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# SEMI-AQUATIC MAMMALS OF THE IRTYSH RIVER FLOODPLAIN AS BIOINDICATOR SPECIES AND THEIR ECOSYSTEM SERVICES

The Irtysh River floodplain in Kazakhstan is home to diverse semi-aquatic mammals that serve as key bioindicators of ecosystem health. This study investigates six species: the muskrat (*Ondatra zibethicus*), Eurasian beaver (*Castor fiber*), water vole (*Arvicola amphibius*), American mink (*Neogale vison*), Eurasian otter (*Lutra lutra*), and Eurasian water shrew (*Neomys fodiens*). These species play critical roles in ecosystem services, contributing to water purification, extreme events mitigation, pest control, retention of greenhouse gases, ecosystem engineering, increase in riverside's recreational potential, prey base, seed dispersal. However, invasive species such as the American mink and muskrat pose threats through competition with native fauna and alteration of local biodiversity.

Field surveys conducted in 2023 along the Black Irtysh and Pavlodar Irtysh recorded 168 activity traces from four key species. Population densities of Eurasian otter and American mink in the Black Irtysh and the Eurasian beaver and American mink in the Pavlodar Irtysh were assessed. The studied section of the Black Irtysh River hosts 6-8 otters, with approximately 10 individuals found from the China border to Lake Zaysan, at a density of 1-1.2 otters/10 km. In the Kalzhyr River near Boran, the otter density is at least 2 animals/10 km. The mink inhabits the Black Irtysh (river and tributaries) area at 0.3-0.5 individuals/km, and the Kalzhyr River at up to 1 individual/km. In the Pavlodar Irtysh, the mink density is lower, at 0.2-0.3 individuals/km. In suitable habitats along the Irtysh River, beaver settlements occur every 3-4 km, and if there are three beavers per settlement, the total population in the Pavlodar Irtysh region is estimated at 300–400 individuals. Overall, our studies reveal a high species density in areas with preserved habitats, while human disturbances negatively impacted their presence in certain regions. More data are necessary to better understand ecosystem services provided by semiaquatic mammals.

**Key words:** Irtysh River floodplain, river ecosystem, semi-aquatic mammals, bioindicators, ecosystem services, population densities.

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## Ертіс өзенінің жайылмасының жартылай су сүтқоректілері және олардың биоиндикатор ретіндегі және экожүйелік қызметтері

Қазақстанда орналасқан Ертіс өзенінің жайылмасы – ерекше аумақ, ол қоршаған орта сапасын көрсететін негізгі биоиндикаторлар ретінде қызмет ететін жартылай суда мекендейтін сүтқоректілердің мекен ету ортасы болып табылады. Бұл зерттеуде алты түр зерттелінді: ондатр (*Ondatra zibethicus*), құндызы (*Кастор талшығы*), сутышқан (*Arvicola amphibius*), Американдық күзен (*Neogale vison*), кәмшат (*Lutra lutra*) және су жертесері (*Neomys fodiens*). Бұл түрлер суды тазартуға, төтенше жағдайларды азайтуға, зиянкестермен күресуге, парниктік газдарды жинауға, экожүйені жасауға, жайылманың рекреациялық әлеуетіне, жемдік база болу және тұқымдарды таратуға үлес қосу арқылы экожүйе қызметтерінде маңызды рөл атқарады. Дегенмен, күзен және ондатр сияқты инвазивті түрлер жергілікті түрлермен бәсекелестікке және тіршілік ету ортасының өзгеруіне байланысты белгілі бір қауіп төндіреді.

2023 жылы біз Қара Ертіс пен Павлодар Ертісінің бойынан төрт жартылай суда мекендейтін түрдің тіршілік әрекетінің 168 ізін анықтадық. Қара Ертістегі кәмшат пен күзеннің, сонымен қатар Павлодар Ертісіндегі құндыз бен күзенінің популяциясының тығыздығын бағаладық. Біздің деректеріміз бойынша Қара Ертісті зерттелген учаскесінде 6–8 кәмшат кездеседі,

 

шекаралы Зайсанға дейінгі аумақта 10 шақты кәмшат (популяция тығыздығы 1–1,2 дара/10 км) мекендейді. Боран ауылының маңындағы Қалжыр өзені учаскесіндегі кемінде 2 кәмшат/10 км кездеседі. Американдық күзен популяциясының тығыздығы Қара Ертісте (негізгі өзен мен арналары) 0,3–0,5 дара/км, Қалжыр өзені маңында 1 дара/км құрады. Павлодар Ертісінде күзен сирек кездеседі, популяцияның тығыздығы 0,2–0,3 дара/км аспайды. Ертістегі құндыздарға қолайлы мекендейтін жерлерде 3–4 км арна бойында бір құндыздар қонысы орналасады. Бір қоныста орташа есеппен үш құндыз болса, олардың жалпы саны Павлодар Ертіс өңірінде 300-400 дараға дейін жету мүмкін. Біздің зерттеулеріміз негізінде, тіршілік ету ортасы жақсы аумақтарда осы түрлердің популяция тығыздығы жоғары екені байқалынды, ал адамның негативті әрекеті олардың белгілі бір аймақтардан жойылуына әкеліп соғады. Жартылай сулы түрлердің экожүйелік қызметтерді егжей-тегжейлі зерттеу үшін қосымша деректер қажет.

**Түйін сөздер:** Ертіс өзенінің жайылмасы, жайылманың экожүйесі, жартылай су сүтқоректілері, биоиндикаторлар, экожүйе қызметтері, популяцияның тығыздығы.

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**Полуводные млекопитающие поймы реки Иртыш как биоиндикаторные виды и их экосистемные услуги**

Казахстанская часть поймы реки Иртыш является уникальным регионом, местом обитания для полуводных млекопитающих, служащих ключевыми биоиндикаторами качества среды. В данном исследовании рассмотрены шесть видов: ондатра (*Ondatra zibethicus*), речной бобр (*Castor fiber*), водяная полевка (*Arvicola amphibius*), американская норка (*Neogale vison*), речная выдра (*Lutra lutra*) и кутора (*Neomys fodiens*). Эти виды играют важнейшую роль в экосистемных услугах, способствуя очистке воды, смягчению последствий экстремальных явлений, борьбе с вредителями, удержанию парниковых газов, экосистемной инженерии, повышению рекреационного потенциала поймы реки, составлению кормовой базы и распространению семян. Однако инвазивные виды, такие как норка и ондатра, представляют некоторую угрозу из-за конкуренции с нативными видами и изменения местообитаний.

Нами в 2023 обнаружено 168 следов жизнедеятельности четырех видов полуводных вдоль Черного Иртыша и Павлодарского Иртыша. Оценена плотность популяции выдры и американской норки в Черном Иртыше, а также бобра и норки в Павлодарском Иртыше. По нашим данным, на исследованном участке р. Черный Иртыш обитает 6–8 особей выдры, а на всем участке от границы с Китаем до оз. Зайсан около 10 выдр (плотность населения 1–1,2 особи/10 км русла). Плотность населения на участке р. Калжыр выше пос. Боран составляет не менее 2 выдр/10 км русла реки. На Черном Иртыше (основное русло и протоки) американская норка населяет с плотностью 0,3–0,5 особи/км русла, а у р. Калжыр до 1 особи/км русла. В Павлодарском Прииртышье норка встречается реже, плотность населения не превышает 0,2–0,3 особей/км русла. В пригодных для бобра местообитаниях на р. Иртыш одно поселение встречается на 3–4 км русла реки. При среднем расчетном количестве три бобра в одном поселении, их общая численность на участке Павлодарского Прииртышья может составлять 300–400 особей. Наши исследования показывают высокую плотность этих видов в районах с сохранившимися местообитаниями, в то время как антропогенное вмешательство негативно повлияло на их присутствие в определенных регионах. Необходимо больше данных для детального изучения экосистемных услуг, предоставляемых полуводными млекопитающими.

**Ключевые слова:** пойма реки Иртыш, пойменная экосистема, полуводные млекопитающие, биоиндикаторы, экосистемные услуги, плотность популяции.

## Introduction

The Irtysh River floodplain is located in the northeastern part of Kazakhstan, spanning the East Kazakhstan, Abai and Pavlodar regions of the country [1]. The floodplain is formed by spring floods and water from the Upper Irtysh cascade of reservoirs [2]. Furthermore, according to the geomorphological zoning of Kazakhstan, the Black Irtysh River belongs to the region of accumulative and denudation plains of the Zaisan Depression of the orogenic belt. As a result, the river's wide valley is characterised by high and low floodplains as well as accumulative terraces.

Several semi-aquatic species, including native and invasive species, are present in the Irtysh River floodplain: the Eurasian beaver (*Castor fiber*), muskrat (*Ondatra zibethicus*), water vole (*Arvicola amphibius*), Eurasian otter (*Lutra lutra*), American mink (*Neogale vison*), and Eurasian water shrew (*Neomys fodiens*). Moreover, native species, such as the Eurasian otter and Eurasian beaver, contribute positively to ecosystem services such as water purification, habitat creation, and flood mitigation. In contrast, invasive species such as the American mink can alter native biodiversity and ecosystem functions, sometimes providing negative ecosystem services through predation or competition with native species.

Ecosystem services include various ecosystem functions and products that are necessary or beneficial to humans [3], and, from an ecological perspective, should be based on healthy ecosystem functioning [4]. Assessing the ecosystem services provided by the semi-aquatic mammals is essential for understanding their ecological roles and for the future planning of conservation strategies. Native and invasive species must be evaluated not only for their positive contributions but also for their potential negative impacts, especially in light of the ecological changes and anthropogenic pressures affecting the Irtysh River floodplain.

In this study, we analysed positive (beneficial to humans and the ecosystem) and negative (harmful to humans and/or the ecosystem) ecosystem services provided by semi-aquatic species and their bioindicator roles. We determined the population densities of three key species: the Eurasian beaver, Eurasian otter, and American mink in the Black (Upper) Irtysh and the Pavlodar (Lower) Irtysh. By understanding the balance of positive and negative ecosystem services provided by these species, we can better inform conservation efforts and the sustainable use of biological resources in the region.

## Materials and methods

In February-May and September-October 2023, we surveyed the Kazakhstani part of the Black Irtysh River and the Pavlodar Irtysh – two parts of the Irtysh River in the north and northeast of Kazakhstan. The total length of the routes by car and foot tracks was greater than 1000 km. Approximately 220 km of the Black Irtysh and Pavlodar Irtysh floodplains were surveyed. All traces of vital activity of semi-aquatic mammals were noted along the routes, their sizes were measured, and, if possible, individual individuals were identified.

We estimated otter population density using the method of recording individual habitat areas [5] with additions by other researchers (Rodikov, 1978; Sidorovich, 1992) and our modifications [6]. The numbers of American mink and beaver were also estimated on the same routes. The study was based on the method proposed by D.V. Ternovsky [7]. To determine the beaver population, we used an ecological method with elements of population density assessment [8, 9].

We carried out a detailed analysis of the literature data on lifestyle and biocenotic role based on the works of Afanasyev et al. [10], Heptner and Naumov [11], Chanin [12], Bazarbekov and Lyakhov [13], Kruuk [14], and others. We considered the ecosystem services provided by mammals in the Irtysh River floodplain based on the combination of anthropocentrism (benefits to humans) and biocentrism (benefits to the ecosystem as a whole) [15, 16]. In our study, we modified the classification in respect to semi-aquatic mammals by combining some aspects of anthropocentrism and biocentrism and divided ecosystem services into positive and negative. Positive ecosystem services include water purification, mitigation of extreme events (floods, droughts, and floodplain overgrowth), control of the number of other species, retention of greenhouse gases, increased recreational activity, ecosystem engineering, a food source for other species, and seed dispersal and storage. Negative services include the impact on the number of other species, destructive competition with other species, impact on infrastructure, and harm to agriculture. Recreational activities include providing conditions for increased tourism, hunting, and fishing in the region, including the species themselves. Ecosystem engineering involves the direct or indirect provision of resource access by organisms to other species by modifying, maintaining, and creating habitats [17].

## Results and discussion

The Kazakhstan part of the Irtysh River floodplain is home to 6 species of semi-aquatic mammals, comprising both native (Eurasian beaver, water vole, Eurasian otter, water shrew) or invasive (muskrat, American mink) species. In 2023, we discovered 168 traces of the life activity of four species of semi-aquatic mammals (Table 1).

**Table 1** – Recorded traces of semi-aquatic mammal activity in two areas of the Irtysh River

| Scientific name | Traces found | | |
|---|---|---|---|
| | Black Irtysh | Pavlodar Irtysh | Total |
| Muskrat *Ondatra zibethicus* Linnaeus | 2 | 21 | 23 |
| Eurasian beaver *Castor fiber* Linnaeus | 0 | 24 | 24 |
| American mink *Neogale vison* Schreber | 54 | 7 | 61 |
| Eurasian otter *Lutra lutra* Linnaeus | 60 | 0 | 60 |
| TOTAL | 116 | 52 | 168 |

The most frequently encountered tracks of the American mink and the Eurasian otter were on the Black Irtysh (n = 54 and n = 60, respectively), while we also registered tracks of the mink in the Pavlodar Irtysh region (n = 7). Tracks of the muskrat and the Eurasian beaver were noted in the Pavlodar Irtysh region (n = 21 and n = 24, respectively). There are also rare encounters of muskrat tracks on the Black Irtysh (n = 2). We have not confirmed the presence of the Eurasian beaver on the Black Irtysh and the Eurasian otter in the Pavlodar Irtysh region.

Below, we provide brief information on the biology of these species, consider their ecological features and ecosystem services, and analyse their density in the studied areas of the Irtysh River.

*Brief information on the biology of semi-aquatic mammal species and their use as bioindicator species for the state of floodplain ecosystems*

Semi-aquatic mammals play an important role in assessing the state of the Irtysh River floodplain ecosystems. The Eurasian otter, American mink, and European beaver are highly sensitive to changes in water quality and habitat conditions, which al- lows them to be used as bioindicators in assessing the ecological state of the floodplain.

Muskrat (*Ondatra zibethicus*) was first introduced into the Black Irtysh basin in 1944, and into the Pavlodar region in 1952 [18]. In the fall of 2023 and summer of 2024, we confirmed the presence of muskrat in the Black Irtysh. After release, the muskrat spread very widely, occupying suitable water bodies almost throughout the entire territory of the Pavlodar region. It is most numerous in the Irtysh valley and along the Irtysh-Karaganda canal. Breeding of muskrats in captivity is widely practised in many fresh water bodies on the right bank [13]. The distribution of muskrats in the Pavlodar part of the Irtysh, according to our data for 2023-2024, is uneven and mosaic. Despite the presence of suitable water bodies with abundant herbaceous vegetation in the river floodplain, not all of them are populated by muskrats. Probably, the mosaic distribution of muskrats in potentially favourable habi- tat conditions may be associated with the chemical composition of the water [18]. Muskrats have been harvested in small quantities in the Irtysh floodplain since 1947. Currently, the resources of this fur animal are used insignificantly. The Tarbagatai subspecies of the water vole (*Arvicola amphibius kuznetzovi* Ognev 1933) lives in the floodplain of the Irtysh River [19]. According to I.G. Schubin [20], the vole was especially numerous here, and up to 40-50 animals or more were often caught per 1 km of the coastline. The water vole feeds on aquatic and coastal vegetation (for example, it gnaws the lower parts of the trunks and branches of the willow Salix sp.) [20]. In the 1960s, the fertility of the voles was high, where 48.1-53% of females were pregnant in June-July, with an average of 7.1 embryos per female. At present, we have not found any water voles in the floodplain of the Irtysh River.

The Eurasian otter (*Lutra lutra*) is one of the most specialised species of near-water ecosystems among terrestrial carnivorous mammals [14]. Despite the plasticity of its diet, its diet consists mainly of aquatic and near-water animals. In different habitats, fish make up 50 to 95% of its prey; the main components of its diet also include amphibians, crustaceans, aquatic insects, mammals, and birds [21]. The otter visits all accessible floodplain water bodies (rivers, channels, lakes, oxbow lakes), and uses intermittent water bodies and small rivers (less than 10-15 km long) only temporarily. Its habitat is located along the shoreline of water bodies. The otter is active all year round and moves around its territory, avoiding areas with intense anthropogenic impact.

The otter was indicated for the Black Irtysh and Zaysan Lakes [10, 22]. Later, it was noted here by I.G. Schubin [23] as a rare species. The Irtysh River is inhabited by the northern subspecies, *L. l. lutra*

[24]. In the Black Irtysh River section, we observed the otter everywhere in May and October 2023. Traces of its life activity were noted on the routes on the Black Irtysh and on the Kalzhyr River. The otter prefers sections of the river with forested banks, bays and channels, and avoids open steppe areas and areas frequently visited by people and cattle.

The otter is mentioned as a rare game species in the Pavlodar Irtysh region [10, 11, 13]. At the time of our research in 2023, there were no signs of otters on the river. The Irtysh River has not been found in the Pavlodar Irtysh region. We can only guess at the real reasons for the otter's disappearance, but we will cite some factors that could have contrib- uted to this. The economy of the Pavlodar region has been developing intensively since the beginning of the last century thanks to the construction of the railway and the development of shipping along the Irtysh. The population has grown sixfold since the beginning of the 20th century by the 1980s, facto- ries and manufacturing plants were launched, and the rapid development of virgin lands began in the 1950s. Most of the settlements in the region are concentrated in the Irtysh floodplain. In addition, since 1949, tests have been conducted at the Semipalatinsk nuclear test site on the border of the Pavlodar and East Kazakhstan regions.

The American mink (*Neogale vison*) is somewhat less specialised to a semi-aquatic lifestyle than the otter. Its diet also includes fish, amphibians, aquatic insects, mammals and birds [25, 26]. Since the American mink is several times smaller than the otter, it consumes smaller prey on average, and there are differences in the species composition of its prey. In the event of a shortage of aquatic prey, it easily switches to using terrestrial prey (in winter); in some periods, voles and other small mammals can form the basis of its diet. Unlike the otter, the mink is able to occupy smaller and drying up or freezing bodies of water, and goes further from the water, the length of its territory is 1.5-3.5 km of the coastal strip.

Mink were first noted on the rivers of the East Kazakhstan region in 1945, where the animals had penetrated from the Altai region, where they were released in 1933 [27, 28]. Later, in 1952, mink were released on the Uba River [28]. Currently, mink has populated all suitable habitats in the surveyed areas of the Irtysh River. Due to trophic plasticity, the species has adapted well to new habitats.

The Eurasian beaver (*Castor fiber*) plays a key role in the formation and maintenance of aquatic biome ecosystems and is recognized as a key indicator of coastal ecosystem health throughout the Holarctic and an ecosystem engineer [29-31]. Beavers are able to exist in certain ecological conditions and are therefore an important indicator organism responding to human intervention [32].

Their presence or absence can serve as an early sign of environmental disturbance in coastal ecosystems [29, 33]. An increase in beaver numbers and expansion of their range may indicate improved environmental conditions, including the availability of suitable burrow sites and an adequate food supply.

The main reason for the disappearance of beavers on the river The Irtysh, as in most of its range, was under commercial pressure [34] as a result of high demand for beaver furs and products made from it [22, 35-37]. The restoration of the historical range occurred gradually. In the early to mid-1980s, the beaver from the Urals was reacclimatised in the upper reaches of the Malaya Ulba and Uba rivers. Beavers began to appear on the Irtysh about 20 years ago, settling upstream along the Irtysh River and along the Altai rivers [38].

The absence of beavers in the Black Irtysh River section at present is not a sign of its poor ecological condition. Moreover, the water quality is better here, the degree of ecosystem disturbance is less, and there are more channels with abundant coastal vegetation and tributaries suitable for the species. According to our expert assessment, the beaver population density here may be higher than in the Irtysh River section in the Pavlodar Irtysh region. In our opinion, the reason for the absence of beavers on the Black Irtysh is the cascade of hydroelectric power plants built on the Irtysh River in the 20th century. The dams of hydroelectric power plants and the banks of reservoirs, subject to significant drawdowns of the water level, are an artificial barrier to the settlement of beavers. The Black Irtysh is separated from the Russian part of the population by the high Altai Mountains.

An ecological feature of the life of beavers living in the Pavlodar Irtysh region is the absence of dams in their areas. Obviously, this is due to the absence of tributaries, small streams and quiet channels here. Most beaver settlements are found in channels, but they are quite full-flowing and unsuitable for building dams. Because of this feature, beavers on the Irtysh do not play a water-regulat- ing role and do not contribute to the flooding of large areas. By building canals, huts and burrows, they play a role in enriching the environment with shelters and new habitats for other species of vertebrates and invertebrates.

The common water shrew (*Neomys fodiens*), if it lives in the Irtysh River valley, is rare. In the 1980s,

it was observed 300 km away from the Irtysh River near the village of Berezovka (oral communication by N.N. Berezovikov [39]). The water shrew is an insectivorous animal, highly specialised to a semi-aquatic lifestyle. During our research, no traces of the water shrew were found.

Semi-aquatic mammals are closely associated with aquatic ecosystems and respond quickly to changes in water quality and pollution levels [12, 40]. Their presence can serve as an indicator of a healthy environment and be used as an indicator of the state of water bodies [12, 14]. These species are susceptible to pollutants such as pesticides, heavy metals, and polychlorinated biphenyls, which can accumulate in their bodies over time through food chains [12, 41, 42]. Analysis of their tissues and faeces provides insight into the levels and types of pollutants in freshwater ecosystems [40, 43]. Semi-aquatic mammals have limited home ranges and are not prone to long-distance migrations, so they are exposed to pollutants year-round [44]. Concentrations of pollutants in their faeces and tissues can be used to assess environmental pollution for humans [45].

*Ecosystem services provided*

As a result of the analysis, we found that 6 species of semi-aquatic mammals provide 26 positive and 7 negative ecosystem services (Table 2 and Figure 1).

**Table 2** – Positive and negative ecosystem services provided by semi-aquatic mammals in the Irtysh River floodplain

| Types | Positive ecosystem services | | | | | | | | Negative ecosystem services | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water purification | Mitigation of extreme events (floods, drought, over-vegetation) | Population control of other species | Retention of greenhouse gases | Increasing recreational activities | Ecosystem engineering | Food source for other species | Seed dispersal and storage | Impact on the abundance of other species | Destructive competition | Influence on infrastructure | Harm to agriculture |
| Eurasian otter | | | + | | + | | + | | | | | |
| American mink | | | + | | + | | + | | + | + | | |
| Eurasian beaver | + | + | + | + | + | + | + | | + | | + | |
| Vole water | | | + | | | + | + | + | | | | + |
| Muskrat | | + | + | | + | + | + | + | + | + | | |
| Eurasian water shrew | | | + | | + | + | + | | | | | |
| Total | 1 | 2 | 6 | 1 | 5 | 3 | 6 | 2 | 3 | 2 | 1 | 1 |
| TOTAL | 26 | | | | | | | | 7 | | | |

As shown in Table 2, all semi-aquatic species participate in population control of other species and serve as prey for birds of prey and carnivorous mammals.

Beavers improve habitat for fish and waterfowl, create filtration zones to improve water quality, and attract tourists to the area, promoting recreation [32, 46]. However, it is also important to consider the sustainability of their populations and possible negative consequences of their activities, such as flooding and changes in the composition of coastal communities, to maintain ecosystem integrity and rational use of the species [47]. The presence of species such as the Eurasian beaver and the otter in the floodplain ecosystems of the Irtysh River serves as an important indicator of the state of the environment.

Ecosystem engineering refers to the environment-forming role of certain species. For example, the burrow system of the shrew ensures the existence of various species of invertebrates and small vertebrates. In the floodplain of the Irtysh River, the Eurasian beaver and the common muskrat are two excellent ecosystem engineers of wetland biotopes.

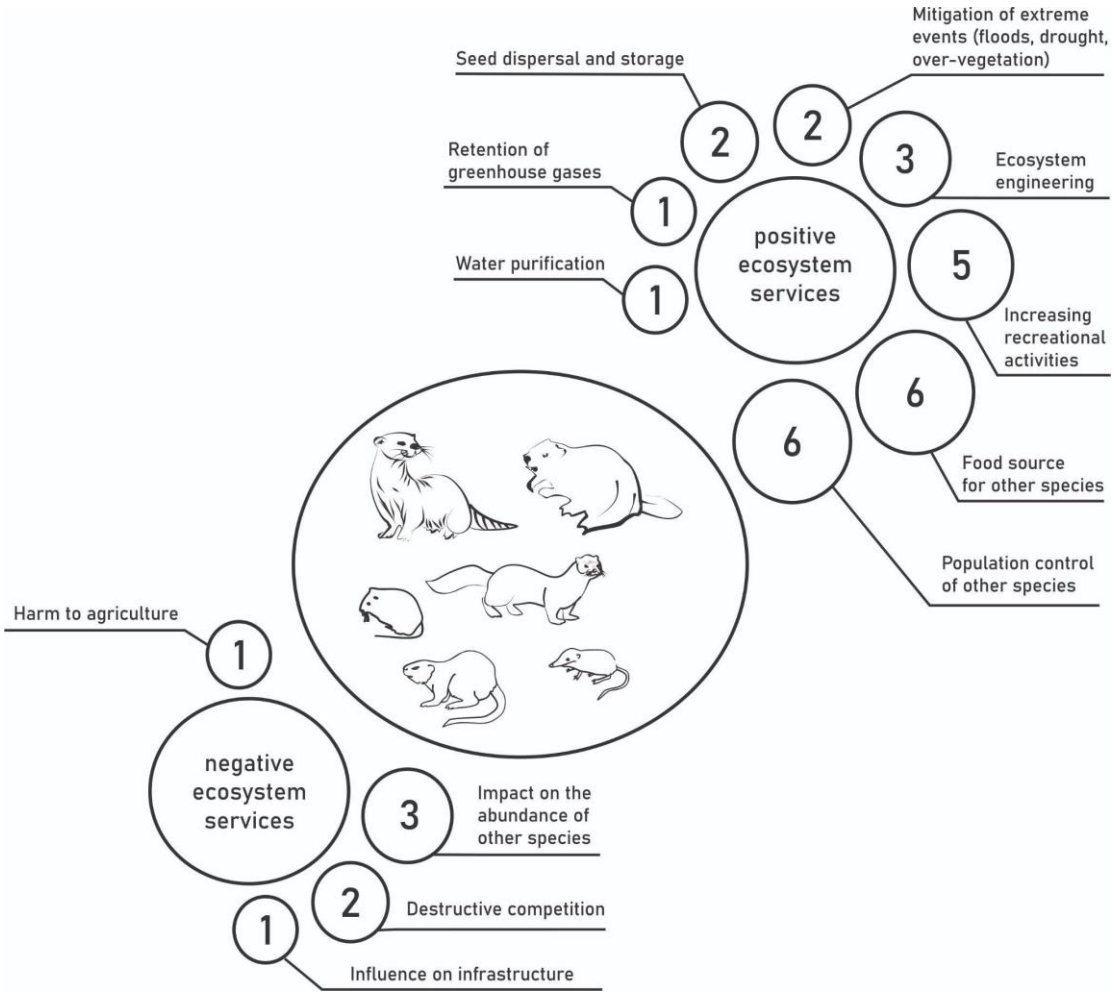


**Figure 1** – Ecosystem services provided by semi-aquatic mammals in the Irtysh River floodplain. Drawing by N. Bizhanova

The otter, as a semi-aquatic species, plays an important role in near-water ecosystems, maintaining the natural balance and diversity of aquatic communities. Moreover, research and monitoring of otter populations can help determine levels of water pollution and detect changes in the ecosystem [12]. Otters are an object of interest for observation in nature and ecotourism. Their presence can attract tourists and promote the development of ecotourism in their habitat. Given the declining population and limited distribution in Kazakhstan, it is necessary to consider the inclusion of the northern subspecies in the Red Book.

Some aquatic mammals of the Irtysh River floodplain can also cause ecosystem damage. In addition to the damage to pastures described above, the Irtysh River floodplain is a natural source of dangerous infectious diseases, with ticks regularly arriving here with livestock during their spring migration to pastures and pastures. The water vole and muskrat are intermediate hosts of infectious disease carriers, where the ticks' habitat is the network of burrows. The water vole and muskrat are pests of agricultural crops and pastures on the Irtysh, feeding on fruits, flowers, plant shoots and gnawing at their root systems [20, 48]. Nevertheless, these animals, like all other semi-aquatic animals, form the basis of the diet of a large number of birds of prey and carnivorous mammals, including economically important ones (Eurasian ermine, steppe polecat, fox, corsac fox, etc.).

As an invasive species, the American mink provides negative ecosystem services in the Irtysh River floodplain by preying on native spe- cies such as fish and small mammals, as well as competing with other carnivores for resources. This predatory behaviour threatens vulnerable populations, potentially exacerbating the decline

of other semi-aquatic mammals and altering local food web dynamics.

Until the 1970s, the water vole was a secondary object of fur trade in the Irtysh River floodplain, and the muskrat was a particularly valuable commercial animal. The Eurasian beaver, Eurasian otter and American mink were also highly valued for their fur. Due to population decline and intense poaching, the fur trade for most species stopped completely. For the future restoration of the fur trade, more com- plete information on the current state and distribu- tion of animal populations is needed.

*Bioindicator mammals' population density*

For the relative ecological assessment of the Irtysh River floodplain condition, we estimated the complex population density indicator of two pairs of indicator species of semi-aquatic mammals and plotted them on a map (Figures 2-3). Since each site is home to only two species of semi-aquatic mammals, we estimated the density of otter and mink for the Black Irtysh, and beaver and mink for the Pavlodar Irtysh region. To assess the entire length of the sites, we extrapolated the data obtained in Black and Pavlodar Irtysh and in their vicinity. As a density gradation, we identified three indicators for each species: high, medium, and absent, and five gradations of complex comparison of the density of two species in each of the sites (Figures 2-3).

For the beaver, we classified having one or more individuals per kilometre of the riverbed as sites with a high population density. For the mink, high population density is considered for more than 5 individuals per 10 km; and for the otter, it is more than 1 individual per km. Between 6-8 otters inhabit the studied section of the Black Irtysh River (58 km), and approximately 10 otters occur in the entire section from the border with China to Lake Zaysan (population density is 1-1.2 individuals/10 km of the riverbed). The population density in the section of the Kalzhyr River above the settlement of Boran is at least 2 individuals/10 km of the riverbed.

We observed otter tracks on a channel in the vicinity of this village. Otters avoid the section of the Black Irtysh River near the automobile bridge (the Zaisan-Kurchum automobile road), areas of intensive cattle grazing in the river floodplain, and areas lacking forest or shrubby riverside vegetation.

The American mink inhabits the Black Irtysh (main channel and branches) with a density of 0.3-0.5 individuals/km of the floodplain, and the Kalzhyr River up to 1 individual/km of the floodplain. Near the village of Boran, the mink is less common, likely due to the presence of stray dogs and human disturbance.

In the Pavlodar Irtysh, the mink is less abundant. We found signs of their presence along the banks of the Irtysh River and its tributary with better protective conditions in the Pavlodar Irtysh. Here, the population density does not exceed 0.2-0.3 individuals/km of the riverbed. Minks are more often found on the tributaries, but also on the main channel, particularly in wooded banks with shelters. The reason for the low number of minks in the lower section of the Irtysh River is probably due to the lack of quality habitats.

We also observed traces of beaver activity in the vicinity of the Irtysh River. The successful settlement of beavers on the Irtysh indicates sufficient preservation of habitats and favourable conditions for the species. In habitats suitable for beavers on the Irtysh River, we found one beaver settlement per 3-4 km of the riverbed.

With an average estimated number of three beavers in one settlement, their total population in the Pavlodar Irtysh region may be 300–400 individuals. Beavers are rarely found in the main riverbed and we have not found their permanent dwellings here. In the Irtysh floodplain, they prefer to inhabit channels with wooded banks.

In the Black Irtysh section, the population density of semi-aquatic mammals (otter and mink) is predominantly high (Figure 2). The habitats, in general, can be assessed as favourable, they are well preserved. The section of the Kalzhyr riverbed near the village of Boran and the section of the Black Irtysh in the area of the automobile bridge are less favourable for semi-aquatic predators, which is probably due to the high disturbance factor from the proximity of a populated area, intensive livestock grazing and automobile traffic.

In the Irtysh River in the Pavlodar Irtysh region, we observed areas with a high population density of semi-aquatic mammals between the villages of Prirechnoye and Zhanabet and below the village of Zhelezinka to the border with Russia (Figure 3). Here, tree and shrub vegetation is well developed; there is a low density of livestock and many channels. The greater length refers to areas with an average density. We also observed areas with absent or very low density of semi-aquatic mammal populations near the cities of Pavlodar and Kurchatov, where channels are very poorly developed, human population density is high, and vegetation is sparse.

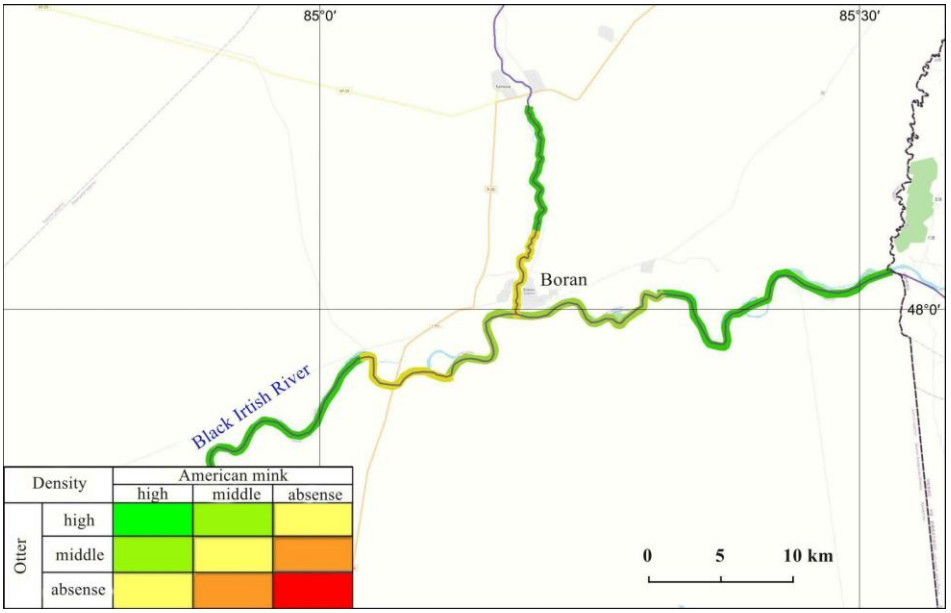


**Figure 2** – Population density of semi-aquatic mammals (Eurasian otter, American mink) in the Black Irtysh area
Note – High population density = beaver > 1 individual/km of watercourse bed, otter > 0.1 individual/km of watercourse bed.
Medium population density = beaver < 1 individual/km of watercourse bed, otter < 0.1 individual/km of watercourse bed.

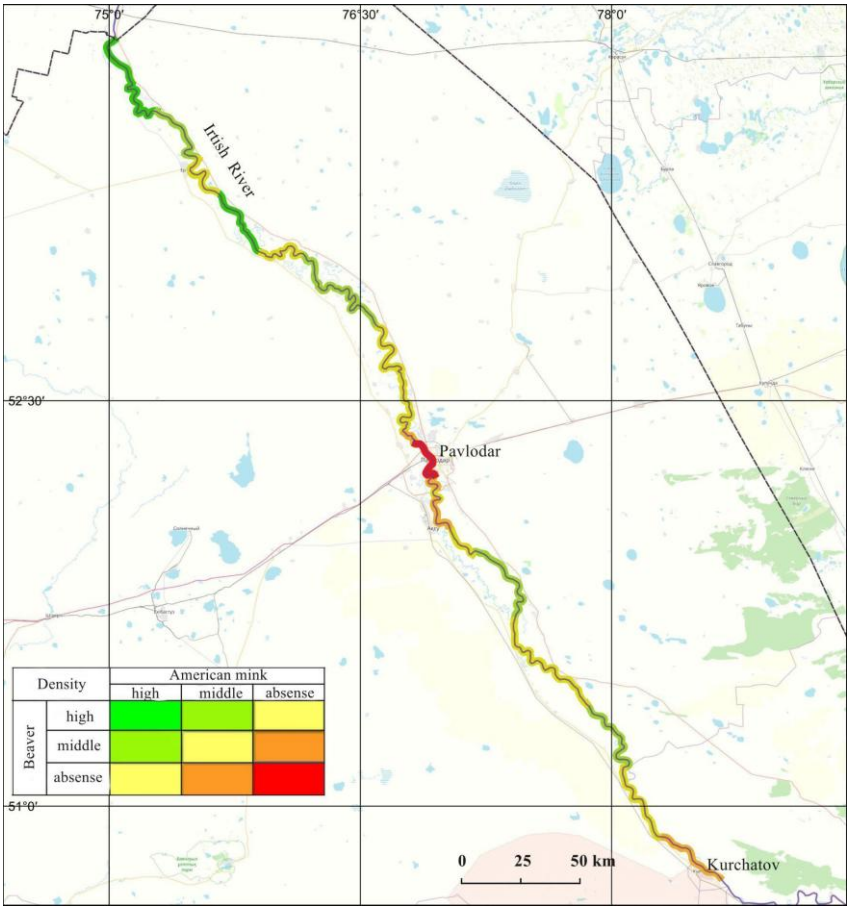


**Figure 3** – Population density of semi-aquatic mammals (European beaver, American mink) in the Pavlodar Irtysh region
Note – High population density = beaver > 1 individual/km of watercourse bed, mink > 0.5 individuals/km of watercourse bed.
Medium population density = beaver < 1 individual/km of watercourse bed, mink < 0.5 individuals/km of watercourse bed.

Thus, mammals provide invaluable positive ecosystem services, but they can also have a negative impact on humans and the environment. Given that the status of their populations is unknown, it is currently impossible to assess the scale of their damage to pastures or their possible hunting and commercial value. More data are needed to identify and study in detail the types of ecosystem services provided by these indicator species.

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