Appendix A

Harmonia^{+PL} – procedure for negative impact risk assessment for invasive alien species and potentially invasive alien species in Poland

QUESTIONNAIRE

A0 | Context

Questions from this module identify the assessor and the biological, geographical & social context of the assessment.

a01. Name(s) of the assessor(s):

first name and family name

1. Henryk Okarma
2. Magdalena Bartoszewicz
3. Wojciech Solarz

acomm01. Comments:

	degree	affiliation	assessment date
(1)	prof. dr hab.	Institute of Nature Conservation, Polish Academy of Sciences in Cracow	03-02-2018
(2)	dr		22-01-2018
(3)	dr	Institute of Nature Conservation, Polish Academy of Sciences in Cracow	05-02-2018

a02. Name(s) of ***the species*** under assessment:

Polish name: Piżmak

Latin name: ***Ondatra zibethicus*** Linnaeus, 1766

English name: Muskrat

Współfinansowano w ramach projektu nr POIS.02.04.00-00-0100/16 pn. *Opracowanie zasad kontroli i zwalczania inwazyjnych gatunków obcych wraz z przeprowadzeniem pilotażowych działań i edukacją społeczną* ze środków Unii Europejskiej w ramach Programu Infrastruktura i Środowisko 2014-2020

acomm02.	Comments:

Polish name (synonym I) –Piżmak amerykański	Polish name (synonym II) Piżmoszczur
Latin name (synonym I) *Ondatra zibethica*	Latin name (synonym II) *Castor zibethicus*
English name (synonym I) Musk rat	English name (synonym II) –

a03. **Area** under assessment:

Poland

acomm03.	Comments: –

a04. **Status** of *the species* in Poland. *The species* is:

	native to Poland
	alien, absent from Poland
	alien, present in Poland only in cultivation or captivity
	alien, present in Poland in the environment, not established
X	alien, present in Poland in the environment, established

aconf01.	Answer provided with a	low	medium	high **X**	level of confidence

acomm04.	Comments: Muskrat is a North American species. In Europe, it appeared in 1905, when 5 individuals (2 males and 3 females) were released in the Czech Republic, on the ponds near Prague (Hoffmann 1958 – P, Sokolov and Lavrov 1993 – P). The local conditions proved to be very favorable to the muskrats and the range of the species population quickly expanded in all directions at a rate of about 25 km per year, and large rivers were the routes of their invasion (Nowak 1971 – P). By 1927, around 40% of the then Austro-Hungarian territory had already been occupied by these animals (Gosling and Baker 1989 – P). In 1924, the first observations in southern Poland took place, where muskrats appeared naturally, most likely expanding their range of occurrence from the Czech Republic. Furthermore, in the 1920s breeding farms were developing in Poland, intended for fur, and the escapees from the farms fed the wild population. By the end of the 1950s, muskrat had already inhabited almost the entire country, with the exception of the highest mountain ranges (Okarma 2011 – P). Since the 1980s, the muskrat population in Poland started to fall quite drastically (Brzeziński et al. 2010) but nowadays slow recovery of the species range in Poland is observed (Okarma 2018 – B).

a05. The impact of *the species* on major domains. *The species* may have an impact on:

X	the environmental domain
X	the cultivated plants domain
X	the domesticated animals domain
X	the human domain
X	the other domains

acomm05.	Comments: Muskrat has a strong impact on the dynamics of aquatic vegetation by biting, changing the composition and structure of species vegetation and the creating muddy elevations (Birnbaum 2013 – B, Triplet 2015 – B). Muskrat affects the vegetation of coastal strip of water reservoirs (Pietsch 1982 – P, Krauss 1990 – P, Diemer 1996 – P), especially the reed beds of *Phragmites communis* (Burghause 1988 – P). It can also destroy water plants belonging to special care species. These rodents can also sometimes feed on molluscs,

crustaceans and water insects, causing strong pressure on endangered species (Hochwald 1990 – P, Zimmermann et al. 2000 – P). By eating clams, the muskrat may indirectly affect fish species that spawn in their shells (e.g. *Rhodeus amarus*). Muskrats also cause damage to agricultural crops near reservoirs and watercourses, particularly in maize and sugar beet (Baker 1972, 1983 – P). Muskrat is a carrier of several dozen parasites, including tapeworms that are dangerous to humans and animals, including *Echinococcus multilocuralis* (Hoffmann 1958 – P, Böhmer et al. 2001 – P). It may also be a source of many diseases such as leptospirosis, tularemia, giardiasis (Hatler et al. 2003 – I). By digging burrows at the edges of reservoirs and watercourses, muskrat may causes their erosion, and also has a significant negative impact on hydrotechnical objects, such as floodbanks, weirs, drainage ditches, as well as weakens constructions of railway embankments and roads (Birnbaum 2013 – B). It also happens to bite through fishing nets and other fishing gear (Burghause 1996 – P).

A1 | Introduction

Questions from this module assess the risk for *the species* to overcome geographical barriers and – if applicable – subsequent barriers of captivity or cultivation. This leads to *introduction*, defined as the entry of *the organism* to within the limits of *the area* and subsequently into the wild.

a06. The probability for ***the species*** to expand into Poland's natural environments, **as a result of self-propelled expansion** after its earlier introduction outside of the Polish territory is:

	low
	medium
X	high

aconf02.	Answer provided with a	low	medium	high **X**	level of confidence

acomm06. Comments:

Muskrat inhabits the whole territory of Poland and is an established species (Okarma 2011 – P, 2018 – B).

a07. The probability for *the species* to be introduced into Poland's natural environments by **unintentional human actions** is:

	low
	medium
X	high

aconf03.	Answer provided with a	low	medium	high **X**	level of confidence

acomm07. Comments:

This species has been present in Poland for several decades.

a08. The probability for *the species* to be introduced into Poland's natural environments by **intentional human actions** is:

	low
	medium
X	high

aconf04.	Answer provided with a	low	medium	high **X**	level of confidence

acomm08.	Comments: The appearance of muskrat and its spread to the majority of Europe is the result of intentional human activities. Over the past few decades the species was kept in fur-farms, however, currently it is not considered as a farmed species. Currently, this species is found in Poland in the natural environment and is an established species.

A2 | Establishment

Questions from this module assess the likelihood for *the species* to overcome survival and reproduction barriers. This leads to *establishment*, defined as the growth of a population to sufficient levels such that natural extinction within *the area* becomes highly unlikely.

a09. Poland provides **climate** that is:

	non-optimal
	sub-optimal
X	optimal for establishment of *the species*

aconf05.	Answer provided with a	low	medium	high **X**	level of confidence

acomm09.	Comments: Within its original range the muskrat inhabits North America, with the exception of its northernmost ends. The success of the establishment and expansion of the muskrat in Poland is proof that the optimal climatic conditions for this species prevail in our country. Climatic similarity between the native and introduced ranges exceeds 90%.

a10. Poland provides **habitat** that is

	non-optimal
	sub-optimal
X	optimal for establishment of *the species*

aconf06.	Answer provided with a	low	medium	high **X**	level of confidence

acomm10.	Comments: Muskrat lives in its natural environment of various types of surface waters. These are mainly freshwater habitats, such as slowly flowing rivers, lakes, ponds, marshes, wetlands, peat bogs, but also drainage ditches (Triplet 2015 – B). It may also live in estuaries, brackish waters and saltwater habitats (McConnell and Powers 1995 – P). However, it avoids watercourses with strong current. The same habitat preferences are found in Europe (Genovesi 2006 – B). Such habitats are commonly found in Poland, that is why the species established here and found optimal habitat conditions

A3 | Spread

Questions from this module assess the risk of *the species* to overcoming dispersal barriers and (new) environmental barriers within Poland. This would lead to spread, in which vacant patches of suitable habitat become increasingly occupied from (an) already-established population(s) within Poland.

Note that spread is considered to be different from range expansions that stem from new introductions (covered by the Introduction module).

a11. The capacity of *the species* to disperse within Poland by natural means, **with no human assistance**, is:

	very low
	low
	medium
	high
X	very high

aconf07.	Answer provided with a	low	medium	high X	level of confidence

acomm11. Comments:

Dispersion from a single source (Data type: A)

Muskrats can migrate over long distances (up to 160 km / day) flowing in river currents (Böhmer et al. 2001 – P).

Population expansion (Data type: B)

)Natural spread is the main reason for expanding the species range (Triplet 2015 – B). The front of invasion moves at a rate of 0.9 to 25.4 km / year, which corresponds to a spatial expansion within a range from 51 to 230 km² / year (Danell 1977 – P, Birnbaum 2013 – B).

In France, the area of existence of the species grew at a rate of 3,300 km² / year within 25 years before 1959 (Aubry 1959 – P). The introduction of muskrat to Norway took place in 1980 and 1988, and already in 1996 the species was found almost throughout the entire country (Danell 1996 – P). Muskrat appeared withing the present borders of Poland in 1924, spontaneously entering from the south. In 30 years it has already spread almost all over the country (Okarma 2011 – P). In the 1980s, the population of this species in Poland dropped but the reasons for this phenomenon are not clear. It was probably the result of natural fluctuations in the population of rodent-like species, as well as diseases, parasites, predation of *Neovison vison* American mink (Okarma 2011 – P, Brzeziński et al. 2010 – P, Romanowski and Karpowicz 2013 – P).

a12. The frequency of the dispersal of *the species* within Poland by **human actions** is:

X	low
	medium
	high

aconf08.	Answer provided with a	low	medium	high X	level of confidence

acomm12. Comments:

The probability of spreading with the participation of humans was high until 1934, when the muskrat was a fur breeding animal in Poland. After introducing orders to apply protection against escapes, the breeding quickly stopped (Okarma 2011 – P). Currently, the muskrat does not have the status of a farm animal in Poland, it is a species widely distributed in nature.

A4a | Impact on the environmental domain

Questions from this module qualify the consequences of *the species* on wild animals and plants, habitats and ecosystems.

Impacts are linked to the conservation concern of targets. Native species that are of conservation concern refer to keystone species, protected and/or threatened species. See, for example, Red Lists, protected species lists, or Annex II of the 92/43/EWG Directive. Ecosystems that are of conservation concern refer to natural systems that are the habitat of many threatened species. These include natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers & ponds that have natural banks, and estuaries (Annex I of the 92/43/EWG Directive).

Native species population declines are considered at a local scale: limited decline is considered as a (mere) drop in numbers; severe decline is considered as (near) extinction. Similarly, limited ecosystem change is considered as transient and easily reversible; severe change is considered as persistent and hardly reversible.

a13. The effect of *the species* on native species, through **predation, parasitism or herbivory is**:

	inapplicable
	low
	medium
X	high

aconf09.	Answer provided with a	low	medium	high **X**	level of confidence

acomm13. Comments:

The muskrat lives in various types of water habitats (Genovesi 2006 – B, Triplet 2015 – B). It is a herbivorous rodent and is considered a generalist species in terms of food eaten – it feeds on locally most abundant food. However, only a few types of plants dominate in its diet: reed, cattail and rush (Ramsgaard 2005 – P). It mainly feeds on plants in the reed beds area (Diemer 1996 – P), particularly on common reed (*Phragmites communis*), and only one individual is able to cut 1.5 m2 of reed during the night (Burghause 1988 – P). In a study conducted on the Valaam Island in the European part of Russia, the share of cane in the vegetation complex decreased from 16.6% to 5.4% after introducing the muskrat (Smirnov and Tretyakov 1998 – P). Muskrats chew primarily on rhizomes and cut lower parts of plants, and in winter they bite plants at their roots, as a result, they remove much more vegetation than they actually eat (Smirnov and Tretyakov 1998 – P). One individual per day will bite 4 times more vegetation than the mass of its body, eats 25% of the plant mass (Birnbaum 2013 – B), and uses a large part for the construction of shelters. Thus, with high population density, it significantly affects coastal vegetation. In addition, it may contribute to reducing the number of rare species of aquatic plants (Skyriene and Paulauskas 2012 – P). Muskrats can supplement their diet with small vertebrates (fish, amphibians, reptiles) and molluscs, crustaceans and water insects exerting strong pressure on some endangered species, for example clams from *Anodonta* and *Unio* genera, and *Margaritifera margaritifera* pearlfish (Hochwald 1990 – P, Zimmermann et al. 2000 – P, Skyriene and Paulauskas 2012 – P). Indirectly, its predation on molluscs may affect some species of fish, including protected species such as rosacea, which developmental cycle requires the presence of suitable mollusc species in the water reservoir (Smith et al. 2004 – P).

a14. The effect of *the species* on native species, through **competition** is:

X	low
	medium
	high

aconf10.	Answer provided with a	low	medium	high **X**	level of confidence

acomm14. Comments:

The most likely competitors of muskrat in Europe are European water vole (*Arvicola terrestris*) and European beaver (*Castor fiber*), which inhabit the same biotope, and additionally in the case of vole – they eat the same food (Wilner et al. 1980 – P, Prūsaitė et al. 1988, Skyriene and Paulauskas 2012 – P). However, there is no clear scientific evidence for direct competition between these species. Conducted research on habitat selectivity of three rodent water species: beaver, nutria and muskrat, do not confirm the hypothesis about competition between beaver and muskrat (Ruys et al. 2011 – P).

a15. The effect of *the species* on native species, through **interbreeding** is:

X	no / very low
	low
	medium
	high
	very high

aconf11.	Answer provided with a	low	medium	high **X**	level of confidence

acomm15. Comments:

There are no scientific reports on the possibility of muskrat interbreeding with native species, because muskrat is not closely related to naturally occurring rodent species in Poland.

a16. The effect of *the species* on native species by **hosting pathogens or parasites** that are harmful to them is:

	very low
	low
	medium
	high
X	very high

aconf12.	Answer provided with a	low	medium	high **X**	level of confidence

acomm16. Comments:

Muskrats are a reservoir of various parasites that can have a negative impact on wild animals (Branquart et al. 2011 – B). In the entire range of species, muskrat is a carrier of nearly 100 pathogens (Grabda 1954 – P, Skyriene and Paulauskas 2012 – P, Najberek 2018 – N). In North America, in the natural range, 66 species of internal parasites were found in the muskrat: 36 species of trematoda, 11 species of tapeworms, 15 species of nematodes and 4 species of acanthocephalans (Jilek 1977 – P). The most common are: *Echinostoma revolutum*, *Plagiorchis proximus* and *Quinqueserialis quinqueserialis* trematoda; *Trichuris opaca* nematode and *Hymenolepis* spp. and *Taenia taeniaeformis* tapeworms (Willner et al. 1980 – P). After introduction to Europe, the species took over many European parasites, and Hoffmann (1958 – P) confirmed that there are 41 species of trematoda, 22 species of tapeworms and 27 species of nematodes found in muskrat. In Lithuania, 5 species of trematoda (*Echinostoma* sp., *Plagiorchis elegans*, *Skrjabinoplagiorchis ondatrae*, *Psilotrema spiculigerum*, *P. simillimum*) and 3 species of tapeworms (*Hydatigera taeniaeformis*, *Tetratirotaenia polyacantha*, *Echinococcus multilocularis*) were found in muskrats (Mazeika et al. 2003 – P, Mazeika et al. 2009 – P). All these species of parasites are found in Europe in many species of aquatic birds and mammals. The biggest threat is the transfer of *Echinococcus multilocuralis* (echinococcosis may lead to animal death) and Q fever (diseases from the OIE list). Various authors indicate that up to 28% of the population of this species is infected. The ultimate hosts are predatory mammals. When the ultimate host catches the rodent, adult tapeworms grow in its small intestine. Because the muskrat is among the victims of the *Vulpes vulpes fox* and *Nyctereutes procyonoides* racoon dog, the infected rodents are a source of infection for predatory mammals (Reinhardt et al. 2003 – P).

a17. The effect of *the species* on ecosystem integrity, by **affecting its abiotic properties** is:

	low
	medium
X	high

aconf13.	Answer provided with a	low	medium	high **X**	level of confidence

acomm17. Comments:

Muskrat affects the abiotic factors of the ecosystem by eating a large amount of aquatic vegetation. It eats a mass of vegetable food that is equal to its body weight, producing a large volume of feces falling into the water (Birnbaum 2013 – B). The effect of this may be the change of some water quality parameters, such as: water temperature, oxygen content, pH, conductivity and content of organic sediments (de Szalay and Cassidy 2001 – P).

Furthermore, the dynamics of soil nitrogen changes, which is an important element of the marshy and wetland communities (Connors et al 2000 – P). The impact of the species was therefore rated as large, i.e. in the worst case, the species can cause hardly reversible changes regarding processes occurring in special care habitats, e.g. 3130 habitat- standing waters, oligotrophic to mesotrophic, with *Littorelletea uniflorae* and/or *Isoëto-Nanojuncetea* vegetation, or 3270-rivers-with-muddy-banks with *Chenopodium rubri* p.p. *Bidention* p.p. vegetation.

a18. The effect of *the species* on ecosystem integrity, by **affecting its biotic properties** is:

	low
	medium
X	high

aconf14.	Answer provided with a	low	medium	high **X**	level of confidence

acomm18. Comments:

Muskrat affects the integrity of ecosystems by strongly reducing plant mass, changing the species composition and vegetation structure, and creating muddy backshores. This significantly changes the habitat conditions for fish and aquatic invertebrates, including species of special care, making them more vulnerable to predation (Birnbaum 2013 – B, Triplet 2015 – B). The number of convenient places for spawning and raising fry is also decreasing. By eating the molluscs, particluarly from *Anodonta* and *Unio* genera, muskrats have an indirect negative impact on some species of fish, e.g. Amur bitterling, which developmental cycle requires the presence of suitable mollusc species in the water reservoir. Muskrats also reduce the overall ecological value of wetlands, by destroying aquatic vegetation and eating protected and endangered species of plants and animals (Triplet 2015 – B). On the other hand, muskrat activity can increase the species diversity of plants, limiting the range (and biomass) of the *Typha angustifolia* narrowleaf cattail (Connors et al 2000 – P). Furthermore, the diversity of microspheres created by the muskrat, the formation of a mosaic of open surfaces among compact aquatic vegetation is important for the feeding of ducks, especially chicks, in the open water (Nummi et al. 2006 – P). The impact of the species was therefore rated as large, i.e. in the worst case, the species can cause hardly reversible changes regarding processes occurring in special care habitats, e.g. 3130 oligotrophic to mesotrophic, with *Littorelletea uniflorae* and/or *Isoëto-Nanojuncetea* vegetation.

A4b | Impact on the cultivated plants domain

Questions from this module qualify the consequences of *the species* for cultivated plants (e.g. crops, pastures, horticultural stock).

For the questions from this module, consequence is considered 'low' when presence of *the species* in (or on) a population of target plants is sporadic and/or causes little damage. Harm is considered 'medium' when *the organism's* development causes local yield (or plant) losses below 20%, and 'high' when losses range >20%.

a19. The effect of *the species* on cultivated plant targets through **herbivory or parasitism** is:

	inapplicable
	very low
X	low
	medium
	high
	very high

aconf15.	Answer provided with a	low	medium	high **X**	level of confidence

acomm19.	Comments: In the natural range of occurrence, muskrat species cause quite significant damage to agricultural crops near reservoirs and watercourses where they live (Baker 1983 – P). In Europe, the influence of these rodents on crops, mainly maize and sugar beet (Becker 1972 – P) has been rather low, thus the impact was rated as low. The probability of impact on crops was estimated as medium (it will affect 1/3-2/3 of target crops) and the impact – as low (the condition of plants or yield will be decreased by less than 5%).

a20. The effect of *the species* on cultivated plant targets through **competition** is:

X	inapplicable
	very low
	low
	medium
	high
	very high

aconf16.	Answer provided with a	low	medium	high	level of confidence

acomm20.	Comments: The species is an animal.

a21. The effect of *the species* on cultivated plant targets through **interbreeding** with related species, including the plants themselves is:

X	inapplicable
	no / very low
	low
	medium
	high
	very high

aconf17.	Answer provided with a	low	medium	high	level of confidence

acomm21.	Comments: The species is an animal.

a22. The effect of *the species* on cultivated plant targets by **affecting the cultivation system's integrity** is:

X	very low
	low
	medium
	high
	very high

aconf18.	Answer provided with a	low	medium	high **X**	level of confidence

acomm22.	Comments: The essential part of the muskrat diet is aquatic vegetation, and in Europe, damage to plant crops occurs only sporadically and is rather small (Becker 1972 – P). Thus, the impact of the species on the condition or yield of crop plants by changing the agro-ecosystem properties, including the circulation of elements, hydrology, physical properties, trophic networks, etc., will be very small.

a23. The effect of *the species* on cultivated plant targets by hosting **pathogens or parasites** that are harmful to them is:

X	very low
	low
	medium
	high
	very high

aconf19.	Answer provided with a	low	medium	high **X**	level of confidence

acomm23.	Comments: There is no literature information about the species being the host or vector of pathogens and parasites harmful to plants.

A4c | Impact on the domesticated animals domain

Questions from this module qualify the consequences of *the organism* on domesticated animals (e.g. production animals, companion animals). It deals with both the well-being of individual animals and the productivity of animal populations.

a24. The effect of *the species* on individual animal health or animal production, through **predation or parasitism** is:

	inapplicable
X	very low
	low
	medium
	high
	very high

aconf20.	Answer provided with a	low	medium	high **X**	level of confidence

acomm24.	Comments: Muskrat is a herbivorous species, but complements its diet with aquatic invertebrates or small vertebrates (Willner et al. 1980 – P). Therefore, it does not affect the health of a single animal or animal production through predation or parasitism.

a25. The effect of *the species* on individual animal health or animal production, by having properties that are hazardous upon **contact**, is:

X	very low
	low
	medium
	high
	very high

aconf21.	Answer provided with a	low	medium	high **X**	level of confidence

acomm25.	Comments: Generally, the species has no biological, physical and / or chemical properties that are harmful when in contact with farm animals and domestic animals or for animal production (e.g., toxins or allergens). Muskrats have sharp incisors and only in the absence of the possibility of escape and danger to life, they can defend themselves very aggressively (Danell 1996), which can result, for example, in biting of domestic animals, especially dogs.

	The probability of direct contact is low (less than 1 case per 100 000 animals per year) and the consequences are low (full recovery).

a26. The effect of *the species* on individual animal health or animal production, by hosting **pathogens or parasites** that are harmful to them, is:

	inapplicable
	very low
	low
	medium
	high
X	very high

aconf22.	Answer provided with a	low	medium	high **X**	level of confidence

acomm26. Comments:

Muskrats are carriers of several dozen different parasites: trematodes, tapeworms, nematodes and headed worms that can have a negative impact on the health of an individual animal and animal husbandry (Hoffmann 1958 – P, Jilek 1977 – P, Willner et al. 1980 – P, Branquart et al. 2011 – B). Many of these parasites can lead to a decline in physical condition, weakness and even death of domestic and farm animals. *Echinococcus multilocularis* (OIE list) is particularly dangerous, and 28% of the population of these rodents may be infected (Ahlmann 1997 – P, Romig 1999 – P). This tapeworm is found, among others in dogs and cats that are its final hosts (just like other predatory mammals). After eating the rodent in the small intestine of the final host, adult tapeworms develop. It was also found that muskrat is a carrier of pathogenic protozoa of the *Cryptosporidium* genus, causing diseases of the digestive system of many species of animals (Zhou et al 2004 – P).

A4d | Impact on the human domain

Questions from this module qualify the consequences of *the organism* on humans. It deals with human health, being defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (definition adopted from the World Health Organization).

a27. The effect of *the species* on human health through **parasitism** is:

X	inapplicable
	very low
	low
	medium
	high
	vert high

aconf23.	Answer provided with a	low	medium	high	level of confidence

acomm27. Comments:

This species is not a parasite.

a28. The effect of *the species* on human health, by having properties that are hazardous upon **contact**, is:

X	very low
	low
	medium
	high
	very high

aconf24.	Answer provided with a	low	medium	high **X**	level of confidence

acomm28. Comments:

Muskrats are small, mainly herbivorous, rodents. However, they have sharp incisors and are able to use them by strongly biting in a situation where they are at risk and are unable to escape. They can then defend themselves very vigorously and even attack a man (Danell 1996). However, this probability is low: there is less than one contact per 100,000 people in a year, and consequences are reversible do not lead to permanent disability.

a29. The effect of *the species* on human health, by hosting **pathogens or parasites** that are harmful to humans, is:

	inapplicable
	very low
	low
	medium
	high
X	very high

aconf25.	Answer provided with a	low	medium	high **X**	level of confidence

acomm29. Comments:

Dozens of species of parasites and various types of pathogens were found in the muskrat (Hoffmann 1958 – P, Willner et al. 1980 – P, Branquart et al. 2011 – B), some of them may even infect humans, usually through the muskrat-domestic animal-human route (Reinhardt et al. 2003 – P). Among the dangerous tapeworms there are *Taenia hydatigena*, *Taenia taeniaformis*, and especially a tapeworm *Echinococcus multilocarus* (OIE list) (Böhmer et al. 2001 – P), causing echinococcosis. For this parasite, man is an intermediate – accidental host. After accidental ingestion of the eggs, the oncosphere released in the small intestine penetrates blood vessels and most of them (99% of cases) enter the liver. The connective tissue develops and infiltrates reminiscent of neoplastic changes are formed. The course of the disease is chronic, clinical symptoms appear after 5-15 years. Echinococcosis treatment is long and expensive. The mortality rate of untreated patients exceeds 90% within 10 years of diagnosis, in patients undergoing surgery and chemotherapy, it drops to 10-14% (Gawor et al 2008 – P). The muskrat can also be a source of many dangerous diseases caused by the pathogens it carries: bacteria, e.g. leptospirosis, tularemia (Hatler et al. 2003 – I) and protozoa, e.g. cryptosporidiosis (Zhou et al 2004 – P) and giardiasis (Hatler et al. 2003 – I). A human may get infected by drinking unboiled water contaminated by these pathogenic organisms (Hatler et al. 2003 – I).

A4e | Impact on other domains

Questions from this module qualify the consequences of *the species* on targets not considered in modules A4a-d.

a30. The effect of *the species* on causing damage to **infrastructure** is:

	very low
	low
	medium
	high
X	very high

aconf26.	Answer provided with a	low	medium	high **X**	level of confidence

acomm30.	Comments: Muskrats dig burrows (usually with underwater entrance, 15-20 cm in diameter), which are their daily shelters, breeding sites and food stores, in the banks of watercourses and reservoirs, and in earth structures built by man. Burrows weaken and destroy floodbanks, dams of fish ponds and other water reservoirs, road and railway embankments or bridgeheads. All these constructions may be consequently interrupted by water pressure, which may result in losses in agriculture, fishing industry and aquaculture, as well as damage to property and threat to human life (Becker 1972 – P, Skyriene and Paulauskas 2012 – P). In Germany, it was estimated that in the years 1996-1997 the total costs associated with losses caused by muskrat and expenditures incurred to reduce the number of these rodents amounted to more than 12 million euro per year, and the expenses incurred as a result of damage done by muskrat on roads and water reservoirs reached 2,5 million euros (Reinhardt and others 2003 – P). In the Netherlands, the costs of very intense control of Muskrat numbers (elimination of all techniques across the country and throughout the year, with the exception of poison) amounted to 35 million euro in 2007 (Bos and Ydenberg 2011 – P).

A5a | Impact on ecosystem services

Questions from this module qualify the consequences of *the organism* on ecosystem services. Ecosystem services are classified according to the Common International Classification of Ecosystem Services, which also includes many examples (CICES Version 4.3). Note that the answers to these questions are not used in the calculation of the overall risk score (which deals with ecosystems in a different way), but can be considered when decisions are made about management of *the species*.

a31. The effect of *the species* on **provisioning services** is:

	significantly negative
X	moderately negative
	neutral
	moderately positive
	significantly positive

aconf27.	Answer provided with a	low	medium	high **X**	level of confidence

acomm31.	Comments: Muskrats only sporadically feed on crop plants and cause little local damage, which is why a small negative impact on plant production is estimated. It is possible that in case of breaking of dams of fish ponds, there may be significant losses in the fishing industry. It seems, however that decrease in the muskrat population in recent years (Brzeziński et al. 2010 – P, Romanowski and Karpowicz 2013 – P) showed that this is not a significant problem in Poland. This is confirmed by surveys carried out in 2003-2004 in eastern Poland: in the vast majority of cases, the muskrat was not perceived as a species that poses economic problems. Species particularly conflicting for fish farmers were: cormorant, gray heron, beaver and otter (Kloskowski 2011 – P).

a32. The effect of *the species* on **regulation and maintenance services** is:

X	significantly negative
	moderately negative
	neutral
	moderately positive
	significantly positive

aconf28.	Answer provided with a	low	medium	high **X**	level of confidence

acomm32.	Comments: Muskrats, especially if they reach a high population density, can have a negative impact on the degree of flood protection (Birnbaum 2013 – B). Floodbanks and banks of watercourses and reservoirs may be weakened by burrows dug in them, which may be broken in case of higher water levels. Due to carrying several dozen pathogens, the species affects the regulation of zoonoses.

a33. The effect of *the species* on **cultural services** is:

	significantly negative
X	moderately negative
	neutral
	moderately positive
	significantly positive

aconf29.	Answer provided with a	low	medium	high **X**	level of confidence

acomm33.	Comments: By digging burrows, thereby weakening the banks of watercourses and reservoirs, muskrats increase the risk of human injuries or animals grazed on the river banks. Collapsing burrows are also a hazard to drivers (bicycles, motorcycles, cars). This may lead to accidents during recreational activity.

A5b | Effect of climate change on the risk assessment of the negative impact of *the species*

Below, each of the Harmonia^{+PL} modules is revisited under the premise of the future climate. The proposed time horizon is the mid-21st century. We suggest taking into account the reports of the Intergovernmental Panel on Climate Change. Specifically, the expected changes in atmospheric variables listed in its 2013 report on the physical science basis may be used for this purpose. The global temperature is expected to rise by 1 to 2°C by 2046-2065.

Note that the answers to these questions are not used in the calculation of the overall risk score, but can be but can be considered when decisions are made about management of *the species*.

a34. INTRODUCTION – Due to climate change, the probability for *the species* to overcome geographical barriers and – if applicable – subsequent barriers of captivity or cultivation in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf30.	Answer provided with a	low	medium	high **X**	level of confidence

acomm34.	Comments: In Poland muskrats inhabit the whole country, it is our established species (Okarma 2011 – P, 2018 – B), therefore climate change will not affect its introduction.

a35. ESTABLISHMENT – Due to climate change, the probability for *the species* to overcome barriers that have prevented its survival and reproduction in Poland will:

	decrease significantly
	decrease moderately
X	not change

	increase moderately
	increase significantly

aconf31.	Answer provided with a	low	medium	high **X**	level of confidence

acomm35. Comments:

In Poland muskrats inhabit the whole country, it is our established species (Okarma 2011 – P, 2018 – B), therefore climate change will not affect this situation.

a36. SPREAD – Due to climate change, the probability for *the species* to overcome barriers that have prevented its spread in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf32.	Answer provided with a	low	medium	high **X**	level of confidence

acomm36. Comments:

In Poland muskrats inhabit the whole country, it is our established species (Okarma 2011 – P, 2018 – B), therefore climate change will not affect its spreading.

a37. IMPACT ON THE ENVIRONMENTAL DOMAIN – Due to climate change, the consequences of *the species* on wild animals and plants, habitats and ecosystems in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf33.	Answer provided with a	low	medium **X**	high	level of confidence

acomm37. Comments:

Predicted climate changes will not change the scale of the species impact on wild plants and animals, as well as habitats and ecosystems in Poland, as the species already occurs throughout the country.

a38. IMPACT ON THE CULTIVATED PLANTS DOMAIN – Due to climate change, the consequences of *the species* on cultivated plants and plant domain in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf34.	Answer provided with a	low	medium **X**	high	level of confidence

acomm38. Comments:

Predicted climate changes will not change the scale of the species impact on crops or crop production in Poland, since the species already occurs throughout the country and its impact on crops remains low.

a39. IMPACT ON THE DOMESTICATED ANIMALS DOMAIN – Due to climate change, the consequences of *the species* on domesticated animals and animal production in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf35.	Answer provided with a	low	medium **X**	high	level of confidence

acomm39. Comments:

Predicted climate changes will not change the scale of the species impact on farm and domestic animals, as well as animal production in Poland, since the species already occurs throughout the country and its impact on domesticated animals and animal production remains low.

a40. IMPACT ON THE HUMAN DOMAIN – Due to climate change, the consequences of *the species* on human in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf36.	Answer provided with a	low	medium **X**	high	level of confidence

acomm40. Comments:

Predicted climate changes will not change the scale of the species impact on humans in Poland. The species occurs throughout the country and probability of direct contact is low.

a41. IMPACT ON OTHER DOMAINS – Due to climate change, the consequences of *the species* on other domains in Poland will:

	decrease significantly
	decrease moderately
X	not change
	increase moderately
	increase significantly

aconf37.	Answer provided with a	low	medium **X**	high	level of confidence

acomm41. Comments:

Predicted climate changes will not change the scale of the species impact on other objects in Poland. The species occurs throughout the country.

Summary

Module	Score	Confidence
Introduction (questions: a06-a08)	1.00	1.00
Establishment (questions: a09-a10)	1.00	1.00
Spread (questions: a11-a12)	0.50	1.00

Environmental impact (questions: a13-a18)	0.67	1.00
Cultivated plants impact (questions: a19-a23)	0.08	1.00
Domesticated animals impact (questions: a24-a26)	0.33	1.00
Human impact (questions: a27-a29)	0.50	1.00
Other impact (questions: a30)	1.00	1.00
Invasion (questions: a06-a12)	0.83	1.00
Impact (questions: a13-a30)	1.00	1.00
Overall risk score	0.83	
Category of invasiveness	very invasive alien species	

A6 | Comments

This assessment is based on information available at the time of its completion. It has to be taken into account, however, that biological invasions are, by definition, very dynamic and unpredictable. This unpredictability includes assessing the consequences of introductions of new alien species and detecting their negative impact. As a result, the assessment of the species may change in time. For this reason it is recommended that it is regularly repeated.

acomm42. Comments:
–

Data sources

1. Published results of scientific research (P)

Ahlmann V-P. 1997. Epidemologische Untersuchung zum Vorkommen der Tollwut und des kleinen Fuchsbandwurmes, *Echinococcus multilocaris* im Saarland. Inaugural-Dissertation, Freie Universität, Berlin

Aubry JR. 1959. The muskrat in Brittany. (Le Rat musqué en Bretagne). Penn Ar Bed. 2: 10-12

Baker RH. 1983. Michigan Mammals. 642 pp. Michigan State University Press

Barends F. 2002. The Muskrat (*Ondatra zibethicus*): expansion and control in the Netherlands. Lutra 45: 97-104

Becker K. 1972. Muskrats in Central Europe and their control. Proceedings of the 5th Vertebrate Pest Conference 6: 18-21

Böhmer HJ, Heger T, Trepl L. 2001. Fallstudien zu gebietsfremden Arten in Deutschland – Case studies on Aliens Species in Germany. Texte des Umweltbundesamtes 13: 1-126

Bos D, Ydenberg R. 2011. Evaluation of alternative management strategies of muskrat *Ondatra zibethicus* population control using a population model. Wildlife Biology 17: 143-155

Brzeziński M, Romanowski J, Żmihorski M, Karpowicz K. 2010. Muskrat (*Ondatra zibethicus*) decline after the expansion of American mink (*Neovison vison*) in Poland. European Journal of Wildlife Research 56: 341-348 (DOI 10.1007/s10344-009-0325-9)

Burghause F. 1996. 40 Jahre Bisam in Rheinland-Pfalz. Die Bedeutung eines eingewanderten Nagers und die Bemühungen, seinen Schaden einzudämmen. Mainzer naturwiss. Archiv 34: 119-138

Connors LM, Kiviat E, Groffman PM, Ostfeld RS. 2000. Muskrat (*Ondatra zibethicus*) disturbance to vegetation and potential net nitrogen mineralization and nitrification rates in a freshwater tidal marsh. American Midland Naturalist 143: 53-63

Danell K. 1977. Short-term plant succession following the colonization of a northern Swedish lake by the muskrat, *Ondatra zibethica*. Journal of Applied Ecology 14: 933-347

Danell K. 1996. Introduction of aquatic rodents: lessons of the *Ondatra zibethicus* invasion. Widlife biology 2: 213-220

De Szalay FA, Cassidy W. 2001. Effects of Muskrat (*Ondatra zibethicus*) Lodge Construction on Invertebrate Communities in a Great Lakes Coastal Wetland. American Midland Naturalist 146: 300-310

Diemer B. 1996. Der Bisam (*Ondatra zibethicus*) in Baden-Württemberg. In: Verein der Freunde und Förderer der Akademie für Natur- und Umweltschutz (Umweltakademie) beim Ministerium für Umwelt und Verkehr Baden-Württemberg (Hrsg.), Neophyten, Neozoen – Gefahr für die heimische Natur? Beiträge der Akademie für Natur- und Umweltschutz Baden-Württemberg 22: 182-186

Gawor J, Borecka A, Malczewski A. 2008. Zarażenie lisów bąblowcem wielojamowym jako potencjalne zagrożenie dla ludzi w Polsce. Życie Weterynaryjne 83: 24-27

Gosling LM, Baker SJ. 1989. The eradication of coypus and muskrats from Britain. Biological Journal of the Linnean Society. Vol. 38: 39-51. Biological Journal of the Linnean Society 38: 39-51

Grabda J. 1954. Pasożyty wewnętrzne piżmaka (*Ondatra zibethica* L.) z okolic Bydgoszczy. Pamiętniki z III Zjazdu Polskiego Towarzystwa Parazytologicznego, 6-7 września 1952: 155-156

Hochwald S. 1990. Bestandsgefährdung seltener Muschelarten durch den Bisam (*Ondatra zibethica*). Schriftenr. Bayer. Landesamt für Umweltschutz 97: 113-114

Hoffmann M. 1958. Die Bisamratte. Ihre Lebensgewohnheiten, Verbreitung, Bekämpfung und Wirtschaftliche Bedeutung. 260 pp. Akademische Verlagsgesellshaft Geest & Portig K. G., Leipzig, Germany

Jilek R. 1977. Trematode parasites of the muskrat, *Ondatra zibethicus*, in southern Illinois. Transactions of the Illinois State Academy of Sciences 70: 105-107

Kloskowski J. 2011. Human–wildlife conflicts at pond fisheries in eastern Poland: perceptions and management of wildlife damage. European Journal of Wildlife Research 57: 295-304

Krauss M. 1990. Die Nahrung des Bisams (*Ondatra zibethicus*) an der Havel in Berlin-West und der schädigende Einfluß auf das Röhricht. Landschaftsentw. u. Umweltforschung 71: 141-181

Mazeika V, Kontenyte R, Paulauskas A. 2009. New data on the helminths of the muskrat (*Ondatra zibethicus*) in Lithuania. Estonian Journal of Ecology 58: 103-111

Mazeika V, Paulauskas A, Balciauskas L. 2003. New data on the helminth fauna of rodents of Lithuania. Acta Zoologica Lituanica 13: 41-47

McConnell PA, Powers JL. 1995. Muskrat. In: Dove L, Nyman RM. (eds.). Living Resources of the Delaware Estuary, USA. pp. 507-513. The Delaware Bay Estuary Program

Nowak E. 1971. O rozprzestrzenianiu się zwierząt i jego przyczynach. Zeszyty Naukowe Instytutu Ekologii PAN 3: 1-255

Nummi P, Väänänen VM, Malinen J. 2006. Alien grazing: indirect effects of muskrats on invertebrates. Biological Invasions 8: 993-999

Okarma H. 2011. *Ondatra zibethicus* (Linnaeus, 1766). In: Głowaciński Z, Okarma H, Pawłowski J, Solarz W. (eds.). Gatunki obce w faunie Polski. I. Przegląd i ocena stanu. pp. 444-449 Instytut Ochrony Przyrody PAN w Krakowie

Pietsch M. 1982. *Ondatra zibethicus* (Linnaeus, 1766) – Bisamratte, Bisam. – In: J. Niethammer, F. Krapp (eds.). Handbuch der Säugetiere Europas 2: 177-192

Prūsaitė J, Maeikytė R, Paua D, Pauienė N, Baleiis R, Jukaitis R, Mickus A, Gruas A, Skeiveris R, Bluzma P, Bielova O, Baranauskas K, Mačionis A, Balčiauskas L, Janulaitis Z. 1988. Fauna of Lithuania. Mammals (in Lithuanian). Mokslas Publishers, Vilnius

Ramsgaard NR. 2005. Bisamrotten (*Ondatra zibethicus*) i Danmark – Status og konsekvensanalyse af bisamrottens udbredelse i Danmark. M.Sc. thesis, University of Aarhus, Denmark

Reinhardt F, Herle VM, Bastiansen F, Streit B. 2003. Economic impact of the spread of alien species in Germany. German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety. Texte 80: 43-47

Romanowski J, Karpowicz K. 2013. Zmiany w występowaniu piżmaka *Ondatra zibethicus* w centralnej i wschodniej Polsce w latach 1996-1997. Studia Ecologiae et Bioethicae 11(1): 49-61

Romig T. 1999. Vorkommen und Diagnostik von *Echinococcus multilocaris* bei Wildund Haustieren. Deutsche Tierärztliche Wochenschrift 106: 352-357

Ruys T, Lorvelec O, Marre A, Bernez I. 2011. River management and habitat characteristics of three sympatric aquatic rodents: common muskrat, coypu and European beaver European. Journal of Wildlife Research 57: 851-864

Skyriene G, Paulauskas A. 2012. Distribution of invasive muskrats (*Ondatra zibethicus*) and impact on ecosystem. Ekologija 58: 357-367

Smirnov VV, Tretyakov K. 1998. Changes in aquatic plant communitieson the island of Valaam due to invasion by the muskrat *Ondatra zibethicus* L. (Rodentia, Mammalia) Biodiversity and Conservation 7: 673 (https://doi.org/10.1023/A:1008860603166)

Smith C, Reichard M, Jurajda P, Przybylski M. 2004. The reproductive ecology of the European bitterling (*Rhodeus sericeus*) Journal of Zoology, Lond. 262: 107-124

Sokolov VE, Lavrov NP. 1993. The Muskrat. Morphology, Systematics, Ecology. 542 pp. Nauka, Moscow (in Russian)

Willner GR, Feldhamer GA, Zucker EE, Chapman JA. 1980. *Ondatra zibethicus*. Mammal. Species 141: 1-8

Zhou L, Fayer R, Trout JM, Ryan UM, Schaefer FW, Xiao L. 2004. Genotypes of *Cryptosporidium* Species Infecting Fur-Bearing Mammals Differ from Those of Species Infecting Humans. Microbiology 70: 7574-7577

Zimmermann U, Gorlach J, Ansteeg O, Bossneck U. 2000. Bestandsstützungsmaßnahme für die Bachmuschel (*Unio crassus*) in der Milz (Landkreis Hildburghausen). Landschaftspflege und Naturschutz in Thüringen 37: 11-16

2. Databases (B)

Birnbaum C. 2013. NOBANIS – Invasive Alien Species Fact Sheet – *Ondatra zibethicus*. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS (www.nobanis.org/globalassets/speciesinfo/o/ondatra-zibethicus/ondatra_zibethicus.pdf)

Branquart E, D'aes M, Manet B, Motte G, Schockert V, Stuyck J. 2011. *Ondatra zibethicus*. Invasive species in Belgium (http://ias.biodiversity.be/species/show/28)

Genovesi P. 2006. DAISIE Alien Species Factsheet *Ondatra zibethicus* (http://www.europe-aliens.org/speciesFactsheet.do?speciesId=52887)

Okarma H. 2018. Piżmak *Ondatra zibethicus* (Linnaeus, 1766) (http://www.iop.krakow.pl/ssaki/Gatunek.aspx?spID=64)

Triplet P. 2015. *Ondatra zibethicus* CABI. Invasive Species Compendium. Alien Species Factsheet. (www.cabi.org/isc/datasheet/71816)

3. Unpublished data (N)

Najberek K. 2018. (in preparation). Pathogens, parasites and disease of invasive alien species of European concern

4. Other (I)

Halter DF, Blood DA, Beal AMM. 2003. Furbearer management guidelines. Muskrat. British Columbia. British Columbia (www.env.gov.bc.ca/fw/wildlife/trapping/docs/muskrat.pdf)

5. Author's own data (A)

–