Information on measures and related costs in relation to species included on the Union list

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This technical note provides information on the effectiveness of measures, alongside the required effort and resources, used to prevent the introduction, and to undertake early detection, rapid eradication, and management for the invasive alien species under review. Each table represents a separate measure.

Technical note

Species (scientific name)	*Ondatra zibethicus* (Linnaeus, 1766)
Species (common name)	Muskrat
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Summary

Highlight of measures that provide the most cost-effective options to prevent the introduction, achieve early detection, rapidly eradicate and manage the species, including significant gaps in information or knowledge to identify cost-effective measures.

Prevention

The muskrat (*Ondatra zibethicus*) main route of entry has been through fur farming. Limiting fur farming of this species and the keeping of animals by individuals are the most effective forms of prevention.

Early detection

The recommended method for detecting muskrat is based on visual inspection for signs of presence in targeted locations, under suitable conditions. The effectiveness is moderate and requires that sufficient time is invested under the right conditions. The chance of detection is enhanced by the use of bait stations or passive traps. Novel methods such as eDNA may supplement these approaches in future.

Rapid eradication

This species has been successfully eradicated from large areas (up to 2,800km2) in the UK and Ireland using trapping. These eradications took place before the animals became firmly established in these areas. Eradication over larger areas with established populations has not been practical due to the continual immigration of individuals from neighbouring populations. However, large areas can be maintained as muskrat free. The trapping methods are well described and there is a lot of experience with its use in population management and control. The costs for removal increase with the area to be trapped, but cost per unit area declines in larger areas. Eradication or complete removal using chemical control is deemed not suitable. Irrespective of that, any EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

Management

Prevention of the most significant damage, and reduction of risks for public safety, can be achieved by fortification of flood walls and/or banks of water bodies. While this approach is financially expensive in terms of investment per unit length of bank protected, a detailed analysis of cost-effectiveness compared to lethal control is not available and would need to also consider the impact of muskrat on biodiversity, related ecosystem services, human health and additional impacts upon the economy than just damage by digging. While bankside management has benefits to animal welfare compared to lethal control, the method also has negative impacts on native biodiversity.

The main measure to manage muskrat populations is trapping. To achieve long-term control of damage, effort needs to be applied indefinitely, unless complete removal can be achieved. Trapping will be required as long as the habitat is suitable for muskrat and low population sizes are desired. Effectiveness is mainly influenced by trapping intensity, but scale of operation, coordination and motivation of staff are also factors. Data, and practical experience, indicate that maintaining a high trapping intensity (percentage of population removed) requires less effort at lower population size.

At lower population sizes, there will be:

- fewer traps in the field and therefore less by-catch of non-targeted species.
- lower absolute number of individuals of muskrat killed
- less undesired effects upon other natural values
- better working conditions for trappers

The capture of muskrats may be more acceptable to stakeholders if the evidence base is further enlarged (research into the justification for management and its effectiveness), and if control is limited to regions characterised by obvious risks for public safety, where prevention is not feasible and where cost-effectiveness is demonstrated.

Prevention – measures for preventing the species being introduced, intentionally and unintentionally. This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation.** The restrictions under Article 7 of the IAS Regulation are applicable since 2 August 2017. Transitional measures for commercial and for non-commercial owners are provided for in the Regulation. The only way to reduce risk of escapes is to restrict trade and captive breeding populations, allowing clearly defined exceptions under licensed ownership and registered facilities. The provision of education and outreach activities would also be needed. It is unlikely that introductions via fur farming are still occurring as there are no active muskrat fur farms remaining in Europe, however this needs confirmation. For these reasons, it seems likely that the human-assisted introduction of further muskrats into Europe is unlikely (Deputy Direction of Nature, 2015). Muskrats are not zoo animals nor are they commonly kept as pets. Nevertheless, there are exceptions, for example in Ireland there have been cases of escaped individuals that were kept as pets (Deputy Direction of Nature, 2015)
Effectiveness of measure e.g. has the measure previously worked, failed	This is a standard measure to prevent escapes. The effectiveness is high if implemented effectively. In the past, however, the closure of fur farms has led to escapes; with the economic crisis of 1929 came the closure of many fur farms, and in that period animals were released in Belgium and France accidentally or intentionally (Triplet, 2015).
Effort required e.g. period of time over which measure need to be applied to have results	The measures and regulations need to be maintained indefinitely.

Resources required [1] e.g. cost, staff, equipment etc.	**Exact costs are unknown**, but would include administration and staff to maintain regulations. Given that there are probably no, or very few, fur farms in Europe and that muskrats are not zoo animals nor are commonly perceived as pets, the costs would be negligible.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	None
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	**Good**. Muskrat farming is not an important economic activity (Triplet, 2015), nor are they commonly kept as pets.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**- Implementation cost for Member States:** See above **- Cost of inaction:** Any escapes may lead to the need for early detection and rapid eradication measures **- Cost-effectiveness:** High. There is general agreement that prevention is cheaper than eradication or control (Genovesi and Shine, 2004). - **Socio-economic aspects:** Muskrat fur farms will need to be closed and people will no longer be able to keep them as pets.
Level of confidence [2] See guidance section	**High**. Note however, information on fur farms is difficult to source, and it is possible that some individuals will keep muskrats as pets, as has occurred in Ireland and the Netherlands in the past.

Early detection - Measures to achieve early detection and run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16 of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Visual inspection for signs.** The basic method for detecting muskrat is based on visual inspection for signs of presence in targeted locations, under suitable conditions. A detailed description is provided by the European Federation of Associations for Hunting and Conservation (FACE, 2014). Basic signs are tracks, droppings, displacement of earth by burrowing, feeding signs and the presence of lodges.

	This method requires knowledge, and presence in the field at the right time. It is preferably undertaken by competent and trained professionals, although it can be supported by members of the public. Targeted locations are optimal habitat that can be reached by muskrats from existing populations. Given that natural dispersal is the main component of range expansion for muskrat (Triplet, 2015), a zone of 5-50 km around the known range of distribution needs to be inspected, with the main focus on the first 5 km. The spreading front moves at a rate ranging from 0.9 to 25.4 km/year (Kadlec, Pries and Mustard, 2007). Visual detection of signs can be supported by detection of smell (dogs are the most effective, however humans can also smell muskrat), detection of DNA (Cannon *et al*., 2016; Ushio *et al.,* 2016), and other innovative tools such as bait stations with camera's, drones, self-resetting traps etc. (Campbell *et al.,* 2015; Robertson *et al.,* 2016). At present, these methods are best considered as supplementary to visual inspection and therefore a separate review on these additional measures is not given. It should be noted however, that muskrat presence in a field situation has already been identified using environmental DNA (eDNA; DNA material released by the animal into the environment; Cannon *et al.,* 2016). This innovative method using eDNA is very promising, and may soon become a very cost effective method for early detection. The Dutch Water Authorities are investing in the methodology and exploring its suitability in practice (D. Moerkens pers. comm.)
Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	**Effectiveness is moderate to high** as long as sufficient time is invested under the right conditions. Some signs may be very obvious (lodges, air-bubbles under ice) but others are more difficult to see for the inexperienced eye (e.g. small fragments of aquatic plants as feeding signs, sand in the waterway indicating burrowing). Signs may become invisible in turbid or turbulent water, after heavy rain or in inaccessible places. Muskrats may rapidly colonise new areas, especially during spring and autumn migrations. This necessitates regular inspection.
Effort required e.g. required intensity of surveillance (in time and space) to be sufficiently rapid to allow rapid eradication	The required effort for inspection differs between habitats and varies depending on means of transportation. The inspection should focus on suitable habitat in a five km buffer zone around the known distribution of muskrat. An estimate of required effort, within the 5 km buffer zone, is 0.8 hour per km of waterway inspected by experienced staff[1]. Additional effort is recommended in a region beyond this zone (at lower intensity; suggested effort 0.6 hours/km). These estimates have been obtained from situations in the Netherlands where population densities have been

[1] the amount of muskrat habitat is expressed as kilometres of waterway, which is estimated as the sum of the length of linear waterways that carry water during more than three months of the year, double the length of linear waterways that are wider than 6m, and that cannot be crossed on foot (deeper than 1 m), and the circumference of lakes and ponds.

	decimated, and therefore effort is concentrated to prevent recolonisation and/or to detect remnant populations (Provinces of Noord Holland and Friesland (NL), pers. comm., J. van den Berg, c.f. van Loon *et al.* 2016). Gosling and Baker (1989) reported a workforce of 5 trappers over 400 square miles in the final phase of muskrat eradication (without the availability of motorised transport). In Flanders, 80 trappers were part time involved in muskrat control at very low muskrat densities in 2013 (VanderWeeën, pers. comm.), mainly inspecting waterways for signs of presence.
Resources required [1] e.g. cost, staff, equipment etc.	The resources required include skilled/trained staff, suitable traps and transport depending upon terrain (boat, canoe, quad, and car).
Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	Apart from potential disturbance to native biodiversity by human presence, early detection by visual inspection has no (negative) side effects. The negative effects may be mitigated by timing (avoiding presence in bird colonies during the breeding season) and the right equipment (prevent the use of heavy machinery on sensitive vegetation).
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	**Moderate to good.** However, it is important that access to private land is granted by land managers and landowners. This needs to be properly supported by national legislation/regulation (Bomford and O'Brien, 1995).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**- Implementation cost for Member States:** see above **- Cost of inaction:** Muskrat colonise new areas at a high rate (Deputy Direction of Nature, 2015), therefore inaction means that there is a chance of not detecting colonisation. This may lead to economic damage, safety risks and impact on biodiversity as described in the muskrat risk assessment (Deputy Direction of Nature, 2015). If colonisation has taken place, inaction also implies that a larger area subsequently needs to be monitored for early detection. Finally, costs for eradication increase with the area colonised (Robertson *et al.*, 2016). **- Cost-effectiveness:** Good. The costs for adequate visual inspection in the absence of muskrat are lower than costs for inspecting, trapping and mitigation of damage in the presence of muskrat. Costs rapidly increase with increasing population density (Barends, 2002) and area colonised (Robertson *et al.*, 2016). Therefore, an effective surveillance system is a cost-effective measure. - **Socio-economic aspects:** Visual inspection is not physically demanding
Level of confidence [2] See guidance section	**High**

Early detection - Measures to achieve early detection and run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16

of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Semi-permanent bait stations or passive traps.** Passive trapping (setting a trap and waiting until the animal enters it) for muskrats consists of using the following types traps: bait stations (Baker, 2006), live-catch traps, body-gripping traps, floating island (raft) with mounted Conibear's, cages with body-gripping traps, and drowning traps (FACE, 2014). Especially during the migration periods drowning- and bait-traps are placed in watercourses to trap migrating muskrats. The traps may be equipped with a camera or a system to report capture using the mobile network. Under certain conditions traps are placed on a raft. These measures will in practice often be complementary to visual inspection.
Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	Bait stations have successfully been applied during the campaign for eradication of coypus from Britain (Baker, 2006), which used rafts baited with carrots that were checked for signs of coypus, such as droppings and teeth marks. The advantage of this technique is that a raft only needs to be checked once every week to ten days, unlike cage traps which must be checked every day they are set. Automatic camera rafts have also been used to confirm the presence of coypus (Gosling and Baker, 1989). The method using kill-traps is commonly applied for early detection of muskrat in several regions in the Netherlands and, using live-traps for coypu, along the border with Germany. The effectiveness may be compromised by people that oppose the catching of animals, by damaging the equipment or removing it. In practice this happens rarely, and more often in urban than in rural areas. It is good practice to label the traps to inform the public and reduce the risks of interference. A public awareness campaign in the area of the trapping is also useful.
Effort required e.g. required intensity of surveillance (in time and space) to be sufficiently rapid to allow rapid eradication	**The required effort is relatively low.** However, traps need to be checked daily, if they are not self-reporting. Bait stations, not using additional trapping, allow a much greater area to be surveyed than would be possible when using additional trapping. The method may be applied as complementary to visual inspection.
Resources required [1] e.g. cost, staff, equipment etc.	The resources required include the cost of the traps, rafts and bait (carrots, apples), and transportation which depends upon the habitats (gasoline, boats, cars, quad bikes). In terms of labour the Dutch coypu control programme, which is almost entirely based on this methodology, required 22,400 man hours (19 full time equivalent) in 2016 to check for the presence of coypu and capture them along an approximate 300 km length of national border (note that this involves thousands of km of waterway).

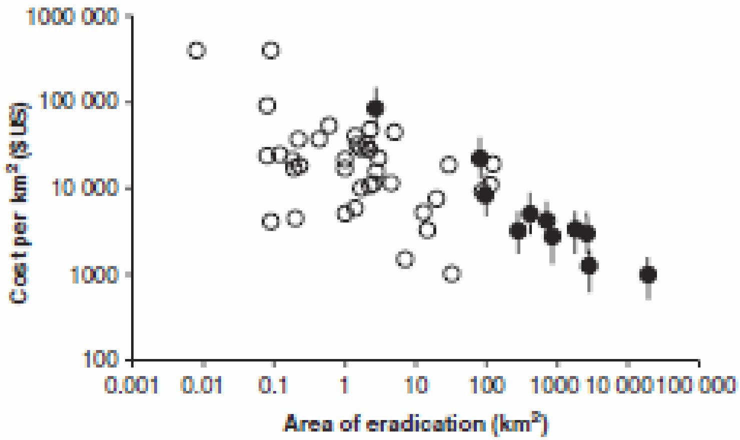
Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	As with visual inspections, there is the potential for the disturbance of native biodiversity by human presence (see visual inspections table above). All trapping may lead to the capture of non-target species (Bos *et al.*, 2016; Klop, van der Heide, and Schoppers, 2011), however this can be minimised by proper placement and design of traps (FACE, 2014; Gosling and Baker, 1989; Hatler, Blood and Beal, 2003), and the use of live-trapping. The main groups registered as by-catch are mammals (72%, mainly brown rat *Rattus norvegicus* and European water vole *Arvicola amphibius*), fish (14%, e.g. Northern pike *Esox lucius* and birds (11%, e.g. mallard *Anas platyrhynchos* and Common moorhen *Gallinula chloropus).* There is a strong positive correlation between the number of traps in the field and the number of individuals of non-target species caught. Together with the costs of placing and inspecting the traps, this is an incentive not to place more traps than required for the purpose of early detection.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	**Moderate to good.** As discussed above, it is important that access to private land needs to be arranged, and cooperation with landowners is essential where the objective is the eradication of a population (Baker, 2006; Simberloff, 2013). Public acceptance is lower in the cities than in the countryside, but this needs not be a major issue as long as there is effective outreach and mitigation of the impact. By minimising impact on any non-target species (using bait stations or cage trapping) in the coypu eradication campaign, it was possible to get the co-operation of all landowners, including those with conservation and game interests (Baker, 2016).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	- **Implementation cost for Member States:** (see above) - **Cost of inaction:** muskrat colonise new areas at a high rate (Deputy Direction of Nature, 2015), therefore inaction implies that a larger area subsequently needs to be monitored for early detection and costs for rapid eradication increase. Also see the species Risk Assessment. - **Cost-effectiveness:** is very high (Gosling and Baker 1989; Baker, 2006). Panzacchi *et al*. (2007) demonstrate that the eradication of coypu in Italy probably has a very positive cost-benefit ratio. - **Socio-economic aspects:** there are no socio-economic concerns
Level of confidence [2] See guidance section	**High**

Rapid eradication

- Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**

Measure description Provide a description of the measure	**Complete removal using mechanical means** Eradication is only possible where the entire population can be targeted and there is no continued risk of reinvasion. The best examples come from Britain and Ireland where introduced muskrats were successfully eradicated from five discrete areas in the 1930s. These eradications took place when the populations were still expanding and establishing. In situations where this species is now established over large contiguous areas, as is the case in much of Northern Europe, it is possible to completely remove animals on one site, but the immigration of young individuals can result in the return of the species if effort is not maintained (Triplet, 2015). In these situations eradication has not been achieved despite considerable effort, although large areas can be maintained muskrat free through ongoing efforts. Examples in practice are found in parts of Flanders and the Netherlands. The main control method has involved the daily checking of static live capture or kill traps, by professional staff (Robertson *et al.,* 2016). The method is well described for the purpose of furbearer management in Hatler *et al.* (2003) and for population control in FACE (2014). It can have only lead to complete removal with a very high pressure of trapping (Gosling and Baker, 1989; Triplet, 2015; van Loon *et al.,* 2016). Some traps work with baits, in particular carrots, celery or fruit. During the spring, some musk drops near the trap increase its attractiveness. Trapping is preferably implemented year-round and in all suitable habitat, although it is wise to allocate effort in space and time to optimise trapping results. This is because catch efficiency varies between seasons and habitats. Cooperation with land managers is also crucial. Ideally the trapping programme should have good coordination, teamwork, motivated and skilled staff that are equipped with the proper tools and means of transportation, and a good link to an applied research (Baker, 2006). The field activities need to be guided by a robust data recording and monitoring system. It is important to provide the staff with an incentive for eradication (e.g. financial incentive; Baker, 2006), or to evaluate their work based on the results achieved (low population left behind, no damage; VMM, 2010). The use of a bounty system is not advisable, as such rewards often encourage husbandry of the animal to ensure a continuing income (Gosling and Baker, 1989). Within the EU, traps for fur-bearers including the muskrat must be approved under the International Agreement on Humane Trapping Standards. Furthermore, it is the responsibility of the trapper to reduce pain, distress and suffering of trapped animals as much as technically

	feasible. When trapping, it is important to avoid catching non-target species, which can be reduced by carefully planning and setting the trap (FACE, 2014). A variety of other methods can be used to supplement trapping, but are not feasible to use on a large scale or to rely on to achieve eradication. These include manual despatch of animals observed during other activities, shooting which is possible at dawn and dusk when muskrat are most active or during high water conditions, when muskrat are forced to sit and wait in trees. However, shooting is not an efficient control method and only low numbers of animals can be killed this way (Triplet, 2015), although it can be useful to remove trap shy individuals. Support for the concept of fertility control via immunocontraception is still restricted largely to experimental studies in the laboratory (Stenseth *et al.*, 2001). Fertility control is not considered feasible at a field scale (VMM, 2010). Genetic approaches for eradicating or reducing the impact of invasive rodents are still in their infancy, the timeline from conception to testing could however be as short as a few years based upon the speed achieved in genetically engineering biomedical models (Campbell *et al.,* 2015). Population control using genetic technology will not be without risk, it potentially has consequences for public safety, and it is controversial in terms of public acceptance. In addition, it is unclear whether genetic approaches to eradication will work in a meta-population, and how it can be controlled (Esvelt *et al.*, 2014).
Effectiveness of measure e.g. has the measure previously worked, failed	Evidence of the effectiveness of eradication through trapping is provided by the several successful muskrat eradication campaigns in Britain and Ireland (Gosling and Baker, 1989; Robertson *et al.,* 2016). Muskrat have also been successfully removed by trapping alone from several regions and small islands in the Netherlands (Bos *et al.,* 2016) and large parts of Flanders, Belgium (VMM, 2010), without the use of poison (Barends, 2002; VMM, 2010).
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	Baker (2006) identifies the need to establish success criteria for management purposes at an early stage. In the eradication campaign for coypu in East Anglia a practical definition was adopted that a 21 month period without any coypus being caught or found was deemed to provide sufficient evidence to disband the trapping force. Complete removal can be considered to be achieved when the captures are restricted to the border of the area subject to the campaign. Depending on the degree of infestation, the actual removal of the newly discovered occurrence could be completed in a few weeks.

	To eradicate the species from Britain in a seven-year campaign 4,388 muskrats were captured (Gosling and Baker, 1989). The removal of a population of about 6,000 adult coypu has taken 8 years to complete (Baker, 2006).
Resources required [1] e.g. cost, staff, equipment etc.	The two largest successful muskrat eradications covered 2,800 km^2 (Scotland) and 1,800 km^2 (Shropshire in England) and took 35.5 and 61 man years of effort respectively (Robertson *et al.* 2016). The costs for eradication increase with area but there is a scale advantage: the cost per unit area declines with the area of eradication (see figure below, taken from Robertson *et al.*, 2016).  **Figure 3.** The relationship between the area of invasive alien mammal eradications and the cost per unit area ($n = 51$, $F = 41.9$, $P < 0.001$, $r^2 = 0.456$). The open circles relate to island mammal eradications worldwide.[19] The closed circles are the 11 large-scale invasive alien mammal eradications in Great Britain, Ireland and Belgium, with the range of cost estimates represented by the vertical bars. Cost per km^2 for mammal eradication was estimated to range between >USD 500,000 for small islands to USD 1,000 for muskrat and coypu in England (see figure above, taken from Robertson *et al.*, 2016). On islands, increased experience has led to a reduction in costs for recent mammal

	eradications. Experience, novel technologies or increased use of volunteers may further reduce these costs.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Muskrat serve as a reservoir or intermediate host for viruses, nematodes, trematodes, cestodes, etc. and are associated with transmission of several diseases to humans (Triplet, 2015; Ulrich *et al.,* 2009; Wobeser *et al.,* 2009). The risks of transmitting zoonoses can be mitigated by working hygienically (RIVM, 2017). All trapping may lead to the unintentional catching of non-target species (Bos *et al.*, 2016; Gosling and Baker, 1989; Klop *et al.,* 2011), but this can be minimised by proper placement and design of traps (FACE, 2014; Hatler *et al.*, 2003), and the use of live-trapping. There is a strong positive correlation between the number of traps in the field and the number of individuals of non-target species caught. Complete removal of the target species leads to the virtual absence of muskrats, which requires fewer traps in the field, and thus to a lower by-catch. Particular types of passive traps, placed in underpasses, may entirely block the passage for dispersing animals. However, tailor-made solutions exist for mitigating this negative side-effect. Additional side effects include disturbance to native biodiversity by human presence in the field, for example the trampling of sensitive vegetation and disturbance of breeding birds.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Animal welfare organisations have proposed to focus effort on the prevention of risk and damage (Zandberg, de Jong and Kraaijeveld-Smit, 2011). The capture of muskrat may be more acceptable to those organisations if the evidence base is enlarged (proper research into the justification and the effectiveness), and if control is limited to regions characterised by obvious risks to public safety, or where prevention is not feasible. Stakeholders may support an argument that the absolute number of animals killed (including of non-target species) under a scenario of complete removal is lower than under a scenario of population control. Nature conservation bodies may oppose access to land without proper mitigation of impact on any non-target animals, sensitive vegetation or other natural values. Politicians and managers will appreciate the prospect of reducing risks to public safety, especially if it can be shown that the eradication of muskrat will have a positive cost-benefit ratio (e.g. see Panzacchi *et al.,* 2007, for coypu).

	Trappers may fear their jobs could be lost, unless they are provided with an incentive for eradication. Job security may be implemented by proper human resource management and through providing alternative, but interesting, tasks for a flexible team of skilled staff to prevent recolonisation. Although it is always likely for there to be some public opposition to the eradication of a vertebrate, experience in Britain and Ireland, and extensive control in the Netherlands, suggests such programmes can be undertaken without undue public concern.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**- Cost for Member States**: given above **- Cost of inaction:** cost of inaction are summarised in the Risk Assessment **- Cost-effectiveness:** Panzacchi *et al*. (2007) show that for coypu even very costly eradication campaigns may have a very positive cost-benefit ratio. The successful muskrat eradication campaigns in Britain were implemented as it was clear in advance that it would be cost-effective in the long run. However, up to now, there is no detailed technical assessment of the effort and costs required for the complete removal of muskrat in parts of mainland Europe and the likely chances of success. **- Socio-economic aspects:** trapping at high population densities is physically demanding work, but under a scenario of rapid eradication this is not an issue because its only short term.
Level of confidence [2] See guidance section	**High**

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Chemical control** copied from Triplet (2015). Chlorophacinone can be used to control muskrat. In Belgium, the first studies were made by Moens and Colin (1971) starting in 1966 and led to the use of this chemical (research cited by Giban, 1974;

	van Melckebeke, 1986). The mortality obtained with a single ingestion was 100 percent when chlorophacinone baits were used up to a dosage of 0.005% of active material (rat dosage). Carrots and beet slices proved effective baits, even when natural foods were abundant. Chlorophacinone seems not to affect carrion-feeding species and there is no evidence of Muskrats developing resistance (Giban, 1974). Zinc phosphide (63% concentrate) and anticoagulants have also been used to control muskrats. However, undesired impacts of toxicants on non-target species (mustelids for example) have been reported. Poison baits are usually placed on floating platforms to minimize risks to non-target species (DAISIE, 2009). Chemical control may be forbidden in some European countries. EU/national/local legislation on the use of plant protection products and biocides needs to be respected.
Effectiveness of measure e.g. has the measure previously worked, failed	No successful eradications of muskrat are known to have been achieved using chemical control. In the Netherlands and Britain poison has never been part of the strategy to control or eradicate muskrat (Barends, 2002; Robertson *et al.*, 2016). In the Loire Atlantique department in France no poison has been used in the control of muskrat since 2003 (Mazaubert, 2016), and in Flanders the use of rodenticides was abandoned at the start of the millennium (Stuyck, 2008). Tuyttens and Stuyck (2002) confirmed that chlorophacinone, despite having been used for more than 30 years, still appeared to be effective against muskrats. The labour required for the baiting campaigns studied, however, was substantially more than anticipated. According to them a strategy using chemical means appears more suitable as a one-off campaign to quickly reduce very problematic populations than as a sustained maintenance control strategy, because of concerns about primary and secondary poisoning of non-target species, animal welfare, and the development of resistance.
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	Eradication or complete removal using chemical control is deemed not suitable. In the study by Moens and Colin (1971), a first poisoning campaign required 70 person-days to strategically distribute 12,057 baits in a 240 km^2 area, and 52 person-days were required for the distribution of 8,681 baits during the follow-up campaign. But Tuyttens and Stuyck (2002) required more time for the same work and highlighted that other factors may hugely influence the effort required in the field. These factors may include, the geography, topography, and accessibility of the terrain, the density of watercourses in the area, and the density of the target muskrat population.

	Their results also suggested, that the efficiency of poisoning is overrated.
Resources required [1] e.g. cost, staff, equipment etc.	No assessment made, because eradication or complete removal using chemical control is deemed not suitable.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	There are realistic concerns about primary and secondary poisoning of non-target species, animal welfare, and the development of resistance (Tuyttens and Stuyck, 2002). The ecological consequences need to be investigated much more carefully. There have been, for example, no rigorous tests on how often non-target animals consume the carrot baits containing chlorophacinone and how this affects their health. The results of Tuyttens and Stuyck (2002) emphasise the potential for secondary poisoning, since roughly three-quarters of the poisoned muskrats were found above ground and freely available to scavengers and predators.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	The widespread use of chemical control for complete removal is unlikely to be acceptable, for the general public, staff, hunters, fishermen, animal welfare organisations and is for the same reasons is forbidden in some European countries.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**- Implementation cost for Member States**: Not estimated **- Cost of inaction:** cost of inaction are summarised in the Risk Assessment. Not using poison is positive in that the environment remains free of chemical residue **- Cost-effectiveness:** poor **- Socio-economic aspects:** see above
Level of confidence [2] See guidance section	**Medium –** Poisons that are effective against muskrats have been developed, however they have not been used on a large scale because of concerns over public acceptability, effectiveness, and possible non-target impacts. However, these remain poorly understood.

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Prevention of the most important damage and reduction of risks for public safety by fortification of flood walls and/or banks of water bodies.**

	In this scenario flood walls are protected against muskrat by 1) enlarging them (over-dimensioning), 2) inserting mesh wire or steel walls or 3) outside reinforcement with a strong layer of large stones, concrete, or bitumen (BCM, 2007; Campbell-Palmer *et al.*, 2016).
Effectiveness of measure e.g. has the measure previously worked, failed	These methods can be effective at preventing muskrat damage to water courses but may only be suitable for use over limited areas due to the high costs. Depending on the financial resources allocated to prevention, this measure may leave some banks of water bodies unprotected. The measure does not counteract the impact of muskrat on biodiversity, related ecosystem services, human health and other effects on the economy than damage by digging. In addition the measure may have negative impact on biodiversity itself (see below). Protection using concrete revetment, mesh wire and stone gabions are technically feasible (Unie van Waterschappen, 2014). It is uncertain whether all types of floodwall may be protected against digging this way, without affecting stability (e.g. some very narrow embankments on peat soils), and there is insufficient knowledge regarding the best materials to use. More research is required. Nonetheless, it is quite likely that this measure may be appropriate to the specific circumstances in less densely human populated areas in Europe that are not sensitive to flooding. A region-specific detailed analysis is required to be able to make a comparison between the case for complete removal or for management measures to prevent damage.
Effort required e.g. period of time over which measure need to be applied to have results	Investment is required to fortifying sensitive floodwalls and banks of waterbodies, until all of them are protected. Depending on the material used maintenance will be required after 10-50 years.
Resources required [1] e.g. cost, staff, equipment etc.	According to Burghause (1996), this may be the "*most successful, but also the most expensive*" form of indirect control of muskrat damage. Costs for implementing such measures at existing floodwalls are superficially estimated at € 25-100 per meter length of floodwall (Bronsveld, van Poelwijk and Prudon, 2010). Higher costs were estimated for a pilot implementation of preventive measures in the Province of Zuid, Holland over three stretches of 100 m. This was despite the fact that this pilot work was integrated within planned maintenance of the floodwall. Additional to the cost of the planned maintenance, protection using concrete revetment, mesh wire and stone gabions were € 225, € 45 and € 75 per

	meter of floodwall respectively (Unie van Waterschappen, 2014).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	If natural banks of waterbodies are replaced by hard substrate over large lengths, there will be significant side-effects upon native biodiversity (vegetation, insects, birds, amphibians, fish) and ecosystem functioning. The measure risks being counter to conservation objectives and restoration efforts implemented as part of the Water Framework Directive.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Animal welfare organisations are proponents of a better evaluation of the pros and cons of this measure (Zandberg *et al.*, 2011). Water managers are cautious about the measure because it potentially involves very high financial investment and negative side-effects to biodiversity.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**- Implementation cost for Member States**: costs of this measure will vary regionally depending upon the length of floodwall and banks at risk. So do the risks, and costs of inaction. **- Cost-effectiveness:** appears to be very poor for densely populated areas, where risks of flooding are prominent. A detailed analysis, taking into account variation in these factors is not available. Any comparison to the case of control and complete removal so far, is based on expert judgment.
Level of confidence [2] See guidance section	**Medium** – while there is experience of the use of these approaches over limited areas, the full costs or consequences have not been studied in detail.

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Trapping and other mechanical means** Trapping is the main measure in all countries where muskrat populations are managed. On rare occasions shooting, and clubbing are applicable as additional means. The measure is summarised above and elaborated in a number of publications (Barends, 2002; Hatler *et al.*, 2003; FACE, 2014). This measures to minimise the impact of muskrat on biodiversity, ecosystem services, human health or the economy are the same as described for eradication and complete removal (see above).
Effectiveness of measure	For effectiveness of the measure for eradication, which has seen complete success in Britain and

e.g. has the measure previously worked, failed	Ireland (Baker 2006), see above 'rapid eradication' section. Muskrat management by trapping has led to a situation of full control (defined as < 0.15 catch/km/year) in Flanders and four provinces in the Netherlands (van Loon *et al.,* 2016). Where concerted action is undertaken muskrat control leads to manageable impacts with little economic damage in Flanders (Belgium) and the Netherlands (Gaaff *et al*., 2007; Stuyck, 2008; Bos *et al*., 2016). The catch in Flanders has declined from more than 150,000 in the first half of 1990 (VMM, 2010), to 730 in 2013 (pers. comm. M. Van der Weeën, Vlaamse Milieumaatschappij). When trapping pressure is not sufficiently high or not maintained (Triplet, 2015), removal will not be achieved. There are still regions in the Netherlands (other than those mentioned above) where the control organisations have not yet succeeded in bringing the population down to the desired levels. There is, however, general consensus among the people involved that strongly reducing the population by intensive trapping is possible (corroborated by VMM, 2010; van Loon *et al.*, 2016). The Dutch Water Authorities are currently considering the possibilities for complete removal at a national level. In the past, however, trapping has led to unconvincing results for many years in Germany, the Netherlands and Flanders due to lack of concerted action (Halle and Pelz, 1990; Pelz, 1996; Reinhardt *et al.*, 2003; VMM, 2010; Mazaubert, 2016; van Loon *et al.*, 2016). Halle and Pelz (1990) conclude that muskrat control in Bremen was without noticeable effect on the population dynamics. Pelz (1996) doubted the effectiveness of the trapping of more than 300,000 animals annually in Germany under a less intensive muskrat control effort. In the parts of Germany studied by Reinhardt *et al.* (2003), muskrat control was implemented using live-trapping methods, in order to minimize risks to protected species. Both Pelz and Reinhardt et al. doubted whether the measures were adequate at the given intensity. This is consistent with the conclusion by van Loon *et al.* (2016) that control measures can make muskrat populations decline, provided that the effort is commensurate with the population size.
Effort required e.g. period of time over which measure need to be applied to have results	The trapping effort needs to be applied indefinitely. There will be no end to the need for control as long as the habitat is suitable for muskrat and low population sizes are desired. Trapping intensity is one of the main factors (Gosling and Baker, 1989), but scale of operation, coordination and motivation of staff also strongly affect the results (Bos *et al.,* 2016). Effort can vary between 0 to 3 person hours/km/year, depending upon the budget or desired effect on population trend. A sustained effort above 1.4 person hr/km/year on average led to declining populations in the Netherlands (van Loon *et al.,* 2016). Once populations have strongly declined,

	operations should not be interrupted (Micol, 1990 in Panzacchi, 2007).
Resources required [1] e.g. cost, staff, equipment etc.	In the Netherlands alone the <u>annual</u> cost of the control operation was 1,036 €/km^2 within a total area of about 33,700 km^2. Cost per km length of waterway[2] was 123 €/km on average in 2013, but varied from 97 to 314 €/km (pers. comm. D. Moerkens) among the eight control organisations in the Netherlands. Data in van Loon *et al.* (2016) indicate that maintaining a high trapping intensity (high percentage of population removed) requires less effort at lower population sizes in comparison to higher population sizes. The annual intervention costs for control of muskrat and coypu in the Loire Atlantique department in France are estimated at 900 €/km for areas accessible by boat. In other habitats it is more expensive (Mazaubert, 2016). When catches decline because of lower population size present, the control organisations in the Netherlands tended to invest less effort (van Loon *et al.,* 2016). These data, and practical experience, indicate that maintaining a high trapping intensity (high percentage of population removed) requires less effort at lower population size. When many muskrats are present, on average 1.4 person hr/km/yr is required to generate a population decline. This effort roughly corresponds to 140 €/km/yr. Depending on the rate of recolonisation, a situation of full control may be maintained using 0.5-1 person hr/km/yr, which corresponds to € 50-100 €/km/yr. The cost of muskrat control in the Netherlands was estimated at € 34.5 million in 2016. According to Reinhardt *et al.* (2003), muskrat trappers employed nationwide in Germany would cost over € 16 million. Flanders employed 90 trappers in the year 2010 and managed with this workforce to reduce the population to very low levels. Only immigration from neighbouring Wallonia, France and the Netherlands prevented a complete removal in Flanders (VMM, 2010).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on	Depending on resulting population density the effects may be more or less pronounced.

[2] the amount of muskrat habitat is expressed as kilometres of waterway, which is estimated as the sum of the length of linear waterways that carry water during more than three months of the year, double the length of linearwaterways that are wider than 6m, and that cannot be crossed on foot (deeper than 1 m), and the circumference of lakes and ponds.

public health, environment, non-targeted species, etc.	At lower population sizes, there will be • fewer traps in the field and therefore fewer non-targeted species will be caught. • lower absolute number of individuals of muskrat killed • less undesired effects upon other natural values (e.g. blocking passage-ways for dispersing animals, disturbance to native biodiversity, trampling of sensitive vegetation). • better working conditions for trappers
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	See trapping section above in 'rapid eradication'. Maintaining non-effective control will not be acceptable, but control with a good result (fewer animals killed, no damage) is likely to be acceptable by many stakeholders.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	**- Implementation cost for Member States:** costs of control (including the option of complete removal) shall vary regionally, and so do risks, and costs of inaction. The cost of muskrat control in the Netherlands was estimated at € 34.5 million in 2016. **- Cost-effectiveness:** appears to be good for densely human populated areas, or where risks of flooding are prominent. However, a detailed analysis taking into account these factors is not available. A comparison with the case of complete removal or management to prevent damage, is based on expert judgment. According to Reinhardt *et al.* (2003) muskrat trappers employed nationwide in Germany would cost over € 16 million. They state that, considering maintenance costs for waterways and reservoirs, costs to fisheries and aquaculture and public health concerns, such an investment could be justified. **- Socio-economic aspects:** The prevention of human injury or death from accidents with vehicles or flooding is extremely important. Trapping at high population densities is physically demanding work and leads to physical strain on trappers, and especially joint complaints. At low population densities this is not an issue.
Level of confidence [2] See guidance section	**High –** ongoing control is widely undertaken in a number of EU member states and there is considerable experience of the methods, their costs and effectiveness.

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Notes

1. Costs information. The cost information depends on the information available.

2. Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for this method.

- **High**: Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.
- **Medium**: Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (e.g. tropical regions) to guarantee that the results will be transposable.
- **Low**: data are not published in reliable information sources and methods are not commonly practiced or are based soley on opinion; This is for example the case of a novel situation where there is little evidence on which to base an assessment.

3. Citations and bibliography. The APA formatting style for citing references in the text and in the bibliography is used.
e.g. Peer review papers will be written as follows:
In text citation: (Author & Author, Year)
In bibliography: Author, A. A., & Author, B. B. (Publication Year). Article title. *Periodical Title*, Volume(Issue), pp.-pp.
(see http://www.waikato.ac.nz/library/study/referencing/styles/apa)