Beavers as ecosystem engineers – a review of their positive and negative effects

I O Rozhkova-Timina, V K Popkov, P J Mitchell, S N Kirpotin
Research Institute of Biology and Biophysics, National Research Tomsk State University, Tomsk, Russia
E-mail: inna.timina@mail.ru

Abstract. The paper reviews the environmental activity of beavers (Castor fiber L. and Castor canadensis L.) and their impact on different aspects of the environment. Beavers inhabit almost all climatic zones but are most abundant in Russia, USA, and Canada. Beavers’ ecosystem engineering activities include building dams and creating ponds. The dams provoke hydrological alteration, soil overwetting, changes in local micro- and nanorelief. The water stagnation in beaver ponds below dams results in lack of oxygen, a high carbon concentration, and the death of many aquatic organisms. The flooding water above the dam causes vegetation death due to overwetting and at the same time a rise in the biodiversity of water organisms. This paper includes original data gathered by Tomsk State University on lack of oxygen and subsequent fish death in dammed ponds. All environmental changes are cumulative and have strong contextual dependence. The beavers’ environmental activity has positive and negative consequences.

1. Introduction
Eurasian and North American beavers (Castor fiber L. and Castor canadensis L.) are very common animal species that live almost across the whole world. They inhabit places with diverse living conditions: climatic zones from forest-tundra to subtropics, rivers’ and other water bodies’ banks and floodplains of different sizes, both on plains and in mountains [1-3]. The largest beaver populations live in Russia, USA and Canada.

At the beginning of the 20th century, the Eurasian beaver was almost exterminated on the territory of Russia: its population was about 900 individuals [4]. But due to measures taken nowadays the Eurasian beaver is common almost in all the forest and forest-steppe zones of the European part of Russia, West Siberia, Baikal Region and Amur lower reach [5,6]. A similar situation is observed in North America with the North American beaver. The beavers reintroducing has much in common with the process of introducing alien species into formed ecosystems. [7].

Beavers are one of the few species of mammals, which intentionally cause habitat transformations and create a specific environment. They are known for building dams and creating ponds. This means that they are ecosystem engineers and change the environment in their life activity [1-3, 7, 8-28]. Their all-round activity is a powerful environmental factor affecting the entire water-coastal complex. Its consequences include the formation of reservoirs in upper reaches, changes in the hydrological and hydrochemical regimen of watercourses, soils hydromorphicity, flora and fauna composition etc. The significance of the environment-transforming activity of beavers on fish migration and the formation
of fish communities has been noted [8]. Some aspects of beavers’ influence are well studied and some aspects are still virtually unknown.

Many authors have studied various aspects of beaver activity at different times. Some authors (Ford, Naiman, Roulet, Bubier, Yavitt, etc.) were more concerned with beavers’ influence on the gas composition of water bodies, and Russian researchers (Zavyalov, Danilov, Kanshiev, Mukhametzyanov, etc.) mostly evaluated their environment-transforming activity. It should be noted that in Russia active research has been conducted in the Republic of Tatarstan, Karelia, and the Volga Federal District, but seldom in Western and Eastern Siberia. Notwithstanding, Siberia is home to one of the largest beaver populations in the world [5, 6, 29].

Researchers from Tomsk State University (TSU) investigated the floodplain of the Ob River’s middle course (Russia). The Ob River lies in the West Siberian Lowland and passes through all the landscape zones of Northern Asia. It is the world’s seventh longest river (3,650 km), whose vast adjacent territories are inundated during the spring flood [30, 31]. Its floodplain is the second largest floodplain in the world (after the Amazon’s Varzea) [32]; it is tens of kilometers wide and reaches 30 km. Because of its size, the floodplain is the main contributor from land to the Arctic Ocean and an important link in the system of the global cycle of matter [31]. The research was conducted at the TSU scientific station Kaibassovo. It is located in the Ob floodplain (N57.246142 degrees, E84.181919 degrees) in Krivosheinskiy District in Tomsk Region (Western Siberia).

The aim of this paper is to review the research into beavers’ influence on the environment and find identify any gaps. This paper can then propose new directions for research into beaver activity.

2. The general characteristics
The Beaver is a genus of semiaquatic mammals, which belongs to the order of rodent and family Castoridae. This genus has two species: the Eurasian beaver C. fiber and North American beaver C. canadensis. In general, these two species have much in common; they merely have some differences in appearance, which in field conditions are unnoticeable even for specialists [33]. It is noted [22, 34] that the European and North American beavers have an identical effect on the environment, but nevertheless, there is strong contextual dependence [1].

Beaver nutrition is strictly vegetative; in choosing food, beavers follow the prevalence of certain species in their territory. In general, they prefer bark and sprout of softwood (aspen, willow, poplar, birch) and different herbaceous plants. Beavers avoid coniferous species. In summer the proportion of herbaceous food in the beaver diet increases. Beavers’ daily food intake is up to 20% of their body weight. In autumn beavers conduct wood foraging for the winter. The food reserve determines the size of the beaver settlements [7, 35-37].

Beavers are monogamous; they form families, which unite in settlements. They reproduce annually; they have from two to five beavers in the brood. After two years, the young beavers start to live separately from their parents [33]. Their life duration in zoos and farms is up to 30 years [38, 39], whereas in the wild it is 20 years [40-43]. According to Swinnen et al. (2015), beavers are nocturnal animals even when there are no predators in their territory, and their greatest activity is noted during moonlit nights [44].

The beaver distribution area is enormous: from forest-tundra to subtropics. But beavers inhabit mostly moderate climate zones and are widely distributed in Russia, Canada, and the USA. They inhabit the banks of any water bodies: big, medium, small rivers; mountain and plain rivers; anthropogenic lakes, wetlands, channels, and quarries. Beaver settlements are common in the floodplains of large rivers. If the number and density of the beaver population are too high, they migrate to suboptimal and pessimal habitats. There they exhibit high ecological plasticity and transform the environment according to their own needs. Depending on the territory’s characteristics, beavers prefer burrowing or construction activity. Beavers live in a cyclic nature: a family of 5-6 individuals inhabits a territory for 3-10 years (depending on the conditions), after which they leave the territory. Resettling occurs after 2-10 years, depending on the rate of vegetation recovery and availability of unoccupied habitats [1-3].
Beavers do not have a natural regulator of their population size. Some beaver territories do not have beaver predators at all [44]. The main beaver predator is the wolf. In winter wolves search for food, looking in beaver burrows. It is noted that in central and north Canada the North American beaver is the main dietary component for the wolf. But through beavers’ own protective mechanisms, the wolf is not able to decrease the beaver population [7, 37, 45]. It might happen that bears destroy beaver burrows, but this phenomenon is not systematic and cannot impact on the beaver population [6]. According to Zavyalov (2017), beavers change their behavior in the presence of large predators. He describes the data of photo-traps: “a bear not only dug out the lodge but also actively pursued beavers in the water, trying to subdue them by flapping its forepaws on the water. Not having achieved success in the evening, the bear came again to the same lodge the next morning and again tried to get the beavers, but did not succeed. The beavers of this settlement showed great caution and even a few months after the attack left the lodge only during total darkness” [3].

3. Beaver environmental activity and its impact on the landscape
The beaver is described as the most striking example of ecosystem engineers, which intensively transform water and near-water systems [1,5,21,25,34,38]. In their vital activity beavers transform the environment for their needs: they dig burrows and build lodges, cut trees, deepen bottoms and build dams for raising and controlling the water level [1,2,7,46] (Figure 1).

Beaver burrows are usually short (1-4 meters long), and complex burrows have many underground branchings and levels. The density of simple burrows in some regions of Russia is estimated as 5-40 burrows per kilometer of river bank [28, 29, 47]. The digging causes the forming of micro- and nanorelief, influences the soil formation, and changes the temperature and water regimes, banking up the pipes. When beavers leave the territory, the burrow nets remain, and new inhabitants add their burrows. Thus, the burrowing activity of beavers has the same influence as dam construction [1, 2, 7, 23, 25, 48].

Lodges are built in territories where burrow digging would be inappropriate. Usually, it is a wooden cone sealed with silt and soil, which is about 180 cm high and with a base diameter of 3-4 m. The entrance in burrows and lodges is located under the water for protection against predators [1, 47].

Beavers build dams (Figure 2) for raising and controlling the water level, which hides the entrance in lodge [29,49,50]. The duration of a dam’s existence can differ: from one year (the dams are often destroyed by the spring flood) to 50 years [47]. The degree of a dam’s impact on surface runoff depends on its age and condition: more contemporary dams do not allow water to pass, but accumulate it in the upper lake, until the water begins to flow over the dam. The oldest dams, which have only a
“skeleton”, virtually do not affect the watercourse [51]. The dams complicate the hydrological regime of the riverbanks, significantly increasing the depth, duration, and flooding area during spring floods and raising water levels in the period of low water [1,3]. The dams impact on the regional water balance, which can be important in the case of a drought: the overwetting prevents the spread of forest fires [6,12].

The increasing of the water level results in the emergence of multi-channel systems, which have great development potential in the lowlands. Because of the rapid discharge of large amounts of water and sediment deposition outside the river bed, the degraded watercourse systems return to their natural state [1,23,34,52].

The total number of beaver dams is unknown: there are different data concerning North America (the US and Canadian territories) [52,53], and there is no estimation for the number of dams in Russia or Europe.

Dams increase the water incoming from the riverbed to soil, which creates the anaerobic conditions. The incoming of soil waters enriched by oxygen and nitrates from surrounded areas stops [1,54]. Territories drained in the absence of beaver activity become more saturated [55]. The rate of restoration of the previous groundwater regimes after the destruction of dams depends on the terrain and permeability of soils and grounds [1].

Organic and mineral silt accumulate above the dam and remain there for many years. The speed of sedimentation can be very high (up to 47 cm per year, Oregon, USA) or very low (0.075 cm per year) [63]. A high speed is often noted when the dam blocks a powerful stream with a large quantity of colluvial deposits [57]. Old ponds have a larger area and accumulate more sediments. Sediment sorting is observed in water bodies with different sizes of particles: the smallest are deposited in the center, the largest – in the upper part of the pond [1].

The environmental activity of beavers includes not only construction of dams, burrows, and lairs, but also creation of pathways and channels, selective consumption of woody and herbaceous vegetation, creation of the feed stocks and the biological signal field. This all increases the beaver’s adaptability to natural conditions [1].

According to Wegener et al. (2017), beaver activity in wide valleys can create a physically complicated hydrologic environment, which strengthens hydrological and biogeochemical buffering and promotes a high speed of metabolism in the water ecosystem. Beaver-mediated hydrological
connections in river, floodplain, and riparian zones provide a high level of retention of carbon and nutrients [19].

The positive effects of beaver activity include not only reducing the number of forest fires, but also the weakening of winter kill processes due to holes in ice, the retention of pollutants by dams, an increase in the rate of recultivation in anthropogenically altered territories (the increase of the surface water mirror, the appearance of floodplain meadows) [23].

The environmental changes have a cumulative character. The saturation limit of beaver constructions in the landscape exists. Those territories with evident traces of contemporary or past beaver impact are called beaver spots. The number of such spots demonstrates beaver influenced landscapes. For example, Voyageurs National Park (Minnesota, USA) and the archipelago Tierra del Fuego (Argentina and Chile) belong to territories with an extremely high beaver impact. The influenced area of other territories is evaluated as 3% [1,2]. Here it should be noted that one of the largest populations of Eurasian beaver inhabits West Siberia [29], but its impact is still mostly unstudied.

The general patterns of consequences of beavers’ environmental activity were described in this section. However, it is always necessary to take into account contextual dependence: the results obtained for one territory may be incorrect for another one [1,3,9].

4. Beaver influence on carbon-related parameters
Many researchers have shown an interest in the impact of beavers’ activity on the carbon cycle for several decades. In 1988 Ford and Naiman published a paper in which they evaluated the beavers’ influence on the carbon cycle. The scientists studied the methanogenesis and methane level in beaver ponds in Quebec (Canada). They noted that bottom sediments below the dam are greatly enriched by organic matter, which is evidence of a high level of methanogenesis. Their results demonstrated that in beaver ponds the methane concentration was much higher than in free streams [56].

Later Naiman et al. (1991), in studying the lakes of Minnesota (USA), showed that beaver activity has a direct influence on hydrology, vegetation patterns, and biogeochemical cycles. Dams result in an increase of the water area above the dam and its shallowness below the dam. As a result, above the dam soil flooding occurs, which causes anaerobic conditions and methanogenic bacteria reproduction. The area for aquatic vegetation, which is the best conductor of methane from the bottom sediments to the atmosphere, increases. Small water bodies formed as a result of the dam construction are better at saving the heat and causing the process of methanogenesis. The carbon accumulated in these reservoirs also contributes to the activation of the methanogenesis. The authors showed that beaver-meadow complexes are the source of 1.9% of the total carbon amount of the wetlands. The result of all these processes is a rise in methane concentration in the troposphere [57]. Subsequently, Yavitt et al. arrived at the same conclusions after studying two beaver ponds in Adirondack, USA [58], as did Roulet and Ash by comparing dammed and not dammed wetlands in Canada [59], Bubier et al. by studying methane emissions in different wetlands of North Ontario, Canada [60], Whitfield et al. by studying the influence of the growth of the beaver population [20], Lazar et al. by studying the nitrogen in beaver ponds [61], Ecke et al. by comparing the effects of beaver and anthropogenic dams [34], Johnston in describing beavers’ habitats [7], and others.

Moreover, McCaffery and Eby (2016) determined that in beaver ponds the tissue of wolf spiders and deer mice had more carbon obtained from aquatic organisms. From this we can conclude that in the water and, consequently, the aquatic organisms of the beaver-inhabited lakes, carbon concentrations are higher than in free streams [16].

Ellen Wohl (2013) described the importance of beaver activity for landscapes of Colorado, USA. Beaver meadows are formed when the beaver dams result in prolonged flooding and the sedimentation of organic matter. They accumulate a great quantity of carbon; the author notes that deposition of fine sediments started in Holocene and that time the carbon accumulation was more intensive. Differences in the total organic carbon between the abandoned and the active beaver meadows indicate that the carbon stocks in the valley significantly decreased as beavers disappeared and the meadows dried up.
Relic beaver meadows have about 8% of the total carbon in the landscape, but this value was 23% when the beaver actively supported wet meadows. These changes represent the total value of cumulative effects in heterotrophic respiration and oxidation of organic substances associated with a historical decline in the beaver population [21].

Johnston (2014) called beaver ponds “hot spots” of carbon dioxide and the methane. She studied the density and the stratigraphy of carbon stocks in the soil of boreal beaver meadows in Voyageurs National Park (USA) after the beaver pond was left and dried. In the soil of the beaver meadows the size distribution of particle changes and the amount of organic matter increases from the depth to the surface. In the soil of beaver meadows, carbon is widely distributed, which plays a part in carbon dioxide (CO$_2$) and methane (CH$_4$) production. A significant amount of carbon is emitted by vegetation overwetting and surface organic carbon is accumulated. This research confirms the carbon presence in the soil in an amount sufficient for trace gases variation but assumes that a great amount of carbon is caught by beaver meadows. This can compensate the carbon losses during the pond stage. The majority of carbon in beaver ecosystems is accumulated in soil and vegetation [7,11].

Whitfield et al. (2015) followed the dynamics of methane emissions during the growth of a beaver population on Argentinian archipelago Tierra del Fuego, which has been weakly anthropogenically influenced. For centuries the beaver population was on the verge of disappearing and then increasing again. The reappearance of the beaver population and its introduction to other regions led to an emission of 0.18-0.80 Tg CH$_4$ annually. This is approximately 200 times more than emissions from the same systems (ponds and flowing water, which have become ponds). It is estimated that the restoration of the beaver population led to the creation of 9500-42000 km$^2$ of drainage basin. Since CH$_4$ is a strong greenhouse gas, the climate change is closely related to changes in the beaver population. All these processes have a cumulative effect. Also, Whitfield notes that previously beaver meadows were widely distributed in North America, but now they have begun to decrease [20].

A comparison of beaver ponds and free streams in the Ob floodplain (Tomsk Oblast, Russia) by researchers from Tomsk State University demonstrated the rise of carbon compounds in dammed lakes. These data fit with previous data concerning the beaver effect in other territories [56-60]. However, there are some significant differences and unusual patterns. Methane is about fifteen times higher, dissolved carbon dioxide three times higher and dissolved organic carbon is twice higher in beaver ponds, but there is no significant difference in the rate of carbon dioxide flux and dissolved inorganic carbon between the two types of streams [62].

The concentrations of dissolved oxygen are much lower in beaver ponds; the difference can reach 70% [18,25,34]. This might be connected with a decay of wood carried by beavers or organism decomposition. The content of suspended particles in beaver ponds is twice as high, which is directly connected with a raising of the silt from the bottom as the result of intensive beaver activity [25]. Regarding BOD$_5$ different results can be observed: this parameter in a dammed pond might be unessentially higher [25] or significantly lower [62].

The main conclusion made by many authors studying the beaver influence on carbon cycle in different countries is that beaver ponds have conditions conducive to methanogenesis: weak water movement, a large flooded area, carbon catching, and anaerobic conditions [18,34,56-60,63]. But it is still unknown how the age of a pond impacts the methane rate.

Some authors tried to compare the parameters from both sides of the dam. Billet and Moore (2008) studied carbon compounds in the surface waters of the Mer Bleue Conservation Area, Canada. He recorded a higher CO$_2$ rate below the dam than in open water. Also he noted that concentrations of CO$_2$ and CH$_4$ peak in July and August, then they steadily decrease until November. At this time, below the dam he noted an abnormally high methane rate [64]. Similar research in the Ob floodplain demonstrated the dam’s influence on the carbon-related parameters in the reservoir. Below the dam the concentrations of carbon compounds (CO$_2$, CH$_4$) are significantly higher, and the concentration of dissolved oxygen is much lower. The difference in the methane concentration of both sides of the dam was six or more times, and for dissolved CO$_2$ almost twice, and for the oxygen content – forty times
[26]. Similar results were obtained by Puttock et al. (2017) in North America: the concentration of carbon-containing compounds below the dam is several times higher [17].

5. Beaver influence on flora and fauna

Microcosm experiments [13,65] demonstrated that beavers’ vital activity increases the abundance and the biomass of the bacterial plankton. The zooplankton also rises in stagnant beaver ponds [10]. The abundance and species composition of invertebrate animals and small mammals also vary greatly [34,66]. According to various data [16,67], different orders of invertebrate animals in beaver ponds can vary in number and species composition.

In the Orenburg nature reserve, the aquatic organisms crawling along the bottom or the substrate predominate in the free part of the stream; this fact is associated with a rapid current. In a beaver stream, the water flows weakly, and there is a large number of swimming aquatic organisms [27].

Beavers, even in the absence of construction activity, cause an increase in zooplankton abundance and changes in its species composition. In the flowing sections, the abundance, biomass, abundance of copepods, number of species increase. In stagnant floodplain reservoirs, the biomass and the abundance of branching crustaceans increase with a decrease in the number of species and equalization of communities [13].

According to the analysis of phytoplankton, zooplankton, and zoobenthos, the tendency of growth in the number of hydrobionts in the center of beaver settlements and the fall in this indicator below the dam has been revealed [68].

Studies of beaver ponds in the Volga forest-steppe (Penza Region) showed that these water bodies are not the key habitats for fish and amphibians [8]. As a result of the reservoirs’ pondage, the abundance and the biomass of zooplankton, amphibians, and fishes increase. If a beaver pond exists for a long time, the concentration of dissolved oxygen and, as a consequence, the number of fish, decrease. But because of the increase in the area of shallow water, the number of amphibians grows. The reverse process occurs with increasing flowage. In addition, beaver dams are mechanical barriers to spawning migrations and affect the mosaic of water bodies, which may be the critical factor [7,24,69].

In 2014 Bylak compared the species composition of fish in beaver ponds and free streams. A significant difference was noted. Changes connected with pond aging were the reason behind the decrease in Siberian bullhead density. Large individuals of Brown trout were found only in beaver ponds, and upper parts of beaver complexes provided an egg-laying and breeding environment. Common minnow and stone loach had greater density in ponds than in free streams. The key factors for ichthyofauna in mountain streams inhabited by beavers were local peculiarities connected with beaver activity [9].

TSU researchers showed studied the part of Ob floodplain with the total area of about 30 square kilometers. They showed the presence on this territory at least 30 lakes. Examination of the beavers’ settlements showed that 5 beaver colonies inhabit elevated parts of floodplain and do not build dams. At the same time at least 10 beaver colonies make their dams at the floodplain lakes and streams. The local fish of these water objects are Carassius gibelio (Bloch) and Carassius carassius L., and introduced species are Percottus glenii Dybowski. At the beginning of spring flood all fish species come from the Ob to the exorheic lakes for the spawn and feed. In the absence of beaver dams the fish catching was performed until the January and the total catch reached 1-2 tons. The appearance of beaver dams resulted in catches decrease and cessation of fishing. It is linked with the fact that fishes come into a pond or a small river for spawning and are not able to exit due to the dam. The dams form mechanical barriers, which prevent fish migration from lakes to the river. The remaining fish die due to the lack of oxygen, especially in winter time.

Mishin and Trenkov (2016) compared the attractiveness of a dry beaver pond and dry marsh for large mammals. They showed that the beaver ponds were more attractive for many mammals, especially for the predators. The predators are attracted by the different amphibians escaping from the draught in beaver burrows. Ungulates (except for wild boar) visited the dry beaver pond more often
than the marsh with similar characteristics. Elk and roe deer were attracted to the beaver ponds by grey willow - this food was more available during the drought. Also during the drought, the beaver ponds held some water: the animals used the beaver pond as a watering place because the river and streams dried [70].

Macrophytes are included in the beavers’ diet and are always influenced by dam building, but this impact has virtually not been studied. But Law (2014) established that the presence and activity of the beavers are favorable for the biodiversity of macrophytes: the abundance and the species diversity of aquatic plants increase [14].

Beavers include wood species for their diet, destroying 90% of aspen and willow and 26% of birch. This along with the dam construction increases the wetlands area [7,66,71]. Dam construction leads to flooding of the greater part of the floodplain and adjacent areas, vegetation death because of the lack of oxygen, and a change in flora and fauna species. Due to the overwetting many trees die: the death of coniferous species is noted 2-3 years after the dam construction, and deciduous species after 3-4 years. Marsh communities appear instead of the coastal forest phytocenosis. Due to the lack of oxygen below the dam, fish death also occurs [25,27,29,50]. In general, in beaver habitats about 40% of trees die [72]. However, in these territories, the biodiversity increases in species living in conditions of high moisture [7,15,73]. Trumpeter swan and other water birds are attracted by open water areas appearing as the result of dam construction. Great blue herons, ospreys, and woodpeckers nest mostly in the dead trees. Beaver meadows are attractive for many sparrow species, which prefer shrubby or grass habitats. The open water is an optimal habitat for amphibians and turtles. Beaver meadows are a source of nutrition for moss and deer [7]. At the same time beaver meadows dry up after beavers leave, which leads to a loss of biodiversity [21].

6. Beaver influence on nitrogen compounds, phosphorus, and other parameters

The environmental activity of beavers influences not only the carbon cycle but also the nitrogen cycle and some ancillary parameters. The nitrogen stock in sediments demonstrates the importance of sediment accumulation and an expanded wetted area to the nitrogen cycle [73].

Naiman and Melillo (1984) studied the amount of nitrogen in the bottom sediments of streams of second order in eastern Quebec (Canada), measuring the nitrogen dynamic during dam building. The most significant changes after stream damming were a decrease in allochthonous nitrogen and rise in nitrogen fixation by sediment microbes. In general, the beaver-altered part of the stream contained 1000 times more nitrogen than the same part before transformation [73]. Subsequent research demonstrated a reduction in nitrate concentrations and an increase in ammonium in beaver ponds in comparison with unaltered territories [75]. Lazar et al. (2015) noted the active processes of denitrification in beaver ponds [61]. According to Johnston, anaerobic conditions in beaver ponds lead to a reduction in nitrogen concentrations [7]. According to Puttock et al. (2017) the presence of a beaver dam impacts on the rate of total oxygenated nitrogen and phosphates: lower concentrations are observed below the dam [17]. Some authors note the rise of total phosphorus concentration in beavers’ habitats [13,65]. Other researches claim the opposite, that beavers do not significantly influence the nitrogen and phosphorus concentrations [25,34]. From the contradictory information on the beaver influence on the nitrogen and phosphorus content, we can conclude that there is a strong contextual dependence of such changes.

The pH parameter slightly differs on the different sides of the dam and does not depend on the beavers’ presence in the pond [17,26,59,64]. Many other parameters (conductivity, bacteria concentrations, water mineralization, iron content) did not show significant differences [18,25,26].

It has been shown that the ponds formed during the construction of beaver dams perform a purifying function. Based on chemical analysis of the water, the purification capacity of a beaver settlement has been established, however, only to eliminate the pollution introduced by the beaver itself, as well as the biogenic pollution of anthropogenic character [68].

McHale and al. (2004) compared the soil of the beaver territory and peatlands in Adirondack, USA. He discovered that in spring and summer the beaver meadows contain a greater concentration of NO₃⁻.
They are a source of dissolved organic nitrogen (and peatlands are the absorber). Both types of wetlands are the source of NH$_4$+ in winter and the absorber in summer [76]. The territory shortly after the flooding sees a sharp increase in the inorganic matter in the soil. At the same time, concentrations of the main plant nutrition elements also increase: phosphorus by 16% and potassium by 8%. This is due to the fact that mineral elements are accumulated with silt and other sediments during the period of the beaver’s habitat in the territory. In areas without beavers, the concentration of ammonia nitrogen in the soil is higher, and the available free nitrogen is lower [25].

7. Conclusion
Beavers are widespread animals and in the course of their activity transform the ecosystem. This transformation has different consequences. Researchers attribute to positive effects a reduction in the number of forest fires, an increase in recultivation speed, retention of the pollutants by dams, a rise in the biodiversity of water species and the species that prefer wet environment. The negative effects are lack of oxygen in beaver ponds, fish death, high carbon concentration, and vegetation death below the dam because of a lack of oxygen and above the dam because of overwetting.

Therefore, it is impossible to make a conclusion on a decidedly positive or negative beaver influence on biodiversity: some species reduce or even disappear in beavers’ territories and for other species these conditions are favorable.

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