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# Distribution of invasive muskrats (*Ondatra zibethicus*) and impact on ecosystem

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The muskrat (*Ondatra zibethicus* L.) after being introduced to Europe quickly colonized new areas. They occupied Northern, Eastern and Central Europe. One of the reasons for their successful invasion into new areas was the release of animals in numerous places and their subsequent successful self-spreading from these places. However, this semi-aquatic rodent negatively impacts the ecosystem (causes damages of watercourse embankment through burrowing, consumes crops). The species possesses a high potential for both environmental and economic impact. Nowadays, following the successful widespread of this species, abundance of its population is reduced in some countries, e. g. Lithuania and Poland. The reasons for that can be ecological factors: availability of food, diseases, parasites and carnivore predators. Moreover, humans cause significant mortality of muskrats. The rodents are extensively trapped for fur, which is of increasing economic value around the world. The paper presents a review of the muskrat introduction history into Europe and whole Eurasia, distribution of the species, the factors important for population abundance increase and reduction, on genetics as well as muskrat invasion impact on non-native ecosystems for this species.

**Key words:** *Ondatra zibethicus*, acclimatization, predator, parasites, impact

## INTRODUCTION

For a long time muskrats were known as animals of economic importance in fur production (Becker, 1972; Genovesi, Scalera, 2008) as well as in breeding business (Birnbaum, 2006). Autoecological matters such as survival, range of expansion, population dynamics and management measures to increase fur yield were investigated (Smirnov, Tretyakov, 1998). In nature muskrats are important for many related organisms, as numerous vertebrates and invertebrates use muskrat lodges as nesting (Willner et al., 1980), resting, basking places, or residence sites (Feldhamer et al., 2003). Muskrats are very important as marsh managers, removing extra plants and making sure waterways are clear (Feldhamer et al., 2003). However, after acclimatization of muskrat in many countries; these animals negatively impacted many communities and ecosystems, caused unwanted damages.

## ORIGINAL DISTRIBUTION

The muskrat homeland is North America, from Northern Canada and South Alaska through the United States, except the arid regions of the Southwest and Texas, and the Florida peninsula (Musser, Carleton, 2005) (Fig. 1).

In North America there are known 16 subspecies of muskrat (*O. zibethicus*) (Lewis, 1998) (Fig. 1). It was presumed that first muskrats were introduced to Europe either from Alaska (Becker, 1972), i. e. the subspecies *O. zibethicus spatulatus*, or from Ohio, i. e. subspecies *O. zibethicus zalopus* (Sokolov, Lavrov, 1993). However, it was revealed that the rodents arrived from southeast Canada and the muskrats are related to the subspecies *O. zibethicus*

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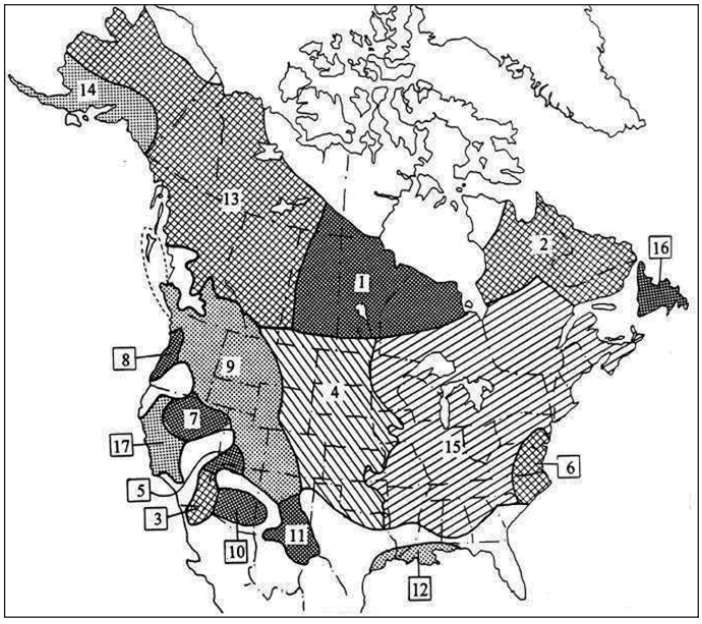


**Fig. 1.** The distribution of *O. zibethicus* subspecies of in North America: (1) *O.* ***z. albus***; (2) *O. z. aquihnis*; (3) *O. z. bemardi*; (4) *O. z. cinnamominus*; (5) *O.* ***z. roidmani***; (6) *O. z. macrodom*; (7) *O. z. mergens*; (8) *O. z. occipitalis*; (9) *O. z. osoyoosensis*; (10) *O. z. pallidus*; (11) *O. z. ripensis*; (12) *O.* ***z. rivalicus***; (13) *O. z. spatulatus*; (14) *O. z. zalaphus*; (15) *O. z. zibethicus*; (16) *O. z. obscurus*; (17) introduced *O. z. zibethicus* (Lewis, 1998)

*zibethicus* (Pietsch, 1970). Later, the muskrat was introduced to Europe repeatedly, and rodents from various parts of North America were transferred, thus now still remains unknown what subspecies live in Europe and Asia.

## ACCLIMATIZATION AND SPREADING

This American species was introduced to Europe and Asia throughout the Palaearctic regions (Genovesi, Scalera, 2008): Mongolia, northeast Korea, and Honshu Island, Japan (Bobrov et al., 2008; Musser, Carleton, 2005; Genovesi, Scalera, 2008) and Chinese territory, through rivers in northwestern border and northeastern border between the former Soviet Union and China (Xu et al., 2006). The muskrat was also introduced to South America, Argentina (Musser, Carleton, 2005; Genovesi, Scalera, 2008) and Chile (Genovesi, Scalera, 2008).

The muskrat successfully colonized many European countries (Brzeziński et al., 2010) from East Scandinavia, West France, North to Denmark, East to Ukraine, South to North Greece (Hoffmann, 1958; Prūsaitė, 1988; Sokolov, Lavrov, 1993; Žiemienė, Paulauskas, 2005) (Table, Fig. 2). Firstly, in Europe, five muskrats were released into the Dobrisch near Prague (around 1905) and later to the **Czech Republic** (since 1908) (Hoffmann, 1958; Prūsaitė, 1988; Sokolov, Lavrov, 1993).

Table. **The muskrat acclimatization in Eurasia**

| Years | Country |
|---|---|
| 1905 | Dobrich (Bulgaria) |
| 1908 | Czech Republic |
| 1914 | Germany |
| 1920 | Poland |
| | Finland |
| | France |
| 1927 | British Isles |
| 1928 | Belgium |
| 1928–1932 | Russia |
| 1930 | Switzerland |
| 1947 | Estonia |
| 1950 | Sweden |
| 1954 | Lithuania |
| 1961 | Latvia |
| 1980–1988 | Norway |
| 1989 | Denmark |

The muskrat was introduced from North America to **Austria** and **Hungary** in 1905: five pairs were released. At the end of 1927 it was estimated that 40% of Austrian territory was inhabited by muskrats, with population of about one hundred million of muskrats, which were spreading to neighbouring countries (Gosling, Baker, 1989).

Naturally the muskrats spread into **Poland** from Czech Republic in 1920 (Brzeziński et al., 2010). After 40 years, in Poland the muskrat population

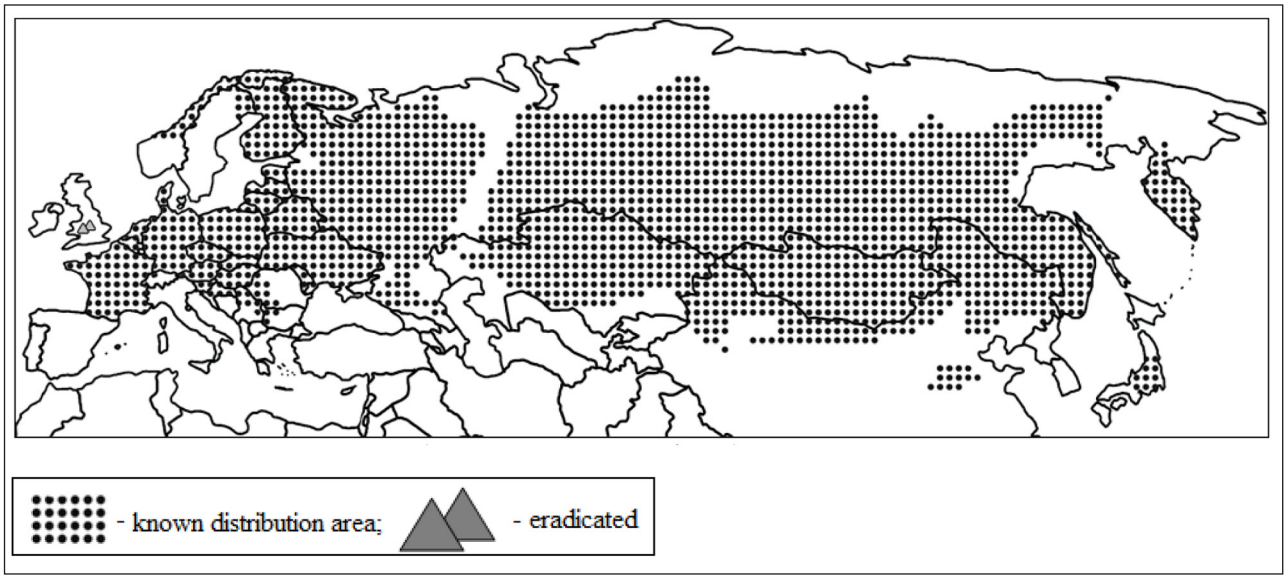


**Fig. 2.** The distribution of muskrat (*Ondatra zibethicus*) in Europe and Asia (after Genovesi, Scalera, 2008; Neronov et al., 2008)

was increasing and spread all over the country. Since 1980 the abundance of muskrat population started to decline (Brzeziński et al., 2010).

For financial reasons, about 1.100 individuals of muskrats were introduced from Germany, Czechoslovakia and North America to **Finland**. In Finland the first introductions were made in the 1920's and the 1930's, both farming and release were continued (Artimo, 1960). In total, the animals were released in 293 localities all over Finland (Birnbaum, 2006). Also, the muskrats were kept in cages but often escaped and spread over the neighbouring areas where they had been introduced, and thus quickly occupied most of the watercourses in Finland (Artimo, 1949).

In **France**, muskrat farms were founded in the southern Vosges Mountains after the World War I. When the price of muskrat fur plunged during the 1920s, a number of farms gave up and released the animals (e. g. 500 animals near Belfort in 1928). This population attained **Switzerland** and Alsace in 1930, and the Meuse and Moselle rivers in 1935. Naturally, the muskrats spread in Bavaria, Southern **Germany** in 1914 from Czech Republic (Becker, 1972). In southwestern Germany, *O. zibethicus* invaded the counties of Kehl, Offenburg and Lahr in 1932 and the counties of Lörrach, Freiburg, Emmen-dingen, Müllheim, and Säckingen in 1955. By 1980, muskrats had colonized every county in the State of Baden-Württemberg (Böhmer et al., 2000). *O. zibethicus* now became naturalized throughout all of Germany (Heidecke, Seide, 1986).

The muskrat was introduced to the **British Isles** in 1927 for fur farming (Hoffmann, 1958) but was sucessfully eradicated in 1939 (Hoffmann, 1958; Sokolov, Lavrov, 1993) and repeated introduction of *O. zibethicus* is prohibited by law (Becker, 1972).

In **Belgium**, the muskrats were released in 1928 (Lambot, 1993; Mathy et al., 2009).

The acclimatization of muskrat in **Russia** (the Soviet Union) started in 1928–1932 (Bobrov et al., 2008; Hoffmann et al., 1958) with animals originating from Finland, Canada and England (Birnbaum, 2006). In 1927, ten *O. zibethicus* were introduced from Finland to Russia and twenty individuals were released near the islands of Solovets (Lavrov, 1957). Starting from 1928, muskrats were released in massive numbers in the territory all over the Soviet Union. By 1955 there were about 160.000 muskrats in large areas near different water bodies (Lavrov, 1957). The animals were released mainly in the areas with low agricultural activity, taking into consideration the risk of damage to dams and other constructions in water (Danell, 1996). Until 1932, above 1600 muskrats were introduced from Finland, Canada and England (Bobrov et al., 2008; Hoffmann et al., 1958; Prūsaitė, 1988). During

1931–1936 about 1000 muskrats were transferred to the Kola Peninsula in the far northwest of Russia. After 20 years *O. zibethicus* has spread all over the Peninsula (Semenov-Tyan-Shanskii, 1987). In 1970 the muskrat has occupied almost all suitable territories in Russia; spreading over Russia from the western border up to Kamchatka (Bobrov et al., 2008) (Fig. 2).

Around 1950 muskrats were introduced to Northern **Sweden** from Finland (Danell, 1977; Artimo, 1960) and is currently spreading southwards at a dispersal rate of approx. 3 km / year (Danell, 1977).

Between 1980 and 1988 the muskrat introduction was accomplished in **Norway** and in 1996 *O. zibethicus* has spread almost over all parts of the country (Danell, 1996).

It is supposed that the first muskrats in **Denmark** were from the island of Rømø in 1989 (Ramsgaard, Christensen, 2006 by Birnbaum, 2006). Since 2000 regular *O. zibethicus* activity has been observed in the southern parts of Denmark close to the German border (Ramsgaard, 2007). Researchers forecast that the muskrat will continue its spread all over Denmark during the course of the 21st century.

## BALTIC COUNTRIES

190 animals of *O. zibethicus* were introduced in 1947 and 361 animal in 1952 to water bodies in the southern and western parts of **Estonia** (Birnbaum, 2006).

In 1951, 114 muskrats from Arkhangelsk (Russia, the former Soviet Union) were released into a tributary of the Nemunas River near the Curonian Lagoon (Slavsk District, Kaliningrad Region, Russia) (Lavrov, 1957). In 1954 the muskrat *O. zibethicus* was introduced to **Lithuania** as a precious furry animal and for financial reasons from Arkhangelsk (82 individuals) into Eastern Lithuania and in 1956 from Kazakhstan (204 individuals) into Eastern and Southern Lithuania (Prūsaitė, 1988). In Lithuania the distribution of muskrat can be divided into 3 periods. The first period (1954–1965) was characterized by the muskrat population increase and expansion in the area. In 1965 approximately 9600 muskrats were present but in 1966 the number of this rodent suddenly decreased to 2300, however, the expansion did not change. During the second period (1967–1975) the muskrat population started to recover and increase again. At the end of this period the number of muskrats was recorded as the peak reaching 40 thousand animals in Lithuania. Later the population of muskrat has decreased to 15 or 17 thousand individuals (this population level remained from 1976 until 1988) and still is reducing. Recently, the number of muskrat dropped down to 2000 individuals. About 70% of muskrats live in the southern and eastern parts of Lithuania (Prūsaitė, 1988; Žiemienė, Paulauskas, 2005). In the northern and western parts of the country muskrat is not found.

The first record of muskrat in **Latvia** is from 1961. The animal spread from Belarus and later from Estonia and Lithuania (Ozols, 1997).

The muskrat has also spread to other countries of Europe.

## THE SUCCESS OF INTRODUCTION

The majority of researchers attribute the success of muskrat (semi-aquatic mammal) introduction to the following factors: a large native range, high abundance in the native range, high vagility, broad diet, relatively short generation time, possibility to colonize a new locality by a single pregnant female, larger size compared to most "relatives" and ability to survive and reproduce in a wide range of physical conditions (Danell, 1996). Moreover, spreading success could be determinated by climate and vegetation similarities in the native and newly introduced habitats, similarities in the predator fauna (American mink) between the native and the introduced (Bobrov et al., 2008, Danell, 1996). Besides, the muskrat found an ecological niche, which had not been occupied (Danell, 1996).

## THE CAUSES OF POPULATION DECLINE

During the period of the last 20 years the number of muskrat has significantly reduced in several European countries, including a large area of Russia (Bobrov, 2008; Brzeziński et al., 2010). The factors limiting muskrat populations include food, parasites, predators, accidents, climatic factors, intraspecific competition (including fighting) and exploitation of resources. These factors vary widely by area, season and muskrat population density present in the area (Feldhamer et al., 2003).

**Food and habitat conditions**

Feeding conditions (food supply, overpopulation, range damage and consequent starvation) are the most important factor for population regulation and the reason for muskrat population cycling (O'Neil, 1949; Feldhamer et al., 2003). The decrease in population number was associated with less dense vegetation thus influencing lighter average weight of animal, a shorter breeding season, fewer and smaller litter (Feldhamer et al., 2003).

Abundant muskrat populations are able to reduce vegetation. In case the habitat is poor, the plants have a lower potential to recover compared to that in a habitat where plants are abundant and rich with nutrients. In poor habitats, which have been occupied by the muskrat following introduction (during the invasion phase), only steady drop in herbivore abundance allows vegetation to recover. Thus, the initial habitat changes caused by the muskrat are reversible, and recovery takes approximately a few years on average. Thus during the invasion phase an extremely high muskrat density may be reached for a few years, and most likely the population level will decrease after the invasion phase (Bobrov, 2008; Danell, 1996; Kadlec et al., 2007).

It is well known that muskrat density is related to habitat quality (Brzeziński et al., 2010). In Finland and Poland the most abundant muskrat populations were recorded in eutrophic water systems with intensive cultivation (Artimo, 1960; Brzeziński et al., 2010). Muskrats are sensitive to changes in water level and habitat conditions as the changes can dramatically increase mortality and population abundance (Brzeziński et al., 2010). Muskrat population size and mortality depend on water pH, salinity, dissolved oxygen, water tables, food plant species composition (Ferrigno, 1967), as well as on floods and hurricanes (Feldhamer et al., 2003).

**Parasites**

Parasites may reduce muskrat populations to a great extent. Trematodes are the dominant helminthic parasites of muskrat, and this is related to the environmental peculiarities of the species: water bodies are rich with intermediate hosts of parasites, namely molluscs. The most widely (geographically) distributed species of parasitic helminths are the following: *Plagiorchis eutamiatis zibethica*, *Notocotylus quinqueserialis* and *Echinostoma armigerum* (Mažeika et al., 2003).

In North America there were revealed 66 species of parasitic helminths within muskrats: 36 trematodes, 11 cestodes, 15 nematodes and 4 acanthocephalans (Jilek, 1977). The most common species are trematodes *Echinostoma revolutum*, *Plagiorchis proximus* and *Quinqueserialis quinqueserialis*; nematode *Trichuris opaca* and cestodes *Hymenolepis* spp. and *Taenia taeniaeformis* (Willner et al., 1980).

Notably, during the acclimatization of the muskrat, new parasite species could be introduced. In the former USSR helminths of American origin were revealed while carrying out parasitological studies of the muskrat. According to Lavrov (1957), 28 species of parasites could be transferred into the USSR from North America during the introduction of muskrat. However, only 4 species survived: 2 species of trematodes (*Notocotylus quinquenserialis*, *Echinostoma armigerum*) and 2 species of nematodes (*Longistriata dalrymplei* and *Rodentocaulus ondatrae*). In total, 39 species of trematodes, 10 species of nematodes and 13 species of cestodes have been identified in muskrat occurring in Eurasia (Ryzhikov et al., 1978).

In Europe the fauna of muskrat's helminths was investigated only in a few countries. In the British population of muskrat (*O. zibethicus*) five species of helminths where revealed, two of them (*Notocotylus quinqueserialis* and *Hymenolepis evaginata*) were introduced with muscrat from North America. Other three species of helminths (*Capillaria hepatica, Taenia taeniaeformis* larva and *T. tenuicollis* larva) have probably been acquired by muskrat from the local fauna (Warwick, 1936).

According to Hoffman (1958), in Germany the muskrat is a host of a great number of parasites (41 species of trematodes, 22 species of cestodes, 27 species of nematodes, and others), some of the species are capable to infest humans, e. g. the dog tapeworm (*Taenia hydatigena*), the cat tapeworm (*Taenia taeniaformis*), and the dwarf tapeworm (*Echinococcus multilocuralis*) (Böhmer et al., 2000).

In Lithuania the helminth fauna of the muskrat is represented by 23 species: 19 species of trematodes, 2 species of cestodes, and 2 species of nematodes. The main parasites are trematodes: *Plagiorchis eutamiatis zibeticus*, *Echinostoma revolutum*

and *Plagiorchis laricola*. Three species originating from America represent recent Lithuanian fauna of muskrat helminths: *Echinostoma armigerum*, *E. coalitum* and *Quinqueserialis quinqueserialis*. Moreover, 3 species originate from Arkhangelsk and Kazachstan: *Pachytrema skrjabini*, *Psilotrema marki*, *Pl. eutamiatis zibethicus*, and all the remaining are of local origin (Kiselienė, Mickus, 1976; Kiselienė, 1983; Mažeika et al., 2009; Prūsaitė 1988; Skyrienė, Paulauskas, unpubl.).

It is known that the enteric parasites of the genus *Cryptosporidium* can be transmitted through ingestion of contaminated water (Fayer et al., 2000). *Cryptosporidium* infection is possible for domestic animals and humans (Zhou et al., 2004).

Moreover, the muskrat contains parasitic ticks *Laelaps multispinosus,* which arrive to Lithuania from North America with muskrat (Prūsaitė, 1988).

Mortality of many of muskrats is caused by Tularemia disease (infection agent *Francisella tularensis*) (Green et al., 1929; Prūsaitė, 1988), Tyzzer's disease, Erington's disease (infection agent *Bacillus piliformis*), Yersiniosis (Feldhamer et al., 2003), Taxoplasmosis (Karstad, 1963). In some areas *O. zibethicus* carries *Leptospira* which causes Weil's disease in humans as well (Becker, 1972; Feldhamer et al., 2003) usually transmitted through contact with water contaminated by rat (Becker, 1972). Muskrat serves as an intermediate host for the cestode *Echinococcus multilocularis* (infection rates up to 28% in wild populations) (Mažeika et al., 2009).

Nineteen genera of bacteria from muskrat were detected. Most frequent were the following species: *Citrobacter freundii* (53%), *Enterobacter* / *Aerobacter* (57%) and *Proteus vulgaris* (40%) (Hockett, 1968; Feldhamer et al., 2003).

There is very little known about diseases of muskrat in Europe, except in Sweden. In this country Tularaemia was recorded as the muskrat decrease (Danell, 1996). Researchers have supposed that a genetic monomorphism of muskrat of European population may increase susceptibility to diseases and parasites (Zachos et al., 2007). For testing this hypothesis more comprehensive research should be carried out.

**Predators and competitors**

Interaction between species depends on external factors, such as the habitats in which the animals live and community composition of the ecosystem (Holmengen et al., 2009). Natural competitors and predators are among the causes which lead to the decrease of muskrat population.

In North America, 17 predator species are important for muskrat. They are indicated below in descending order of effect: mink, raccoon dog, barn owl, barred owl, alligator, ant, northern harrier, eastern cottonmouth, bullfrog, garfish, bowfin, snapping turtle, lagernouth bass, crab, hog, domestic cat and dog (O'Neil, 1949; Feldhamer et al., 2003), fox and otter (Errington, Scott, 1945).

The mink is a primary predator of muskrat (Holmengen et al., 2009) which lives in the same habitat and decimates whole families of muskrats, thus affecting muskrat numbers not only in North America but also in Europe (Brzeziński et al., 2010; Prūsaitė, 1988). Supposedly, one American mink can decimate up to 20 or 30 muskrats per year (Prūsaitė, 1988). Recently in Poland the abundance of muskrat population became low and in some localities nearly extinct, namely due to activity of mink (Brzeziński et al., 2010).

Predation by red fox (*Vulpes vulpes*) can be also considered as an important factor affecting muskrat populations (Danell, 1996) as foxes prey for young but not for adult muskrats (Danell, 1978).

The foxes and minks are known as the main mammalian muskrat predators in Sweden (Danell, 1996). During winter foxes regularly patrol the frozen lakes and sometimes make successful attempts of catching muskrat, especially in late winter / early spring or after mild-weather periods when the muskrats leave their lodges or when it becomes possible to dig out their lodges. Even in summer foxes regularly visit muskrat lodges in search for litter and they can be quite efficient in taking young muskrats (Danell, 1996).

Otters (*Lutra lutra*), barn owls (*Tyto alba*) and harriers (*Circus* spp.) also prey on muskrats (Genovesi, Scalera, 2008). The predator otter is widely spread across Lithuania (Baltrūnaitė et al., 2009) and thus can influence the population size of muskrat.

Indirect enemies are wild boar which using the food dismantle the lodges of muskrat. Sometimes people (especially fishermen) damage or destroy the lodges, thus causing mortality of all the muskrat family, particularly in winter season, when muskrat cannot build a new lodge or rebuild

the damaged one. The most severe predation occurs in late winter and early spring when muskrats come out on the ice (Kadlec et al., 2007). The main competitors are beavers and water voles which live in the same habitat and use the same food (Prūsaitė, 1988).

## THE GENETICS OF MUSKRAT

Although muskrats are geographically widespread, genetic investigations of only a few populations have been carried out. Relevant studies have been conducted in:

- USA – electrophoretic patterns of erythrocyte and tissue lactate dehydrogenase (LDH) were detected (Willner et al., 1980);
- Canada – DNA fingerprinting technique – the genetic techniques allow to detect how close genetically are related individuals; high level of genetic variability was detected; DNA fingerprinting gave evidence that males exclusively bred associated (not accidental) females (Marinelli et al., 1992; Marinelli et al., 1997);
- North America – microsatellites – the markers revealed high polymorphism (Laurence et al., 2009) and the evidence of genetic differences of muscrats originating from western and eastern North American regions as well as from Newfoundland was demonstrated, as significantly lower genetic diversity was present compared to that from the central regions. Furthermore, a strong isolation depending on the distance between populations was revealed (Laurence et al., 2011);
- Serbia – genetic monomorphism of mitochondrial DNA proved that muskrat has an enormous ecological success irrespective of the small founder population and the lack of genetic variability (Zachos et al., 2007);
- Lithuania – muskrat populations were investigated by the vertical polyacrilamide gel electrophoresis and using 8 protein systems; 12 polymorphic and 3 monomorphic loci were found (Norvaišaitė, Paulauskas, 2003).

## DAMAGE CAUSED BY MUSKRAT AND THE IMPACT ON ECOSYSTEM

To assess the muskrat impact on native community (C), habitat (H) or ecosystem functioning (E) and to determinate the biopollution level Bioinvasion Impact / Biopollution Assessment System (BINPAS) method can be used (Olenin et al., 2007).

The main impacts of muskrat are the burrowing activities (Bobrov et al., 2008), feeding aquatic plants and lodge building (Danell, 1996). Muskrats are harmful to embankments on rivers and lakes. As they settle down in dikes at the seashore, the damages caused by muskrats may be threatening the lives of many people. During springtime as river banks are breaking in places where muskrats were active, the flooding damages great parts of agricultural farmland (Becker, 1972). Moreover, the muskrat burrowing activity can cause serious economic damages as it undermines banks, dams, and road and railway embankments, causing their collapse during floods (Böhmer et al, 2000). In rural districts, they damage cultivated farmland especially in fields with corn and sugar beet where they are biting off the growing tops and gnawing the roots (Becker, 1972).

Burrowing can weaken river banks causing them to collapse (Danell, 1996). Erosion problems from muskrat activities are worsened by wave action caused by high winds. Trees growing on the dam may exacerbate the problem because muskrats may tunnel along one or more of the roots (Glass, 1952).

A negative effect of economic importance caused by muskrats includes burrowing-related damage of dikes, ditches, ponds, and removal of vegetation in wetlands used for wastewater treatment, as well as occasional losses of crops (Miller, 1994). The introduction of muskrats to the former Soviet Union followed by a significant impact of the muskrat on emergent vegetation; especially in Western Siberia and Kazakhstan, where thousands of hectares of *Phragmites* stands were extinct (Bobrov et al., 2008; Danell, 1996). Muskrat fourage activity can increase floristic richness and diversity via decrease of the biomass of dominant narrowleaf cattail (*Typha angustifolia*) and, thus, muskrat may increase potential net nitrogen mineralization and nitrification rates through aeration and reduced plant uptake because of herbivory. It was recorded that muskrat activity reduced the total plant biomass including *Typha* biomass (Connors et al., 2000). Moreover, muskrat reduces the number of

wintering rhizomes of reed by biting off terminal buds of the winter sprouts at surface-water border. This prevents oxygen uptake by the rhizomes and the plants suffocate (Smirnov, Tretyakov, 1998). According to Smirnov and Tretyakov (1998), the reed was the dominant species in 1962 (relative abundance within the sample equal to 16.6%) but after muskrat introduction it occupied merely 5.4% of the total vegetative canopy in 1993–1994. The muskrat eats only rhizomes of sedges and basal parts of stems, so it removes markedly more plants than it actually needs (Smirnov, Tretyakov, 1998).

It was found that muskrats consumed only about 2% of the annual net primary productivity, primarily rhizomes, but that biomass in their mounds represented about 20% of this production in Chech Republic (Berg, Kangas, 1989).

The muskrat creates openings in dense vegetation stands and thus prevents lakes from being overgrown by vegetation. The muskrat was blamed for destroying valuable vegetation and creating mud flats. Depending on human interest in the development of a particular wetland, muskrat may be regarded as a valuable element or as a "pest" species (Danell, 1996). Muskrat grazing can replace treatment of wetlands with the aim to reduce dense vegetation and make open areas, and even completely denude the wetland in some cases (Kadlec et al., 2007).

Muskrat impact extends beyond local habitat damage and affects all ecosystems (Danell, 1996). In Lithuania, muskrats were assessed as having a strong impact (E3) on ecosystem functioning (Ulevičius, 2010) and energy flow by consuming riparian vegetation, and by releasing of the subsurface ground by burrowing and thus influencing chemistry and physical properties of water (Ulevičius, 2010; Sokolov, Lavrov, 1993). The opening up of dense vegetation beds creates a mosaic of sites with different light and temperature climates, where ecological processes proceed at different rates and intensity (Danell, 1996).

Muskrat negatively effects populations of fishes (Becker, 1972), mollusks, shellfishes and mussels (Genovesi, Scalera, 2008). Muskrats are nuisances in fishing areas because they often disturb the nets and other equipment used for fishing (Becker, 1972). The muskrat affected species composition, population size and age structure of freshwater unionid mussel communities (Owen et al., 2011). The muskrats kill mussels directly by digging them up, carrying to shore and either prying them open or crushing the shell. Also, the muskrats reduce the number of mussels indirectly by leaving live mussels on shore and waiting for the mussel to die of aerial exposure. Moreover, the muskrat is a predator on freshwater crayfish and bivalves, including threatened taxa such as *Anodonta*, *Unio*, and the freshwater pearl mussel *Margaritifera* (Hochwald, 1990; Zimmermann et al., 2000). This affects (indirectly) rare fish species that deposit their eggs in bivalves, such as the bitterling (*Rhodeus amarus*) (Böhmer et al., 2000). At least three species of unionid mussels (*Pyganodon grandis*, *Lampsilis siliquoidea*, and *Toxolasma parvus*) were preyed by muskrats (*O. zibethicus*) as has been revealed by analysis of shell remains at feeding sites (Diggins, Stewart, 2000). Apparently muskrats began to prey zebra mussels (*Dreissena polymorpha*) that were attached to unionids following an increase in zebra mussel abundance (Sietman, 2003).

Muskrats also impact the semi-aquatic rodent guild species composition, particularly the indigenous semi-aquatic rodent *Arvicola terrestris* (Danilov, 2009). They caused a moderate impact on riparian vegetation structure by feeding on it, and also burrowing in the banks of water bodies (Sokolov, Lavrov, 1993).

High population density of muskrats often destructs local habitat, including damage of river banks caused by burrowing, and reduces aquatic vegetation due to its overconsumption for food and building materials. In the systems of embankments the caves dug by muskrats cause much damage to equipment of hydraulic engineering. As a result, muskrats are often treated as pest species and are trapped, hunted or poisoned with the aim to control their population level.

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## ONDATROS (*ONDATRA ZIBETHICUS*) INVAZINIS PAPLITIMAS IR POVEIKIS EKOSISTEMAI

*S a n t r a u k a*

Ondatros (*Ondatra zibethicus*) greitai paplito naujuose biotopuose po to, kai buvo introdukuotos į Europą ir užėmė jos šiaurinę, rytinę ir vidurinę dalis. Viena sėkmingos invazijos priežasčių – greita reprodukcija ir sėkmingas savarankiškas plitimas naujose vietose. Ondatros yra pusiau vandens graužikai, neigiamai veikiantys ekosistemas. Ši rūšis, ženkliai veikianti aplinką, gali būti pakankamai svarbi ekonomikos požiūriu. Šiuo metu ondatrų labai sumažėjo, ypač Lietuvoje, Lenkijoje, ir tai gali būti ekologinių veiksnių, tokių kaip maisto prieinamumas, ligos, parazitai, plėšrūnai, poveikis. Be to, ondatrų mirtingumą nemažai lemia ir žmogaus veikla: jos intensyviai gaudomos dėl kailio, kurio ekonominė vertė yra išaugusi visame pasaulyje. Straipsnyje apžvelgiama ondatros (*Ondatra zibethicus*) introdukcijos į Europą istorija, paplitimas visoje Eurazijoje, veiksniai, nulėmę populiacijos didėjimą, o vėliau ir mažėjimą, genetiniai tyrimai ir šios invazinės rūšies poveikis ekosistemai.

**Raktažodžiai:** *Ondatra zibethicus*, aklimatizacija, plėšrūnai, parazitai, poveikis