tool to deal with surplus animals, which cannot be suitably placed. This should also be considered for blood lines that are over-represented in captivity. Euthanasia should involve a painless death (AVMA 1978) and all measures possible should be implemented beforehand to minimise stress to the individuals involved. Euthanised animals can also provide important material for research and efforts should be made to identify a suitable receiving research institution for whole carcasses or specific organs and tissues.

8.5 Humane Dispatch in the Wild

Populations of both Eurasian and North American beavers are expanding within Europe. Eurasian beaver are protected under EU law. Presently, beavers are being harvested or ‘problem’ animals removed primarily by trapping throughout the former Soviet Union countries, Estonia, Latvia and Lithuania, and primarily by shooting in Norway, Sweden and Finland (Hartman 1999, Parker *et al*. 2002, Parker & Rosell 2003). For example, in Norway quotas are set by local game boards based on rough estimates of population size. Adults and pregnant females are more prone to being shot, as these tend to be more active and hence most obvious to hunters, especially on land while feeding and/or scent marking (Parker *et al*. 2002). Therefore, when setting hunting quotas, the sustainable yield depends not only on the proportion of the population harvested, but also the sex and age of shot individuals. Studies in Norway have demonstrated that a 25% harvest of the autumn population resulted in almost a 50% decline in the number of territories the following year, because of selective hunting of pregnant and adult animals (Parker *et al*. 2002). In Sweden, hunting pressure is presently light and quotas are considered unnecessary (Hartman 1999). The maximum sustainable yield, when hunting beavers in spring in Nordic countries, is between 10-20%, depending on habitat quality and population growth rate (Parker *et al*. 2002).

Modern, body-gripping traps, such as the Conibear 330, kill beavers humanely (Novak 1987), as does shooting with centre-fire rifles (Parker *et al*. 2006). However, use and legality of these methods vary across Europe. It should be particularly noted that this species is protected in many parts of Europe. For captive or trapped individuals a practical solution is euthanasia through humane injection by veterinary surgeon (section 7.13.2) or a beaver may be placed in a kill pen with a deep straw floor. The beaver will walk around slowly or settle into a corner where it can then be shot at point-blank range (figure 85).

Figure 85. Humane killing of a beaver by state wildlife personnel in Bavaria.

9. CONSERVATION MANAGEMENT

Translocation and reintroduction of captive and wild-caught individuals are viable conservation strategies that have been implemented very successfully for beavers. However, these should be seen as long-term conservational goals, requiring a multi-disciplinary approach, financial support, and governmental and public support. Beaver populations have also readily responded to controls on hunting pressures and recovery from much reduced populations. However, given the history of over-hunting and near extinction of this species, habitat loss across Europe and potential beaver-human conflicts, conservation management is recommended to ensure this species does not become threatened again (Batbold *et al*. 2008).

9.1 History of European Reintroductions

Documented translocations and reintroductions of beavers were first recorded in Europe in the 1920s (Halley & Rosell 2003), but unrecorded releases may have taken place before this time. Beaver reintroductions and translocations have been carried out for a variety of purposes, including the establishment of harvestable populations for the fur trade, species recovery, ecological restoration, and heritage reasons (Müller-Schwarze & Sun 2003). Over the past 40 years there has been a steady growth in the number of Government-sanctioned and unsanctioned translocations and reintroductions. These have proved a vital conservation tool in the recovery of the Eurasian beaver throughout Europe.

Fifty three percent of the 87 beaver reintroductions, for which at least 5 years of demographic data exist, have been deemed a success, as measured in terms of population increase through reproduction (Macdonald *et al*. 1995). Release into unsuitable habitat has been suggested as the most likely reason for slow population growth or failure to establish reintroduced beaver populations (Macdonald *et al.* 1995). The number of individuals released is also an important determining factor, as particularly within a small population dispersers will have greater difficulties in finding a mate, which in turn will affect population growth. However, poor animal management of reintroduction projects has also been suggested. Humans and infectious disease have been cited as the main cause of mortality among released beavers in the Netherlands (Nolet *et al*. 1995).

The positive effects of beavers and their activities on ecosystems have been widely documented, and in more modern times provide the main justification for their reintroduction. As a keystone species, the beaver can significantly change the geomorphology, hydrological characteristics and biotic properties of a landscape, and underline their important role as ecosystem engineers (see Rosell *et al*. 2005). Through their dam building, tree felling and digging behaviours, beavers increase habitat heterogeneity and species diversity. However, their behaviours and activities may also conflict with other land uses (table 8).

Table 8. Potential positive and negative effects of the presence of beavers (Macdonald *et al.* 1995, Rosell *et al*. 2005).

Positive	**Negative**
Improving water quality	Flooding or water logging land (e.g. roads, agricultural land)
Preventing flooding downstream	Feeding on softwoods and crops
Regulating water flow	Burrowing through dikes
Creating and maintaining wetlands	Eroding river and ditch banks
Benefiting other species	Undermining fields and roads
Raising water table	Reducing water levels downstream
Conserving water	
Potential tourist attraction	

9.2 Situation in the UK

Presently in Scotland, beavers are outside their "native range" as defined under the Wildlife & Natural Environment (Scotland) Act 2011. It is also considered that beavers are outside their "natural range" for the purposes of the Habitats Directive. Therefore, it is considered that beavers in Scotland are not subject to legal protection from being killed or captured under either domestic or European legislation. It follows that animals may be legally controlled by a landowner or any other person having the right to kill or take animals on the land in question as long as animal welfare legislation is complied with. Any person who releases, or allows to escape from captivity, any animal to a place outside its native range is guilty of an offence. In England & Wales it remains an offence to release, or allow to escape, an animal which is not ordinarily resident in Great Britain in a wild state.

In the UK a government licence is required under Section 16(4) of the Wildlife and Countryside Act 1981, to release a non-native species into the wild. Therefore, any release or translocation that is unlicensed is currently illegal. In Scotland and Wales the licensing of such activities is a devolved matter for the Scottish Government and Welsh Assembly respectively, and therefore all translocations and reintroductions should be licensed by the relevant government agency.

At the time of writing, the Scottish Beaver Trial in Knapdale, Mid Argyll is the only government-sanctioned beaver reintroduction project in the UK and it is independently monitored by SNH. However, a number of private enclosures across the UK contain beavers living in ‘wild’ environments. Additionally a wild population of beavers of unknown origin, presumably escaped or illegally released from captive collections, is currently known to be living and breeding in the River Tay catchment around east Scotland. A recent survey suggests that about 140 animals are present in the Tay catchment.

9.3 IUCN Guidelines & Best Practice

Currently the best-practice guidelines for species reintroduction projects are set out in the International Union for the Conservation of Nature’s (IUCN) guidelines on reintroduction (Anonymous 1998), which cover key aspects of reintroductions, including animal selection and provenance, site selection, resourcing, local consultation, Government authorisation and post-release monitoring. All translocations and reintroductions should, where possible, adhere to these guidelines.

A review of the research literature and recent experiences of beaver translocations and reintroductions has resulted in a list of recommendations (see section 9.4).

9.4 Provenance of Founder Stock

Eurasian beavers have been extensively reintroduced across Europe with little consideration of provenance or selection of founder stock. In Britain there has been increasing discussion of which stock to use for reintroductions (Halley 2011, Rosell *et al*. 2012). There are multiple factors that should be considered when selecting individuals for reintroduction, such as health status, relatedness of individuals, genetic diversity, disease/parasite load, cost, behavioural competency, availability of stock, etc. The IUCN guidelines for reintroductions (Anonymous 1998) make a series of recommendations, which incorporate these factors. It is recommended by the IUCN that any reintroduction aims to create a founder population that most closely represents an extinct population, taking into account the genetic diversity and health of available populations.

Based on mitochondrial DNA, Eurasian beavers may be separated into two management units (MU), eastern and western (Durka *et al*. 2005), but it was also recommended that each former relict population within Europe should be treated as distinct populations until further information was available on their taxonomic status. There are morphological differences in the skulls of current western European populations, particularly those from the Elbe, and when exposed to the castoreum of Elbe beavers, Norwegian beavers do not respond aggressively, as they normally would to scent from other Norwegian beavers (Rosell and Steifetten 2004). A recent molecular study suggests today's relict populations diverged from each other about 210,000 years ago, so that there is strong support for subspecies status being maintained (Horn *et al.* 2011).

Following IUCN guidelines, if a choice of source populations exists then the population that is closer genetically (or more ecologically similar) should be selected. Therefore, reintroductions into Western Europe should select western MU stock, if a purely phylogenetic approach is applied. However, if the most genetically similar population has been compromised in some way, then further investigation will be required to evaluate the suitability of this population for reintroduction purposes. In order to determine if this is the appropriate strategy, further comprehensive evaluation of the phylogeography of Eurasian beavers is required, including the incorporation of data from ancient DNA analyses. While these have been completed recently for mainland European beaver populations (S. Horn, personal communication), no such analysis has been carried out for British beavers. The full extent of any loss of genetic diversity, and therefore future genetic adaptability, is still to be assessed, but studies are currently underway which will inform decision-making at Governmental level. Until this occurs a precautionary approach is recommended, in that populations of beavers should remain unmixed until further genetic information becomes available (Rosell *et al*. 2012).

At the time of writing, only beavers from Norwegian stock have been licensed for a trial reintroduction in Scotland based on their western origin and morphological similarities to the extirpated British population (Kitchener & Lynch 2000). If a potential lack of genetic diversity is identified in these founders, this will be mitigated by the exit strategy of the trial or through genetic rescue.

9.5 Recommendations for Beaver Reintroductions

It should be noted that this section refers in particular to the British trial beaver reintroductions and is based on experiences of the Scottish Beaver Trial. There are a wide range of variables that will affect decisions relating to a specific reintroduction scenario. Beaver trials have not occurred to any real extent within the rest of Europe, and are quite different from many of the 'full' reintroductions that have occurred here. Health screening and quarantine restrictions in other countries also vary greatly from those in Britain.

9.5.1 Selection of individual animals

1) It is important to consider the collective group structure of any beavers used in a monitored reintroduction project. The age, sex and relatedness of each individual will create various constraints upon their use and placement. The use of entire families may be the ideal in relation to encouraging rapid territorial establishment, but this approach may require significantly greater resources to obtain, quarantine and transport the animals. There is also a danger of family units being adversely affected by mortality prior to release; making putting together 'family' groups more difficult or requiring more resources to house appropriately.

2) The use of young animals (around natural dispersal age 2-4 years) of different sexes, which can then be paired in captivity prior to release, should be considered as a first choice. McKinstry & Anderson (2002) found that 2-2.5 year old beavers had greater average reintroduction success. This age class may be more suitable for re-colonising new areas, since they are predisposed to emigrating and establishing new territories. McKinstry & Anderson (2002) recommended translocating 2-4 year old beavers.

3) A full health examination should be carried out on each individual prior to release. Individuals in poor body condition, with dental abnormalities, sensory impairment, any disabilities, pregnant, very young or suspected very old animals should not be used for translocation or reintroduction.

4) All individuals should be subcutaneously implanted with PIT tags for individual identification.

5) If possible, a wider pool of beavers should be trapped in the source area. Following body-condition scoring and health screening by an experienced veterinary surgeon, only the fittest animals should be selected for transport, quarantine and release.

6) Evidence suggests that translocations have been shown to be generally more successful with wild-caught than captive-bred animals. However, this has not been verified in beavers.

7) Given that some mortality may be expected in transportation and quarantine in any reintroduction, a captive breeding population is also recommended as a backup.

9.5.2 Quarantine (see also section 6.5)

1) Water for animals in quarantine needs to be of good quality and should ideally be changed every day to prevent the accumulation of high ammonia levels and faeces. Filtration systems built into bathing pools could clean water and also produce a current of water, which could potentially provide a form of exercise for them in captivity.

2) Wild shrub browse, taken from the release site, should be introduced to the animals whilst in quarantine to allow a gradual change in gut flora.
3) Beavers should be quarantined at low densities to reduce stress levels of unrelated beavers living in close proximity and reduce the opportunity for the transmission of pathogens. Barrier techniques should be employed.
4) Beavers should ideally be housed in open environments, i.e. in external captive pens, with large pools.
5) In order to reduce stress for animals during the captive period, handling should be minimal and undertaken by experienced personnel.
6) Care should be taken if attaching external tags, including ear tags, in captivity in case of injury. If this is necessary, we suggest using only PIT tags.

9.5.3 Release site

1) Release sites should be selected so that chances of establishment and breeding are maximised, and mortality and conflicts with humans are minimised. Sites should have sufficient and constant water levels, along with suitable vegetation throughout the year to reduce mortality levels. It should be noted that beavers are adapted to live in a wide variety of conditions and will alter the environment to suit their needs, with water habitat being the crucial determining factor.
2) The primary cause of extinction/decline should be removed.
3) Public and stakeholder opinions must be taken into consideration, and a local engagement strategy implemented before and throughout the reintroduction process. It is also recommended that any local legacies, e.g. infrastructure or jobs, are put in place.

9.5.4 Release process

1) Reintroduction success will be increased through strategic planning and implementing an appropriate monitoring and management programme. There is a need to ensure that all required specialist equipment is available on site and that it is tried and tested well ahead of any release date.
2) Any personnel involved in the reintroduction process, e.g. animal handling, transportation and monitoring, need to be well trained and experienced. Animal handling, transportation, capture and re-capture, invasive monitoring and disturbance should be kept to a minimum.
3) All those involved in the release need to be aware of the potential detrimental implications of stress in animals and instructed accordingly. Linked to this, numbers of individual people in release teams should be kept to the minimum required.
4) Beaver transport crates should be covered, but well ventilated, in order to reduce stress in transit. Avoid extremes in temperature. Handle with care and ensure animals have appropriate bedding, food and water.
5) It is important to carry out a full health examination on each individual beaver prior to release. Individuals in poor body condition, displaying dental abnormalities, sensory impairment, disability, injury, heavily pregnant, and very young or suspected very old animals should not be released. All individuals should be subcutaneously implanted with a PIT tag for individual identification and traceability.
6) Beaver releases should occur by autumn to enable released animals to establish territories, build shelters and have ready access to food supplies, so they can

prepare for the colder winter months when food is less available. The creation of small ponds at release sites to provide temporary refuge for released beavers, or a selection of release sites into larger river systems over smaller streams have been recommended (McKinstry & Anderson, 2002). Careful consideration should be given to the most suitable form of "hard" or "soft" release type as required, along with the potential need for any artificial lodges or temporary deterrent fencing, to deter animals from dispersing soon after release. Artificial lodges have been used in a number of release programmes, with beavers only able to exit once they had cleared the blocked exit. Only 18% of translocated beaver families used these artificial lodges after release (Nolet *et al*. 1997). The SBT also experienced low use of artificial lodges (Campbell-Palmer R, personal comment).

7) To discourage rapid dispersal, releases involving more than one beaver should be carried out in a simultaneous manner, or sequentially, if animals are in areas which are spatially separated.

8) When a release programme requires simultaneous releases of unrelated groups of beavers, in order to establish a larger wild population, it is important to ensure that adequate habitat corridors exist between release sites to facilitate dispersal and the establishment of new territories and breeding pairs.

9) Additional releases are likely to be required to encourage population growth (McKinstry & Anderson 2002, SBT 2010).

9.5.5 Post-release monitoring

1) Release success will be increased through strategic pre-release forward planning, and active monitoring and management post-release.

2) Any monitoring programme should be well planned, sustainable and established pre-release, with all required personnel well briefed, organised and trained beforehand.

3) It is helpful, especially initially, if all beavers have unique ear tags to allow identification of individuals in the field and from a distance.

9.5.6 Post-release management

1) Given the expected mortality in the release process and early years of any reintroduction programme, a captive breeding population is recommended to supply extra animals.

2) Any project should secure experienced staff, have adequate resources and planning ability to deal with potential animal management problems.

3) Provide regular public updates, community engagement and keep precise records.

4) Animal welfare should be a priority and reviewed regularly.

5) Monitoring protocols should be reviewed and revised regularly.

6) Dispersing animals may leave any trial area or have difficulty finding suitable mates; interventions such as trapping, relocating and pairing with other dispersers should be considered to reduce animal loss.

7) Level of veterinary intervention in the field should be considered, particularly in small populations and/or during the trial period, to reduce potential animal loss particularly in the establishment phase.

8) Post-mortem examinations, with appropriate actions if cause of mortality is significant to animal or public health, or owing to unexpected environmental factors or a result of human-wildlife conflict.

9.6 Veterinary Considerations

Any translocated animal is a package, containing an assortment of potential viruses, bacteria and parasites. There needs to be an evaluation of the possible impact of potential infectious disease from reintroduced beavers on indigenous wildlife, as well as any local endemic diseases affecting reintroduced animals. It is important to note that there is a difference between an animal having an infection and its health being impacted, e.g. animals may harbour parasites with no ill effect. The same parasite in different hosts, or in individuals of the same species, but in different physiological states, could cause disease. For example, the stress of captivity/reintroduction process could cause an infection or parasite burden to have a significant impact on an individual.

In order to assess the health status of animals prior to release, each beaver should be given a clinical examination and screened for important pathogens. Despite numerous beaver reintroductions throughout Europe there is little published information concerning beaver health care during the reintroduction process. However, Goodman *et al*. 2012 have described the establishment of a health surveillance programme for beaver reintroductions in Scotland. Indigenous wildlife (rodents) should be screened for endemic pathogens. Any animals that die prior or post release should be subject to a full post-mortem. Regular health monitoring, following the release of the animals and that of indigenous wildlife, should be an integral part of the post-release programme.

9.7 Minimising Disease Risk

9.7.1 Pre-release

Quarantine facilities

Beavers should be kept in quarantine for as short as possible, but consistent with fulfilling government requirements, and allowing the detection of animals harbouring disease and the required turnaround times for laboratory tests. A minimum quarantine period of 35 days has been recommended for Rodentia (Sainsbury 2001). Within the UK quarantine facilities need to meet both veterinary standards and UK government requirements (Rabies Act 1974). Prolonged captivity may have a detrimental effect on the health of wild-caught beavers. Foot baths, protective clothing and designated staff minimise the risk of transfer of disease between translocated animals and other species.

Health screening while in quarantine

Health screening should include the following test and procedures:

- Faecal examination (direct and flotation, sedimentation) at 15-day intervals for endoparasites such as *Giardia*, *Cryptosporidium*, round worm and trematodes (three consecutive negative samples are recommended).
- Faecal culture for enteric pathogens such as *Salmonella, Campylobacter, Yersinia* and *Clostridium* (3-5 day-pooled faecal samples on arrival and prior to release).
- Bacteriology culture from upper respiratory tract.
- Serological test such as leptospirosis, tularaemia (*Francisella tularensis*) and yersiniosis (*Yersinia pseudotuberculosis* and *Y. enterocilitica*).
- Full blood-cell counts, biochemistry profile and blood smears for haemoparasites.

- Screening for *Echinococcus* through visual examination of liver via laparoscopy/ultrasound and blood testing, if beavers imported from areas where this parasite is present. Screening methods are in development.
- Banking serum.
- Urinalysis, where possible.
- Clinical examination, with special attention to presence of ecto-parasites, dental abnormalities, body condition and weight (section 7.1).
- Sex determination (by palpation and radiography, if needed).
- Inputting PIT tag for identification.

9.7.2 Post-release

Health screening of indigenous wildlife

It should be remembered that not only should the translocated animals undergo health screening, but so also should the indigenous wildlife in the reception area (Woodford 2001). This will also aid the health-risk analysis in wild animal translocation (CCWHC). Indigenous rodents should be trapped, ideally prior to the beaver release. These are then blood sampled and swabbed (oral, rectal and nasal), and faecal pellets collected and screened for potential pathogens. The appropriate permits/licences must be obtained, e.g. from the Home Office.

Health screening post release

The health of the beavers should continually be assessed following release. Regular logged field observation will allow continuous assessment. At the start of the release programme the beavers should ideally be caught annually. The same test and procedures described in the pre-release health screen should be performed again. Currently the SBT repeats blood, faecal and body-condition evaluation on a yearly basis during the 5-year scientific trial. If animals are caught in the interim, the type of collected biological samples and the depth of the examination of the beaver will depend on the circumstances of the capture. Whatever the circumstances, any capture opportunity should be used to evaluate an animal.

Post-release treatment

Provision should be made in case any beaver requires treatment post-release. A contact list should include veterinary practices/surgeons within easy reach for emergencies. Ideally beavers should be treated on location or close by, and released as soon as possible, if their conditions allows.

9.8 Mortality

In a study of a translocation of 277 North American beavers in Wyoming, 234 were actually released, 15 died during trapping, 13 died during transportation and 15 lactating females were re-released immediately after initial capture (McKinstry & Anderson 2002). 114 of the transported beavers were fitted with radio transmitters, of which 30% died within 180 days of release (mainly due to predation) and 51% emigrated from their release sites. Eight beavers died within 7 days of release, whereas survival estimates for all translocated beavers were 86 days on average, most dying within 0.5km of their release site. High predation and emigration rates for reintroduced beavers should be expected (Griffith *et al*. 1989) and planned for in any beaver translocation/reintroduction project (McKinstry & Anderson 2002). Predation, especially of adults, will not be a significant factor in many European countries, but other hazards, such as road traffic accidents may be more of an issue.

European studies on beaver translocation and reintroduction reveal mortality and emigration rates (14-36% and 23%) were highest in sub-adult animals (Zurowski & Kasperczyk 1988, Hartman 1994, Nolet and Baveco 1996). First-year mortality rates were 14% in Poland (Zurowski & Kasperczyk 1988), 17% in Germany (Heidecke 1986), 36% in Biesbosch and 73% in the Gelderse Poort (Netherlands, Nolet *et al.* 1997). In a Netherlands reintroduction (Nolet *et al.* 1997), 22 out of the 57 released animals were found dead (86% of these in the first year). Most of these deaths (50%) were caused by infectious diseases, namely yersiniosis and leptospirosis. Other causes of death included avian tuberculosis, pneumonia, sepsis from beaver bite wounds, old age (determined through tooth wear) and obstruction of the ileum by an internal radio transmitter. Nolet *et al*. (1997) suggest that the stress experienced by beavers from capture, captivity and release into an unknown environment, weakened their immune systems, thus increasing their susceptibility to disease.

Thirty percent of the deaths in the Netherland reintroduction were related to humans, such as road injuries (Nolet *et al*. 1997). In France 37% of beavers were killed in road traffic accidents (Esteve 1988), whilst in Switzerland this accounted for 16% of deaths (Stocker 1985). Common causes of death in wild beavers include age-related mortality, predation, disease, parasites, hunting, flooding events, traffic and infected wounds caused by territorial fighting (Piechocki 1977). Sixteen percent of beavers in Sweden died through intraspecific competition and territorial fighting (Stocker 1985). Extremely cold winters can cause beavers to starve (Rosell *et al*. 1996).

9.9 Managing Beaver Impacts

Public support is vital for any reintroduction programme. Although 100% public support will never be achieved, it should be encouraged through a well-conceived education programme. Pre-release public consultation should clearly lay out the benefits and costs associated with living with a beaver population, and note should be taken of the local public and stakeholder issues and concerns that surround the arrival and impact of the beavers in the local area. Beaver activity can significantly affect the surrounding environment, therefore potential conflict between beavers and humans should be managed to encourage support for the reintroduction and existence of this species, especially in areas where it has been absent for many years. Education and regular stakeholder liaison are important tools in this process. However, practical measures, such as deterrent fencing, management of dams and even removal of problem animals, may take place in order to reduce beaver impacts. One study on human-beaver conflicts found that most reported 'damage' had occurred repeatedly at the same sites (Czech & Lisle 2003). Non-lethal mitigation at established conflict sites can be a workable, efficient method to minimise conflict.

The majority of beaver impact is recorded as being within 20m from the water and most of this relates to feeding and damming activity (Hiedecke & Klenner-Fringes 1992, Elmeros *et al*. 2003). Therefore, buffer zones consisting of natural vegetation at least 20m around associated waterways and water bodies should contain most of the beaver activity and consequent impact. Valuable plantations and individual trees can be protected through appropriate fencing, tree guards and anti-game paint. The negative effects of dams can be managed through dam removal or through use of overflow pipes (Rosell *et al*. 2005). Beaver activity can often be easily identified through characteristic field signs, so compensation schemes could also be established. In time these may focus most effectively on land purchase to allow for the recreation of wetlands without further conflict of interest.

In some parts of Europe beaver populations have recovered so well, through the removal of hunting pressure, that population control is now employed. Harvest schemes, hunting licences and seasons exist in several countries, e.g. Norway, and careful codes of best practice are required to regulate wild populations (Nolet & Rosell 1998). It should be noted that modern beaver management can be controversial. Norway offers a potential model for beaver management once wild beaver numbers have recovered (see Parker & Rosell 2003, 2012). However, whether this is acceptable or not will greatly depend on the hunting ethic of the country in question. In time conservationists may have to make a case for encouraging responsible beaver hunting for animal management purposes. Until then problem individuals may need to be targeted and managed appropriately. Bavaria offers another option, involving mitigation in advance of any potential problems with a responsive system advocating a non-lethal approach. This is followed by controlled capture and culling by nature management organisations as a community-based system, if non-lethal methods fail or are deemed unsuitable.

Lessons from beaver management methods in Europe suggest landowners and stakeholders, who experience conflicts with beavers, must be provided with a quick and efficient method with which to deal with problems and be involved in the development of their management plans (Parker & Rosell 2003, 2012). Otherwise public tolerance and support for beavers and their reintroduction may decline (Bishop *et al.* 1992). The socio-economic benefits of beavers should also be recognised (Campbell *et al*. 2007) and encouraged, along with the development of methods to reduce human-beaver conflicts, in order to increase tolerance and acceptability (Parker & Rosell 2003).

Non-lethal control methods

An increasing number of wildlife organisations and governmental bodies, both in America and Europe, are seeking to employ non-lethal control methods on recovering beaver populations (Conover 2002). These include relocation, water-level control, chemical repellents, habitat alternation, protective fencing and fertility control (Hammerson 1994). However, it should be noted that some of these methods may still lead to welfare concerns and are often expensive (Conover 2002). Many problem beavers across central Europe have been live-trapped and relocated to establish new populations, if other non-lethal means prove futile (Schwab & Schmidbauer 2001, Halley & Rosell 2002). However, this approach is not viable in the long term as suitable habitats become saturated with beavers (Parker & Rosell 2003), e.g. now in Bavaria 700-900 beavers are removed and humanely killed annually (G Schwab, personal communication).

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