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What is the risk of introducing Echinococcus multilocularis to the UK wildlife population by importing European beavers which subsequently escape or are released?

Qualitative Risk Assessment

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Summary

Echinococcus multilocularis, a Taenid tapeworm, is one of the most pathogenic, parasitic zoonoses present in Central Europe. It is the causative agent of alveolar echinococcosis disease in humans. The typical transmission cycle in Europe is wildlife based. It involves red foxes (*Vuples vulpes*), and the non-native raccoon dog (*Nyctereutes procyonoides*) as the definitive (final) host. Domestic dogs can also serve as a definitive host; domestic cats although also definitive hosts seem not to play a significant role in the transmission cycle. Currently the United Kingdom (UK) is classified as *E. multilocularis* free.

In May 2010, a female Eurasian beaver (*Castor fiber*) held in captivity was found dead and upon further examination of the liver *E. multilocularis* was isolated (Barlow *et al*., 2011). The beaver had been imported from Bavaria, Germany in late 2006.

This risk assessment aims to address the risk posed by imported European beavers infected with *E. multilocularis* to UK indigenous wildlife. On the basis of the scientific evidence presented in this risk assessment with attenuating uncertainties, we consider that:

- The probability of a beaver being infected with *E. multilocularis* is **negligible** if sourced from a free area (e.g. Norway) and **low** if sourced from an endemic area (e.g. Bavaria).
- There is a **medium** probability the beaver will survive quarantine (if it applies) and be transferred to be held in captivity or subsequently released as part of a re-introduction programme.
- The probability an infected beaver will escape from captivity is **low to medium** but uncertain due to practical difficulties around legislation.
- The probability of an infected beaver dying and being scavenged by a definitive host (e.g. dog or fox) is highly uncertain as it depends on the manner of death and if the carcase is in a location accessible to foxes. However, **it cannot be considered negligible**.

- Once it has scavenged the beaver, the probability of a definitive host becoming infected depends upon whether the cysts remained infectious post-mortem. Assuming they are infectious at the time of consumption, the probability a definitive host becomes infected is **high**.
- Given a definitive host is infected, the probability of infection getting into subsequent wildlife including intermediate hosts is **uncertain but may be low to medium**.

Overall, the risk of importing *E. multilocularis* infected beavers from free areas and infection being established in indigenous UK wildlife is considered **negligible**.

Likelihood - For beavers imported from endemic areas, the likelihood of being infected and resulting in the establishment of *E. multilocularis* in wildlife is considered **low but this is uncertain** due to the factors involved (e.g. beaver escaping, a fox scavenging an infected dead beaver, infection established in intermediate host species).

Impact - The consequences of *E. multilocularis* being introduced into the definitive species (e.g. foxes) in the UK include an increased risk of the human population being exposed to the parasite. This is a high impact disease in affected humans, but the number of humans that would be infected is likely to be low.

There would also be a significant impact on the UK negotiations with the Commission and EU Member States regarding the PET travel scheme.

Risk management - To minimize the risk of *E. multilocularis* being introduced and establishing within UK wildlife, the only suitable risk mitigation measure would therefore be to source beavers from either captive bred populations in the UK or from countries which are currently free of *E. multilocularis*.

Background

In May 2010, a female Eurasian beaver (*Castor fiber*) kept in captivity was found dead in a pond in her enclosure. *Echinococcus multilocularis* was isolated upon further examination of the liver (Barlow *et al*., 2011). This was the first time the pathogen has been isolated from an imported captive European beaver in England. The beaver had been wild-caught in Bavaria, Germany in late 2006 and quarantined in England for 6-months in early 2007. The area in Bavaria from which the beaver was originally caught is under a managed cull program. In this area, the *E. multilocularis* prevalence in beavers could be approximately 2.5 to 5% (Barlow *et al.*, 2011).

Since 2001, at least 49 beavers have been imported from Germany (AHVLA Pet Travel, pers. Comm). There is a risk therefore, that *E. multilocularis* infected beavers have been imported into the United Kingdom (UK). Until recently beavers transported to the UK under the Rabies Order have required 6 months quarantine and no other control measures (e.g. vaccination, anthelmintic treatment). There is no statutory requirement to post-mortem a dead beaver originally imported into the UK either during quarantine or after it has been relocated.

Once in the UK, beavers are often held in locations that may allow them to have contact with wildlife species (e.g. in watercourses). Further, even if the beavers are kept in secure facilities, they are frequently reported to escape from their enclosures. There is therefore potential for disease transmission to a definitive host (e.g. fox) and subsequently to an intermediate host (e.g. common vole). In Scotland, Scottish Natural Heritage (SNH) estimate there are about 100 beavers living in the wild Tay catchment (http://www.scotland.gov.uk/News/Releases/2012/03/taybeavers16032012). These are likely to be mostly the progeny of escaped or deliberately released animals, a small number of which may originally have been imported from Bavaria.

At present, the UK is free of *E. multilocularis* as demonstrated by studies such as Smith *et al.,* (2003), for example. If the parasite became established, there are several ideal conditions for it to spread in animals and pose a risk to humans. These factors include: a large rural and urban fox population, large domestic dog population, the field vole (a potentially significant intermediate host) is the most abundant mammal species, and the bank vole (a less important host) is widely present in the country (Barlow, *pers. Comm*).

Hazard Identification

The hazard is identified as: *Echinococcus multilocularis*

Echinococcus multilocularis, a Taenid tapeworm, is one of the most pathogenic, parasitic zoonoses present in Central Europe (Torgerson & Budke, 2003). It is the causative agent of alveolar echinococcosis disease. The typical transmission cycle in Europe is wildlife based. It involves red foxes (*Vulpes vulpes*), and the non-native raccoon dog (*Nyctereutes procyonoides*) as the definitive (final) host. Domestic dogs can also serve as a definitive host; domestic cats although also definitive hosts seem not to play a significant role in the transmission cycle even if they are a risk for their owners or veterinarians (OIE Terrestrial Manual, 2012, Petavy et al. 2000).

The adult tapeworms live in the small intestines of the definitive hosts and parasite proglottids and eggs are shed in the faeces. Intermediate hosts (e.g. the common or field vole (*Microtus agrestis*)) ingest the eggs, which release an oncosphere and develop into larvae. These larvae form vesiculated small cysts in internal organs, mainly the liver and lungs but also the brain. Definitive hosts prey on these infected intermediate hosts and the adult worm stage of the parasite develops thereby completing the sylvatic cycle. Principle intermediate hosts in Europe include the common vole (*Microtus arvalis*), the water vole *(Arvicola terresteris*), and the bank vole (*Myodes glareolus*). Other intermediate hosts include muskrats, squirrels, and beavers (MacManus 2010).

Humans may become accidentally infected by ingesting eggs from the contaminated environment. The eggs again release oncospheres which develop into larvae and form cysts. Pathogenic cysts form around the tapeworm segments and lodge in the liver, lung and other organs including the brain and these are very difficult to treat and once infected, the prognosis is poor (MacManus, 2010).

A summary of the life-cycle is illustrated in Figure 1.

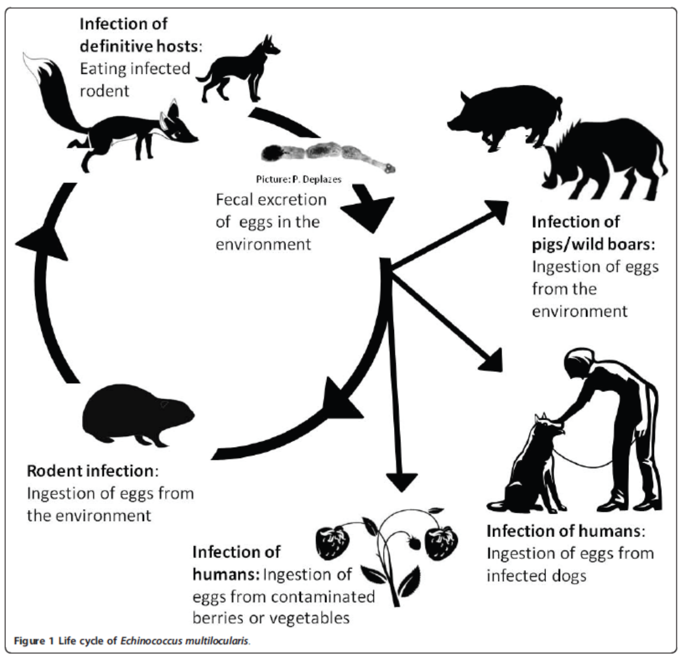


Figure 1: Life cycle of *Echinococcus multilocularis* (taken from Wahlstrom *et al*., 2011)

The adult tapeworm survives for about 100 days in the definitive host and the time between ingestion of an infected intermediate host and the development into the adult stage in the final host is approximately 4-5 weeks.

In GB, *E. multilocularis* is listed in the Specified Animal Pathogens Order which only permits possession of the parasite or carriers of the parasite, including infected animals, in premises that have been licensed under the Order.

Risk Question

This risk assessment considers the risk posed by imported beavers (non-native species) infected with *Echinococcus multilocularis* to UK indigenous wildlife and humans. The specific risk question addressed is:

What is the risk of introducing *Echinococcus multilocularis* to the UK wildlife population by importing European beavers which subsequently escape or are released?

To answer the above question, the risk assessment follows the OIE framework of release (or entry), exposure and consequence assessment. Specifically, it is divided into three key areas:

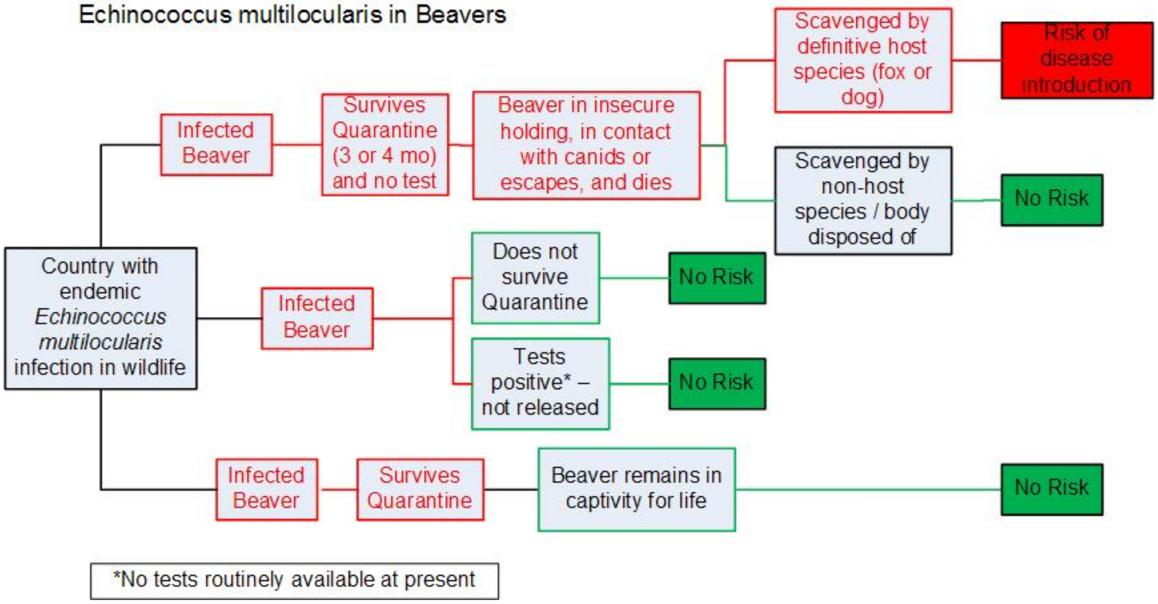
1. What is the probability of introducing an *E. multilocularis* infected beaver into the UK from current exporting countries?

2. What is the probability of an infected beaver escaping its enclosure or "release" site and/or contacting susceptible wildlife species?

3. What is the probability of a wildlife host (e.g. foxes) becoming infected given contact with an infected beaver and the subsequent risk of infection in wildlife and/or humans?

Figure 2 below describes the possible routes of introduction through trade in beavers for re-introduction of *E. multilocularis* into the UK. The risk arises from beavers which are sourced from a country with *E. multilocularis* in wildlife. Once in the UK, the risk arises from one of these beaver, being infected, escaping and being scavenged by a suitable native canid host (e.g. fox or dog).

Fig 2: Possible routes of introduction of Echinococcus multilocularis in Beavers



Although one route in Figure 2 currently suggests that a positive test would result in the animal not being released from quarantine and therefore pose no risk, there is no test for *E. multilocularis* at present which is currently used for beavers. Additionally it should be noted that beavers may die in captivity but the holding is not secure, therefore the carcass may still be scavenged.

As a recommendation for future action to lower the risk of introduction further, if a suitable test becomes available, beavers that test positive should be destroyed under SAPO legislation unless held in a SAPO licensed facility.

Risk assessment

Terminology related to the assessed level of risk

For the purpose of the risk assessment, the following terminology will apply (OIE, 2004; EFSA, 2006):

Negligible	So rare that it does not merit to be considered
Very low	Very rare but cannot be excluded

Low	Rare but does occur
Medium	Occurs regularly
High	Occurs very often
Very high	Events occur almost certainly

Entry assessment

Sourcing and numbers of beavers imported into the UK

Beavers from the European Union (EU) Member States can be imported into the UK via one of three main routes:

1. under the Balai Directive (Council Directive 92/65/EEC)
2. under the Rabies (Importation of Dogs, Cats and other Mammals) Order 1974 requiring quarantine and importation with a licence
3. direct importation to a licensed zoo or wildlife park

Trade between Member States of beavers born in captivity must meet the requirements of Council Directive 92/65/EEC which lays down rules for movements on non-livestock animals. The Directive lays down conditions for movements of such animals and requirements to prevent the spread of certain diseases which are laid down in Annexes A and B of the Directive. The Directive prevents EU Member States prohibiting trade for animal health reasons unless these are laid down in the Directive. The Directive does not include any provisions for *E. multilocularis* so movement restrictions on these grounds are prohibited. Where beavers cannot meet the Balai directive, they move under licence and may have to undergo rabies quarantine.

For this risk assessment, the historical evidence for the number of imported beavers has been considered to ascertain from where beavers have been sourced, the risk that the previously imported beavers pose in terms of importing *E. multilocularis* and the trends (if any) in importing beavers (e.g. increasing over time or decreasing over time). This will be used to inform any potential future risk posed from beaver importations.

Balai Directive

Since April 2009, under the Balai Directive, there have been 6 beavers imported into England from Nurnburg Zoo, Germany and are reported within TRACES. In addition, in 2008, 2 beavers from Neumunster Zoo, Germany were imported into England (D. Gow, *pers. comm*., 2012). Of these 8 beavers, 4 still reside in Kent, 1 was for a private landowner (but subsequently escaped and died), 1 died and 1 was taken to Beaver Water World, Kent (D. Gow, *pers. comm*., 2012).

Under the Balai Directive, rabies susceptible species including beavers can be commercially imported from an EU Member State without the requirement for quarantine provided they meet specific requirements. These include: that the animal was born in the holding of origin and remained there since birth, they do not show any obvious signs of disease, they do not originate from a holding subject to animal health restrictions, and they are accompanied with an owner's certificate confirming the preceding conditions. Animals under the Balai Directive are captive-bred.

Animals imported under the Balai Directive should be recorded within the EU Trade Control and Expert System (TRACES), an on-line system for recording animal movements into and within the EU. The database provides information on the taxonomic group being imported, the number of consignments entering the country, the number of animals within a consignment, the origin of the consignment, the consignee address, method of transport, date of departure, and age and gender of the animals. For beavers the lowest taxonomic detail in the database is 'Rodentia' and so it cannot be ascertained for certainty that the imported animal is a beaver or other rodent species.

Rabies quarantine or direct import to licensed zoo or wildlife park

Since the end of 2005, the Specialist Serve Centre for Imports at the Animal Health and Veterinary Laboratories Agency (AHVLA), have been responsible for issuing licenses for lagomorphs or rodents going to a zoo or wildlife premise authorised under the Rabies Order (RLZ license) and also for animals that do not meet the requirements under the Balai Directive and need to enter quarantine (RMZ license). Prior to the end of 2005, Defra were responsible for recording and handling the licenses. The license does not include details of whether the animal is captive-bred or a wild animal.

Since 2001, there have been 49 beavers imported from Germany and 39 beavers imported from Norway (Pet Travel, AHVLA). The data is summarised in Table 1.

Table 1: Summary of the licenses issued under the Rabies Order and/or enter quarantine (Pet Travel, AHVLA)

Year	Country of origin	Number of consignments	Total number of animals
2001	Norway	1	10
	Germany	1	4
2002	Germany	1	10
2004	Germany	1	2
2006	Germany	1	14
2008	Norway	2	25
	Germany	3	17
2010	Germany	1	2
	Norway	2	4

The four beavers imported from Norway in 2010 are recorded in TRACES and originated from Telemark. Since September 2010, there have been no beavers imported under the Rabies Order and licensed for importation.

Natural England and Scottish Heritage license

Under the Wildlife and Countryside Act 1981 and the Habitats Regulations 1994, Natural England and Scottish Natural Heritage issues licenses to individuals for possession of wild caught beavers and for beavers being released into the wild.

In 2008, as part of a drive to establish the beaver back into Scotland, Scottish Natural Heritage issued a license to release beavers into Knapdale. It was aimed to follow the principles of the International Union for Conservation of Nature (IUCN) which states, “the source population should ideally be closely related genetically to the original native stock" (Halley, 2010). To meet this requirement, it was observed beavers that historically resided in Scotland were similar to the Western Evolutionary Significant Units (ESA) which includes the *C. f. fiber* from Telemark, Norway. The Bavarian stock is a mix of various European stocks including Telemark, Propet and Rhone (Halley, 2010). For this reason, the beavers released as part of the Knapdale study, were sourced from Telemark, Norway.

Natural England has issued 9 licenses since July 2007 for either possession or release into a fenced enclosure. Each license covers a 5 year period and then a renewal is required. The 9 licenses cover up to a maximum of 43 beavers all sourced from Bavaria for possession and/or release in England. In addition, Defra provided a license in 2003 for possession of beavers from Poland.

Overall conclusions

Given the publicity surrounding the current campaigns in England, Scotland and Wales to bring back beavers to the countryside, there are several reports of imported beavers that can be found using standard internet search engines (e.g. Google). Accumulating the information from the above reports and information provided by Derek Gow Consultancy and the AHVLA Wildlife Group, it can be ascertained that Eurasian wild-caught beavers predominantly originate from Germany, particularly Bavaria, and Norway and, historically, also from Poland. These beavers are mainly destined for wildlife parks, private estates and landowners. A summary of the known beavers imported into the UK between 1997 and 2011 from all available data sources is provided in Table 2.

Table 2: Summary of the beavers imported into the UK between 1997 and 2011

Year	Month	Origin	Destination	Quantity
1997		Popielno, Poland	English Zoos	4[D]
2000		Popielno, Poland	Scotland	8
2001	March	Telemark, Norway	Ham Fen, Kent & Scotland[++]	10[D]
	September	Germany		4
2002	November	Germany		10
2004	June	Germany		2
2005		Bavaria, Germany	Gloucestershire	~12
2006	December	Germany	Devon, Scotland, Lancashire,	14

			Kent	
2008	January	Germany		6
	February	Norway	RZSS+	8
	April	Germany		7
	November	Telemark, Norway	Knapdale**	17
	December	Germany		4
2010	January	Germany		2
	April	Telemark, Norway*	Edinburgh Zoo	2
	September	Telemark, Norway*	Edinburgh Zoo	2
	December	Nurnberg, Germany	Devon	3
2011	December	Nurnberg, Germany	Devon	3

+2 families for use by Royal Zoological Society of Scotland (RZSS) & Scottish Wildlife for Edinburgh Zoo and Highland Wildlife Park stocks

++A number died in quarantine; only 6 animals released into Ham Fen Nature Reserve, Kent and a pair went to Perthshire, Scotland

*TRACES database

**4 separate families – quarantined in Devon

D Deceased (where known)

In summary, the beavers imported from Bavaria over the years are held in private estates in Scotland, and various wildlife and nature parks/reserves in England including Cotswold Wildlife Park, Escot House, WWT Martin Mere, Paradise Wildlife Park, Ham Fen, Beaver Water World, and Upcott Grange (Gow, *pers. Comm.*).

Prevalence of *Echinococcus multilocularis* in wildlife and the probability of a beaver selected for import is infected

At present, the known geographic range of the parasite in west and central Europe includes regions in Austria, Switzerland, France, Germany, Liechtenstein, Luxembourg, Belgium, The Netherlands, Poland, Czech Republic, Slovak Republic and Denmark (Vervaeke *et al*., 2006). However, there is a trend towards increasing parasite density and subsequent range in the last decade in central and parts of west Europe. Current highly endemic areas include parts of Germany, France and Switzerland (Torgerson &

Craig, 2009 & Torgerson et al. 2010) (see Figure 3). The sporadic nature of infection in countries such as Denmark is endorsed by the rarity of reports. The latest Danish disease report followed surveillance of 300 foxes and 80 raccoon dog, when one fox tested positive. This was the first report in 12 years from Denmark (OIE, 2012). Sweden also has reported cases recently following surveillance in foxes as part of requirements for their (now lapsed) disease freedom status (OIE, 2011).

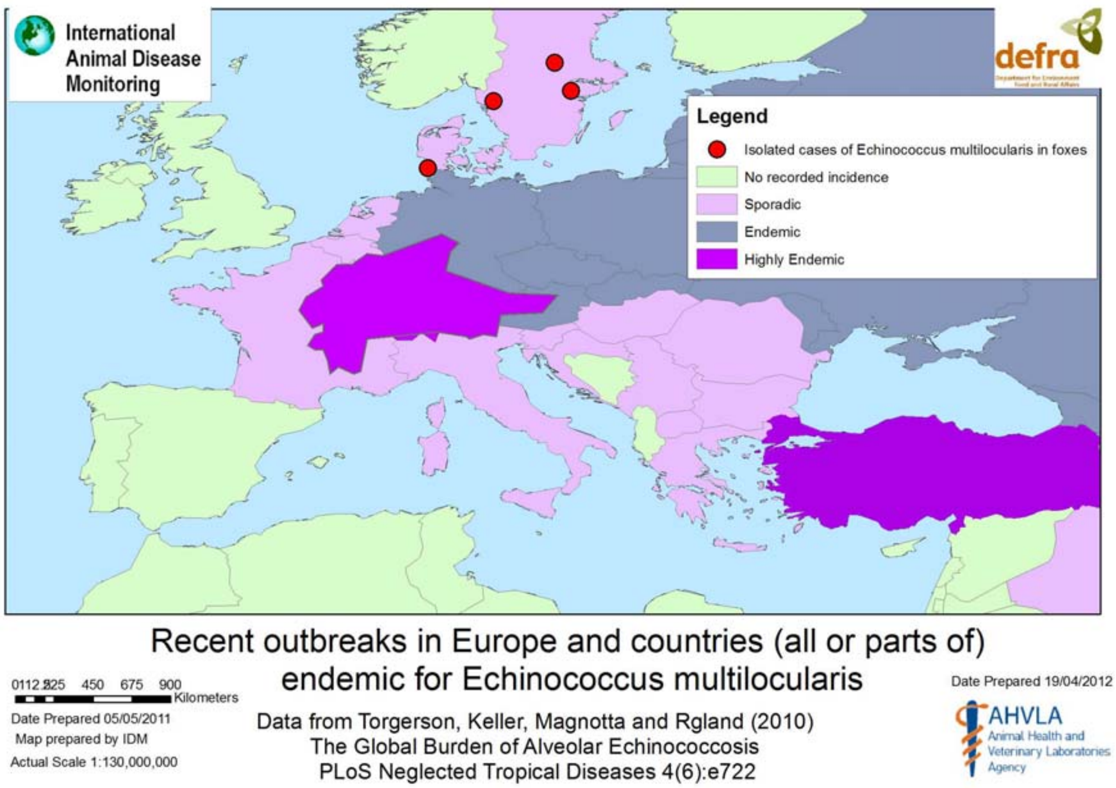


Figure 3: Disease distribution map of *Echinococcus multilocularis* in Europe including recent reports in foxes (from Torgerson, *et al.* (2010))

The main definitive reservoir for European *E. multilocularis* is the red fox (*Vulpes vulpes*). Accordingly, predominantly studies have been undertaken studying the prevalence in this host species and there is less information available on other susceptible intermediate species including beavers. However, as infected foxes are the main source of environmental contamination with *E. multilocularis* eggs, a high *E. multilocularis* prevalence in foxes may lead to an increase in infected intermediate hosts including unusual hosts such as beavers (Dyanchenko *et al*., 2008; Janovsky *et al,* 2002). Therefore, it is of direct relevance to consider the prevalence of *E. multilocularis* in foxes (or wildlife generally) when estimating the probability of a wild beaver selected for import being infected with the parasite.

It is important to note, however, that in estimating the probability of a beaver being infected, although serological tests could be used (P. Craig, *Personal communication)* and laparoscopic examination has been described (Pizzi at al., 2012) there is currently no accepted validated ante-mortem diagnostic test for *E. multilocularis* in living beavers (Campbell-Palmer *et al*., 2012).

As discussed in Section 6.4.1, Eurasian beavers are currently imported into the UK from Germany and Norway and, historically, from Poland. The assessment, therefore, focuses on the prevalence of *E. multilocularis* in these countries. However, a brief summary of the *E. multilocularis* prevalence in foxes (wildlife) and beavers, where available, in other European countries is also provided given that there could be free movement of beavers from any EU member state into the UK. Beavers are currently distributed in all countries within their former natural range in Europe (e.g. Austria, Belarus, Belgium, Estonia, Finland, France, Germany, Hungary, Lithuania, Netherlands, Norway, Poland, Russia, Sweden, Switzerland, Ukraine) except for the UK, Portugal, Italy and the south Balkans (Halley & Rosell, 2003).

Prevalence in Germany

The area in North Bavaria from which beavers imported into UK have been caught is under a managed cull program. Of 400 culled beavers from the area, 10 to 20 had liver lesions, which could be consistent with *E. multilocularis* (Barlow *et al*., 2011). This would yield an *E. multilocularis* prevalence of approximately 2.5-5%. These liver lesions were not tested for *E. multilocularis* or seen by a veterinary pathologist so there is some degree of uncertainty associated with this observation but suspicious liver lesions assumed to be caused by the parasite do seem to continue to be found in up to 1 in 20 beavers culled in this area (G Schwab, *personal communication*).

The Bavarian State Authority for Health and Food safety tested 97 foxes for *E. multilocularis* infection in 2009 (LGL, 2009). The parasite was detected in 21 (22%) of the foxes. In a larger sample in 2007, 32% [27.5-35.5] of the 410 foxes tested were positive for *E. multilocularis* (Conraths, *pers. comm.*.). The prevalence of *E. multilocularis* in foxes in Bavaria (51.1%) is higher than other areas of Germany including Lower Saxony (11.4%), and Stuttgart (16.8%) (EFSA, 2006). These prevalence levels are similar to those observed in a survey of foxes from October 2002 to March 2003 in which 268 foxes were examined using an intestinal sampling technique in Starnberg, Southern Bavaria (Konig *et al*., 2005). Overall, the prevalence was 51% which was an increase in previous studies from 1989 to 2001 when the prevalence was

32% (Konig *et al*., 2005). Similar increases in prevalence have also been observed in Western Bavaria where the prevalence increased from 35% to 80% in a similar time period (Konig *et al*., 2005).

In Thuringia, central Germany, between 1990 and 2009, the prevalence of *E. multilocularis* in foxes, specifically, varied between 11 and 42% annually (Staubach *et al*., 2011). Of note, is that during the period of study, there was substantial expansion of the area where *E. multilocularis* infections occurred in foxes.

Prevalence in Norway

Mainland Norway is officially free of *E. multilocularis.* Between 2002 and 2009, 1633 red foxes have been examined for *E. multilocularis* during the licensed hunting periods from July to April of which all have been negative (Davidson *et al*., 2009). This low estimated prevalence was further assessed in a study examining surveillance data from five animal species (red fox, racoon dog, domestic pig, wild boar and voles and lemmings) in which Wahlstrom *et* al., (2011) estimated the probability that mainland Norway is free of *E. multilocularis* to be 0.98 [0.95-0.99].

Prevalence in Poland

The northern regions have higher prevalence of *E. multilocularis* in foxes (2.2% to 11.8%) than the southern parts of the country (0.4%) (WHO, 2001). In an EFSA risk assessment, data from several studies is presented on the prevalence of *E. multilocularis* in foxes in different regions of Poland and highlights the variation observed across the country. Specifically, it is noted that the single-point prevalence is 0.3% in southwest Poland, 7.9% in Pomerania, 39.6% in Mazuria and 36.8% in Carpathians (EFSA, 2006). In Poland, the raccoon dog (*Nyctereutes procyonoides*) is an additional definitive host that is highly susceptible to infection (EFSA, 2006).

Prevalence in other European countries

- **Austria** – *E. multilocularis* has been isolated from a beaver in Austria (Cronstedt-fell *et al*., 2010 cited in Barlow *et al*., 2011).
- **Belgium** – Between 1996 and 1999, 237 foxes in Northern Belgium were examined for *E. multilocularis* of which 4 (1.7%) were found to harbour high parasitic burdens (Vervaeke *et al*., 2003). In annual surveys in Southern Belgium, the prevalence varied from 23.7% (1998) to 8.6 (2001) (Vervaek *et al*., 2006). The data from these surveys was analysed within a spatial model from which it was concluded that there was a north western spread of *E. multilocularis* and there was a continuous distribution in the region bordering The Netherlands (Vervaek *et al*., 2006).

- **France** – Guislain *et al*. (2008) conducted a survey of dead foxes in the Ardennes, north-eastern France and observed the prevalence reached 53% (45-61%).
- **Hungary** – In early 2000's, *E. multilocularis* was isolated from foxes in Hungary for the first time (Streter *et al*., 2003). Of 100 foxes examined, 5 adults were found to be infected. The foxes originate from an area 60-120 km from the nearest known endemic area in Slovakia.
- **Italy** – Previously considered free of the parasite, *E. multilocularis* was isolated for the first time in Northern Italy in 2001 in red foxes (Calderini *et al*., 2009). Recent studies in Central Italy have failed to identify the parasite in the fox population (Calderini *et al*., 2009).
- **Switzerland** – The first report of *E. multilocularis* in a European beaver was in August 2000 from a male beaver in the Canton of Aargau (Janovsky *et al,* 2002). Foxes from 21 of 26 Cantons in Switzerland had varying prevalence levels of *E. multilocularis* from 2% to 53%.
- **Sweden** - Sweden has been considered free of *E. multilocularis* (Wahlstrom *et* al., 2011) until recently when the pathogen was isolated from two foxes less than 65km from the Norwegian border (Lind *et al*., 2011). In February 2011, *E. multilocularis* was detected in a fox in south-west of Sweden which had been shot in December 2010. A second fox from the same area was detected in March 2011. This latter fox was identified as part of an intensified screening of foxes in which 3189 foxes were submitted.
- **Slovakia** – *E. multilocularis* was first detected in Slovakia in 1999 and is now present in all districts of the country, with an average prevalence reaching 29.4% (Antolova *et al*., 2009). In 2005, 37.4% of foxes (*n=289*) were reported to be infected (EFSA, 2006).

Overall conclusions

In countries in which *E. multilocularis* is endemic, the long-term equilibrium prevalence in foxes is up to 40% (Torgerson & Craig, 2009). In isolated areas, the prevalence can be as high as 80% (Konig *et al*., 2005). An increase in infected foxes can lead to *E. multilocularis* being isolated from unusual intermediate hosts including beavers due to heavy environmental contamination with *E. multilocularis* eggs as has been observed in Switzerland and Austria (Janovsky *et al*., 2002; Barlow *et al*., 2011).

The probability a wild-caught beaver selected for import into the UK is infected with *E. multilocularis* varies according to the country of origin. For example, the probability of importing infected beavers from Norway (or other *E. multilocularis* free country) is considered **negligible**. However, with the recent isolation of the pathogen in foxes near the Norwegian border, if *E. multilocularis* becomes established in Norway (or other free country) then the risk a beaver is infected will change accordingly.

A beaver imported from Bavaria (or other endemic area) poses a **low** risk of being infected with associated uncertainty.

Probability infected beaver survives journey and quarantine process without being detected

Wild-caught beavers that are licensed to enter the UK under the Rabies Order are required to undergo quarantine (see previous Balai exceptions for captive-bred animals). This quarantine process is specifically aimed at detecting rabies in rabies susceptible species and not identifying *E. multilocularis* and other diseases, per se. Screening for the cyst stage of *E. multilocularis* in intermediate hosts including beavers is still under development and is not routinely undertaken during quarantine. Therefore, there is no specific *E. multilocularis* testing conducted prior or during quarantine. An animal has to be designated visually healthy upon release from quarantine and checked by an Official Veterinarian. However, there is no legal requirement to conduct a post-mortem examination of animals that die either during or following quarantine beyond excluding suspicion of rabies.

Upon arriving in quarantine, there is a probability that the animal will not survive the quarantine period, which until recently was 6 months and is currently 4 months in England / Wales and 3 months in Scotland, although this may be reduced or waived where there is negligible risk of the introduction of rabies. This variable survival rate has been observed in the beaver populations that have entered quarantine in England over the years. For example, of the 31 animals that have been quarantined in the Wildwood Centre, Kent, 5 died in quarantine of various causes, 3 died shortly after the completion of rabies quarantine and an additional 3 were euthanized on veterinary advice (Gow, 2002). Therefore, of the 31 animals entering quarantine, 20 animals (65%) survived the quarantine process. The quarantined beavers had problems with tooth malocclusion, enteritic bowel infection, pseudo tuberculosis, terminal ascarid infestations and blow fly strike; many of these conditions can be fatal (Gow, 2002). All of the beavers that died in quarantine at Wildwood Centre had a thorough post mortem.

The probability a beaver survives quarantine and is subsequently released is **medium** based on the experience in the Wildwood Centre and this may be only in part influenced by the new quarantine rules, but not enough to increase the likelihood level. It is assumed that infection with *E. multilocularis* does not impact upon the fitness of the animal and therefore its survival in quarantine. This is based on the finding that infected pregnant and lactating voles have been found with massive infections indicating infection does not necessarily shorten the intermediate host life span significantly (EFSA, 2006).

Exposure assessment

Probability of infected beaver escaping original release site

“Once in captivity, beavers can be notorious escape artists, but even those successfully confined may not be living in isolation” (Campbell-Palmer *et al.*, 2012). This statement is supported by several reports of beavers escaping from their enclosed release sites in England and Scotland. As early as 2001, for example, it is possible that a family of beavers escaped from a facility in Kent. There are reports of four or five beavers present near Sandwich in Kent (D. Gow, *pers. Comm.*). Later, in the summer of 2006, a female and male escaped after a grille was dislodged by storm water (Fair, 2010). The female was quickly caught but the male reached a tributary just west of Oxford before being caught (Fair, 2010).

In Scotland in 2007, a female beaver broke loose from the grounds of Bamff estate and may have been forced out by the other resident beavers in the private estate. In October 2008, a male and two female Eurasian beavers escaped from Upcott Grange Centre, Lifton in Dartmoor (Morris, 2008). During a period of heavy rain, the electric fence surrounding their enclosure short-circuited allowing the beavers to creep though (Morris, 2008). The females were quickly recovered while the male lived for 2 months in Gunnislake, Cornwall approximately 20 miles away from its original site. The escaped male was an imported beaver from Germany.

There are likely to be other escaped beavers (e.g. in South-west and Cotswolds) including deliberately released beavers as has been suspected in the original of the free-living Tayside beavers. The latter are thought to be captive bred descendants of Polish and Bavarian beavers (Barlow, *pers. Comm.*.). There are free-living beaver populations in England too which are thought to be escaped individuals and/or their progeny. These populations reside in the following locations: Tavy, Devon, Bristol, Avon, Stour (near Canterbury) (Gow, *pers. Comm*.). Recently an escaped beaver has been recaptured from a farmyard slurry pit in Devon (BBC, 2012). The origin of the beaver is not known.

As the beavers in the UK are wild animals, they do not necessarily respect the boundaries in which they are placed. It is evident that beavers are capable of escaping their release sites, particularly in favourable conditions (e.g. flooding of facilities). It is estimated that there is a **low** to **medium** probability of a beaver escaping but there is uncertainty associated with this estimate.

Probability of infected beaver being scavenged by a primary host species

The main primary host of *E. multilocularis* is the red fox (*Vulpes vulpes*) but domestic dogs may also serve as primary hosts. The principle route by which such a species may become infected is to scavenge on a recently dead infected intermediate host and in the process, ingest cysts, resulting in an infestation of tapeworms in the canid intestine. Alternatively, a fox may directly kill and scavenge an infected host. The latter route probably occurs less frequently but has been witnessed. In Norway, for example, a red fox was observed killing a 2-month old beaver kit and fed on the carcass (Kile *et al*., 1996). The main organs including the liver had been consumed. The authors considered that this was unusual fox behaviour and only young beavers are likely to be susceptible to fox attacks whilst feeding on land as older animals have better developed escape behaviour unless affected by ill health (Kile *et al*., 1996).

Beavers spend a significant amount of their time in or near water and rarely forage more than 100 metres away from the water's edge (Gaywood *et al*., 2008). It is likely, therefore, that beavers will die near their abode either in their lodges or underwater. Those that die in captivity in an enclosure may be collected by their owners upon their death. Alternatively, some beavers may die in the open in the wild, or within the semi-wild in large enclosures, and may be accessible to definitive hosts such as foxes and dogs. The latter will be more likely for those beavers that have escaped and are free-living in the wild. Anecdotally, a beaver carcass was found and reported by members of the public at Den of Airlie in late April 2011.

The red fox population density in the UK varies from 40 per km^2 (rural Scotland) to 1.17 per km^2 (Wales) with approximately 30 foxes per km^2 in urban areas (IUCN Red list, 2011). Therefore, it is possible given the current fox population density a fox could discover a dead beaver in a semi-wild or wild area and feed on the carcass. There is considerable uncertainty associated with the probability of this occurring but it cannot be considered to be negligible.

Consequence assessment

Probability of primary host being infected by scavenging infected beaver

Given that foxes in UK are currently free of *E. multilocularis*, the population has had no previous exposure to the parasite and would be highly susceptible to infection (Torgerson & Craig, 2009). In order to become infected after scavenging an infected beaver, the cysts must still be infectious and there is likely to be a minimum 'infectious dose' (i.e. minimum number of cysts required to initiate infection). The duration of time tapeworm cysts remain infectious after the death of a host is not known precisely but is thought to be about 7-10 days, depending upon environmental temperatures. A study by Jensen *et al.* (1984) found cysts remaining infectious in dead cotton rats as long as 64 days at 0°C or 5°C, but at 10°C only 8% of infectious cysts survived in the carcasses.

There are no data on the number of infectious cysts in an infected beaver. However, research on voles in Japan suggests that animals infected by *E. multilocularis* become increasingly infectious over time following initial infection of eggs as they develop increasing number of infectious protoscoleces (i.e. larval stages) in their bodies (Nishina & Ishikawa, 2008). One vole, for example, had 37 million protoscoleces 142 days after infection. Assuming that a similar pattern of infection occurs in beavers as in voles, both intermediate hosts, there would be a large number of infectious protoscoleces in the beaver at the time of its death.

In the theoretical scenario that a previously uninfected fox scavenged a recently dead infected beaver and ingested the parasite, it is **highly likely** that the tapeworm would develop in the fox with the subsequent production of significant numbers of eggs. Dogs and foxes are particularly effective producers of large numbers of tapeworm eggs after infection. Foxes, specifically, may harbour between 2 and 73,380 worms (Guislain *et al*., 2008). This production of eggs would be approximately 28 days after ingestion of the protoscoleces (larvae) (EFSA, 2006). Overall, therefore, the probability of a definitive host being infected by *E. multilocularis* if it eats the carcass of an infected beaver (intermediate host), is considered **high**.

Subsequent infection in wildlife

An infected fox or dog can excrete large quantities of eggs in their faeces (as high as 75,000 to 100,000 eggs per gram of faeces) contaminating their local environment and serving as an infection source for intermediate hosts, thereby completing the sylvatic cycle of *E. multilocularis* (Bodker, et al. 2006; Torgerson & Craig, 2009). A definitive host can be infected for up to 100 days and produce eggs every day during this period. There are a number of suitable intermediate hosts in the UK including (Janovsky *et al*., 2002):

- bank vole (*Myodes* (*Clethrionomys) glareolus*)
- field vole *(Microtus agrestis*)
- common field vole (*Microtus arvalis*)
- water vole *(Arvicola terresteris*)

The bank vole is common and widespread whilst the field vole is the most common mammal in the UK with a population of 75 million (Harris *et al*., 1995). Importantly, these species make up a portion of fox's diets and could assist in perpetuating *E. multilocularis* infection in wildlife. In a study in France, for example, voles (*Microtus sp*) were present in one-third of the fox faeces sampled (Guislain *et al*., 2008). The bank vole is considered a less important host. Water voles are rare in the UK due to habitat loss and predation by American mink (*Mustela vison*) (Barlow, *pers. comm.*, 2012).

Studies have been conducted on the prevalence of *E. multilocularis* in intermediate hosts in endemic areas. For example, in Wallonia, Belgium, between January 2003 and December 2004, only one common vole (*M.arvalis*) (0.11%) and one bank vole (*Clethrionomys glareolus*) (4.3%) was found infected (Hanosset *et al*., 2008). However, the muskrat (*Ondatra zibethicus*) was identified as a good intermediate host with 11.18% (of 1718) animals infected and further a positive correlation was found between the prevalence in foxes and in muskrats (Hanosset *et al*., 2008). In an earlier study in Switzerland, each spring from 1993 to 1998, water voles (*A. terrestris*) and common voles (*M. arvalisi)* were trapped and examined for *E. multilocularis* (Gottstein *et al*., 2001). It was observed that, on average, 14% of water voles and 19% of common voles were positive by microscopy and, if required, by immunohistochemistry (Gottstein *et al*., 2001).

Rodents become infected at varying levels in areas where *E. multilocularis* is present in the resident fox population and this is positively correlated with the prevalence of the parasite in foxes. The probability of an intermediate host becoming infected is dependent, therefore, on the density of infection in the primary host species and the overlap in the territory of the primary species and intermediate host. Given a single infected fox sheds eggs into the environment, the probability of an intermediate host becoming infected is likely to be **low to medium** with associated uncertainty**.** However, as this process is critical for the life cycle of *E. multilocularis*, the consequences are high as infection in the intermediate host population leads to perpetuation of the lifecycle.

Subsequent consequences of *E. multilocularis* in UK

Once established in foxes, the projected long-term equilibrium of *E. multilocularis* prevalence in red foxes is approximately 40% as observed in endemic countries in Europe (Torgerson & Craig, 2009). This is in the absence of targeted control measures. Intermediate hosts may become infected given the environmental contamination from eggs excreted in fox faeces but typically have a lower equilibrium prevalence of around 6.5% in endemic areas. Another direct consequence of the disease in foxes is infection in domestic dogs which may become a source of incidental infection in humans. Indeed, in Germany, 0.24% of dog samples (n=17894) were positive for *E. multilocularis* with a significantly higher prevalence observed in Southern Germany (0.35%) compared to Northern Germany (0.13%) (Dyachenko *et al*., 2008).

In terms of alveolar echinococcosis (AE) infection in humans, it typically is 10 to 12 year later than the isolation in wildlife due to the long incubation period. Indeed, in Reuben Island in northern Japan, the first cases of AE were diagnosed 12 years after the introduction of red foxes from Russia (Torgerson & Craig, 2009). In endemic countries, the occurrence of AE in Europe is low with an estimated annual incidence of 0.02 to 1.4 cases per 100,000 inhabitants for endemic regions of Central Europe (Eckert & Deplazes, 1999). However, the number of human cases of AE is increasing in Switzerland in parallel with increasing fox populations (Torgerson & Craig, 2009). This may be due to the urbanization of the *E. multilocularis* cycle thereby increasing the risk of infection in the human population (Schweiger *et al*., 2007). It could be expected that a similar level of AE as observed in endemic European countries could be expected in the British population assuming the same equilibrium prevalence in foxes (Torgerson & Craig, 2009). AE is a serious disease and prognosis in humans is good only where treatment is available, but this treatment is expensive and often life-long.

Control and risk management options

The most important risk management measure is sourcing the wild caught beaver from a non-infected area, such as the UK (as second generation beavers from captive populations) or Norway, rather than a country with high endemicity, such as Germany, France or other areas of Northern Europe.

A second generation captive bred beaver even from a highly endemic country might be considered a lower risk if it has been held captive in Balai approved premises since birth, if these premises are subject to high levels of biosecurity. However it is difficult to prevent beavers being exposed to eggs shed by foxes in endemic areas despite secure enclosures, so this cannot be a reliable risk management measure.

There are no reliable tests at present which would allow us to check consignments of beavers from endemic areas. However, the use of serology and/or laparoscopy would be a useful indicator for the potential presence of *E. multilocularis* in an imported beaver.

The need for careful disposal of all potentially infected beaver carcasses must be made clear to keepers.

Conclusions

The risk of *E. multilocularis* being imported and introduced into a definitive host species (e.g. fox or dog) via beavers is dependent upon the probability an infected beaver is selected for import, it survives quarantine, it dies in a location accessible to a host species and is scavenged by a host species resulting in infection. Beavers infected with *E. multilocularis* cannot transmit the infection directly to other beavers, wildlife or the environment. Onward transmission can only occur by a definitive host (dog or fox) scavenging the infected beaver's organs.

Historically, beavers have been imported from two main areas namely, those from endemic *E. multilocularis* countries (e.g. Bavaria, Germany) and those from free countries (e.g. Norway). For imports from *E.* multilocularis free countries, the risk of importing infected beavers and infection being established in indigenous UK wildlife is considered **negligible**. For beavers imported from endemic areas, the risk of being infected and resulting in the establishment of *E. multilocularis* in wildlife is considered **low but is uncertain** due to the factors involved (e.g. beaver escaping, a fox scavenging an infected dead beaver, infection established in intermediate host species). The consequences of *E. multilocularis* being introduced into the definitive species (e.g. foxes) in the UK include disease establishment, loss of disease free status and therefore an increased risk for the human population being exposed to the parasite.

To minimize the risk of *E. multilocularis* being introduced and establishing within UK wildlife, the only suitable risk mitigation measure would therefore be to source beavers from UK captive bred populations or from countries which are currently free of *E. multilocularis*.

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