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BEAVER ACTIVITY AND ENVIRONMENTAL AND HYDROLOGICAL CHANGES IN FOREST AREAS

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ABSTRACT

The purpose of the study was to present researchers' knowledge of the impact of beavers on hydrological conditions in forests. A historical outline, reasons for the drastic decline in the beaver population in Poland and Europe, as well as positive examples of the restoration of the Eurasian beaver population are presented. The paper provides information given by authors from countries with beaver populations on the impact of these rodents on the natural environment, the way in which it transformed it, as well as threats, losses and benefits of beaver activity brought to man.

Keywords: European beaver, Canadian beaver, environment, water

INTRODUCTION

An important goal of water resource management is to improve and increase resources of both surface and ground waters. One of the ways to achieve this objective in forests is to implement a small retention program. Where there is a lack or deficit of water, the species composition is impoverished, while in drastic cases the total extinction of the populations of species forming the local fauna and flora in the natural environment is observed. Beavers are natural regulators of water relations in forest and meadow areas. Our forests are inhabited by the European beaver (*Castor fiber* L.), which is able to transform ecosystems and adapt them to its needs. By building lodges and dams a beaver family can retain large amounts of water in the environment.

The purpose of this study was to analyse the impact of the rodent on forest ecosystems and to determine the amount of water retained based on a review of Polish and foreign research.

POLAND'S WATER RESOURCES

Poland's water resources consist of the country's own resources estimated at 53.9 km^3 constituting 87.5% and the remainder of 12.5% coming from abroad. The vast majority (95.5%) of water resources flow into the Baltic Sea, with the remaining share flowing beyond our borders (Gutry-Korycka et al., 2014). Water is such an important element of human life that it was decided to control its resources and counteract threats associated with fluctuations in its states. The World Water Council in 1990 published a report that classified Poland as a water deficit country. This conclusion was based on the resource indicator included in the report, which was set at 1460 m^3 per capita per year. In turn, Chełmicki (1999) at the end of the 1990s calculated this indicator at 1580 m^3, while Gutry-Korycka et al. (2014) estimated the unit total resources per capita

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at 1839.3 m^3 per year. The problem of water deficit has been recognized for a long time. In the 1960s and 1970s, the government of the Polish People's Republic made the first attempts to improve the state of water resources through simple measures such as rebuilding impoundments on rivers or building small water reservoirs. After nearly 25 years, in 1995, an agreement was signed between the Minister of Agriculture and Food Economy and the Minister of Environmental Protection of Natural Resources and Forestry of the Republic of Poland regarding the introduction of small retention schemes. In 2002, the need to expand the project was noted, which resulted in the creation of the first small retention development programs mainly for rural areas (Mioduszewski, 2008).

Kowalczak (2007) estimated the effectiveness of these programs at 15 million m^3 of retained water, which accounts for 25% of the assumed effects. Actions need to be taken at the local level to improve the situation. Therefore, it is necessary among other things to build retention reservoirs and to conduct economical and pollution-free management of water resources (Suligowski, 1997). Any activity aimed at improving this state is desirable. Actions related to human activities as well as those that can be offered by nature can be distinguished in this respect. Beavers are certainly such elements of the environment that can consciously regulate the water status in the micro-region scale.

THE EUROPEAN BEAVER

The presence of beavers in Poland is relatively well documented. Until the 13th century, namely in the years 960−1370, during the reign of the Piast dynasty, beaver hunting was the privilege of princes, which in effect led to the establishment of a special position called dominus castorum or Beaver Master (Bóbr..., b.d.). In the early medieval times, the beaver was one of the most abundant animals, among other things thanks to king Bolesław the Brave who at the beginning of the 11th century banned hunting for this animal in his lands. The population of this rodent in our country began to decline systematically since the 13th century, which was a consequence of the high demand for its black fur, characterized by high utility value and which was considered to be particularly valuable on foreign markets. The Polish beaver population had a high percentage of black-coloured beavers as a result of the selection carried out by the Piast royal court (Czech, 2010). In the 16th century, several important decrees came into force that regulated the acquisition of such animals as the auroch, the European bison and the beaver. First, thanks to Sigismund I the Old, protection of the aforementioned species was introduced in 1523, and then in 1529, 1566 and in 1588 the Lithuanian Statutes came into force, which guaranteed legal protection of beavers and their lodges until 1840. These statutes imposed severe penalties for non-compliance with the established law. Due to the aforementioned Lithuanian Statutes, zone protection was initiated. The zone was established at a distance of "stick throwing" from the beaver lodge. These zones meant a ban on ploughing fields, mowing grass or harvesting willow (Dziubecki and Pisarczyk, 2014). Certainly, the Christian religion also contributed to a drastic reduction in the population of the beaver. The church's doctrine of fasting permitted some exemption. One such "convenience" is the recognition of the beaver as a fish, which on the part of godly courts and monasteries created additional pressure on this animal. Jan Kitowicz (1728–1804) in his work concerning customs prevailing in the times of August III wrote about the beaver in the following way: "Lenten fish could be consumed in the company of other cold-blooded animals and animals that could be defined as fish (ad pisces reductive pertinent) such as crayfish, lobsters, oysters [...] beavers, turtles, frogs, and here and there even ducks and common moorhen because they cannot live without water. In this way the fish wasn't meat, the water bird became a fish, and the birds' eggs constituted the meat, the consumption of which broke the fasting!". In addition, the aforementioned author writes: "When they eat in the refectory, they do not use glasses but flat clay bowls for the drink, expressing in this way the manner of the former hermits who scooped the drink with turtle shells; wild ducks, also called mallards and Muscovy ducks, as well as beavers, otters and turtles are eaten as fish, because these animals, according to naturalists, are more aquatic than terrestrial in nature...". As a result of the deeply rooted Christian tradition, recurrent war turmoil and constantly growing demand for furs, in 1918 the population of the beaver in Poland was reduced to a limited area in the basin of the Neman River and the Pripyat River. World War II effectively

contributed to the reduction of the already modest beaver population. The last beaver families were reported on the Marycha and Czarna Hańcza rivers (tributaries of the Neman River). The early years of the Polish People's Republic were the years of revival of the beaver population in Poland, which resulted from their development and dynamic expansion in the Soviet bloc countries namely Lithuania, Belarus and Russia, leading to the beaver population of 1,000 individuals in the mid-1970s (Dzięciołowski and Goździewski, 2011). A great contribution to the revival of the beaver population may be rightly attributed to Professor M. Czaja, who in 1958 founded a beaver farm at the Experimental Station of the Polish Academy of Sciences in Popielin, with the core of the colony coming from the Soviet Union (Janiszewski, 1995). As a result of the initiative of Professor W. Żurawski, in the years 1975–2007 a resettlement program of beaver families from the Suwałki region and Masuria to the basins of the Odra and Vistula was carried out (Goździewski, 2007 after Czech, 2010). Apart from scientists' activities, also the Polish State did not remain indifferent to the drastically small population of beavers and on September 16, 1919 the Ordinance of the President of the Republic of Poland and the Ordinance of the Ministry of Religious Denominations and Public Enlightenment came into force, owing to which among others the dwarf mountainpine, the European bison, the marmot, the black stork and the beaver became subject to legal protection (Janiszewski and Misiukiewicz, 2012). In 1975 the "Active protection of the European beaver in Poland" program was launched, which is credited with great success (Goździewski, 2007 after Czech, 2010). Researchers' initiatives, conservation programs, the declining demand for fur caused by the growing public awareness, as well as natural factors such as a rich feeding base and the lack of natural population reducers have contributed to the success of the beaver population in our country (Giżejewski and Goździewski, 2016). According to the Central Statistical Office of Poland (2017), in 2016 the number reached 121,000 and it is estimated that beavers inhabit 29% of lakes in Poland, 17% of drainage ditches and 54% of all rivers (Janiszewski et al., 2009). Owing to successful resettlement actions and active protection of the species, the European population of the beaver is found in 30 European countries and its population in Eurasia is estimated in the range of 600,000 and 1 million (Dzięciołowski and Goździewski, 2011; Halley et al., 2012). This is a huge increase in the population size given the fact that Halley et al. (2012) maintained that at the most critical moment in the 19th century the beaver population was estimated at 1,200 individuals in 8 isolated populations. By all means, the beaver population will continue to grow because it is protected by many international legal acts, such as the Bern Convention, where the beaver is mentioned in Annex III, which covers protected species of fauna. Another act legally binding for European countries is Directive 92/43/EEC of May 21, 1992 on the protection of natural habitats and wild fauna and flora - the so-called Habitats Directive. In addition, Annex IV of the directive also obliges the EU countries to strictly protect many plant and animal species. However, the Polish population of beavers is included in Annex V, according to which the acquisition and exploitation of the population is allowed provided that the population is maintained at an appropriate conservation status (Janiszewski and Misiukiewicz, 2010).

THE NATURAL ENVIRONMENT

Both European and Canadian beavers are aquatic animals. Unlike the ground and soil, water quality is not a determinant for the occurrence of these animals. An example may be provided by a beaver family which lived in a watercourse contaminated with sewage discharged from a large pigsty, which confirms the opinion that beavers can be found in various water purity classes, including those not classified (Czech, 2010). However, as noted by Dzięciołowski (1996), the factor that beavers do not like are fluctuations in water levels that can directly threaten the safety of their families by exposing or uncontrolled flooding of their lodges. Additionally, beavers are not found in watercourses or water reservoirs which bottom is stony or rocky (Hacker and Coblentz, 1993 after Gurnell, 1998; Hartman and Törnlöv, 2006). Beavers are animals that are extremely flexible and easily adaptable to a variety of living conditions. Their presence is also noted in highly urbanized areas such as the Poznań agglomeration, near human dwellings or in agricultural areas. If necessary, they can solve the problem of drying swamps and watercourses by digging lodges or deepening

canals and adjusting the environment to their requirements (Bereszyński and Homan, 2007; Czech, 2010; Dzięciołowski and Goździewski, 2011).

Certainly, their being the largest European rodent (the largest individuals weighed up to 29 kg) significantly contributes to a noticeable transformation of the natural environment to their needs, thanks to which beavers on the national scale are able to retain up to several million cubic meters of water (Czech, 2010). By erecting numerous dams and dikes on watercourses, beavers are able to interact in the way they want. It is observed that dams may raise the water level by a minimum of 50 cm, which is particularly important in shallow watercourses or reservoirs (Ganzhorn and Harthun, 2000). Beaver's activity alters the status of water resources and leads to related environmental transformations such as changes in flora and fauna species. The research conducted in the Wigry National Park can provide an example in this respect. In 1949 the first beaver family was found there and in 2015 it was determined to what extent these animals exploited the river and drainage ditch environments. For their needs they used 40.3% and 42.7%, respectively, of woody plants available in those locations (Czech, 2007; Misiukiewicz et al., 2016). This change in the species composition structure of the watercourse bank vegetation leads to the initiation of the process restoring the natural habitats of scrub communities with growing layers of vegetation forming the undergrowth (Grygoruk, 2008). The decrease in the number of trees shading the surface of water contributes to an increase in water temperature and provides favourable growth conditions for such species as water lily or duckweeds. However, McRae and Ewards (1994) reported that in the case of small pools water temperature does not change significantly, which results from the short retention time, shallow depth and seepage through the entire length of the dam. A team of Lithuanian researchers, Margolis et al. (2001), defined the beaver pond in the summer as an energy sink. They noted a difference in water temperature in the beaver pond and beyond it amounting to 9°C. In addition, water dams built along watercourses act as natural filters retaining sediment and thus reducing water turbidity. As a result, an increased availability of nitrogen, organic carbon and other nutrients is observed in the micro-cycle of elements. Another aide effect of these changes is the creation of appropriate conditions for methane producing organisms, thus altering the pH of the stream. All this increases the resilience of the ecosystem (Kesminas et al., 2013; Mundała et al., 2008; Szpikowska and Szpikowski, 2012). In the case of fast-flowing streams, dams and dikes are important factors producing an ecological niche for fish that require calm waters and as a consequence displace the current ichthyofauna (Margolis et al., 2001; Miszczuk and Oglęcki, 2004). Dams and dikes are also excellent reservoirs and water storage facilities in periods unfavourable to vegetation due to drought and water shortages (Kobojek, 2013). Beavers have a huge impact on the amount of water in the forest ecosystem. This amount depends mainly on the size of dams and on terrain geomorphology (especially the profile and slope of the valley) (Johnston and Najman, 1987 after Gurnell, 1998). There are numerous publications, in which attempts were made to determine the specific extent of changing water levels with the appearance of rodents. The measurements of Grygoruk (2008) are a perfect example in this respect. That researcher using a digital model of the pool created by beavers observed that depending on the damming ordinate beavers could retain from 386 m^3 to 7249 m^3 of water. Other studies on this subject conducted in the Białowieża Forest proved that beavers could increase the water supply in the ecosystem by as much as 30 times compared to the state before the appearance of rodents in a given area (Boczoń et al., 2009; Ryś, 2011; Wróbel et al., 2016). One of the less evident arguments in favour of the beaver, raised by Czech (2005), is the fact that the beaver enriches the landscape by diversifying and changing the monotonous and "boring" ecosystem into an area that evokes a positive feeling in the observer by the fact that there are dams and lodges. By supporting forest pools, it undoubtedly has an emotional impact on forest visitors, while encouraging and promoting the use of such places for natural science education.

Hammerson (1994, after Gurnell, 1998) attempted to point out the natural consequences that occur in ecosystems where the activity of the Canadian beaver is observed. In addition to obvious observations such as slowing down flow velocity of the watercourse and raising the groundwater table, he indicated an over 100-fold increase in humidity around watercourses with gentle river valley slopes or an increase in the average

amount of water in ecosystems. From the point of view of farmers or foresters the positive natural changes caused by beaver activities are not always what they would find desirable due to flooding of meadows, arable fields or forest crops or destroying fruit shrubs. Beavers can also cause damage or destruction of transmission lines, e.g. telecommunications lines, they "clog" drainage ditches, undermine levees and flood houses. According to the Central Statistical Office data (2015), the damage caused by beavers is estimated at PLN 16.97 million. Another source of conflict with people is connected with the disintegration of dikes and the related expenses of pond owners and claims for damages from the Provincial Nature Conservation Officer (Miszczuk and Oglęcki, 2004). Czech and Lisle (2003) drew attention to the need to understand species trends. They also noted the need for public education to facilitate mitigation of conflicts in the future and at the same time eliminate problems such as poaching.

CONCLUSIONS

The beaver is one of the few animals worldwide that is able to adapt the environment to its needs. In the ecosystems in which it functions, through the erected dams it is able to store several million m^3 of water and is much more effective in water retention than all national water retention programs. The amount of water accumulated in the beaver pond is the result of the size of dams and local geomorphology of the area, especially the profile and slope of the valley. Beavers affect almost all components of ecosystems, both abiotic and biotic. Through their activities, it is possible to change the water temperature, the species of ichthyofauna or the shore flora and fauna. In the opinion of farmers or foresters positive natural changes caused by beaver activities are not always what they consider desirable. According to the data of the Central Statistical Office of Poland, the damage caused by the beaver in 2015 was estimated at PLN 16.97 million. One of the most effective methods of preventing damage is to resettle entire families using live traps.

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DZIAŁALNOŚĆ BOBRÓW A ZMIANY ŚRODOWISKOWE ORAZ HYDROLOGICZNE NA TERENACH LEŚNYCH

ABSTRAKT

Wstęp. Bobry są naturalnym regulatorem stosunków wodnych w obszarach leśnych i łąkowych. Lasy Polski zamieszkuje bóbr europejski (*Castor fiber* L.), który jest w stanie przekształcać ekosystemy, dostosowując je do swoich potrzeb dzięki budowaniu żeremi oraz zajmowaniu przestrzeni umożliwiających zatrzymanie w środowisku dużych ilości wody.
Celem analiz było przedstawienie wiedzy badaczy na temat wpływu bobra na warunki hydrologiczne w lasach.
Zakres analiz. Zaprezentowano rys historyczny i przyczyny drastycznego zmniejszenia liczebności bobrów na terenie Polski oraz Europy, a także pozytywne przykłady odtworzenia populacji euroazjatyckiej. Przytoczono wyniki z krajów, w których występuje bóbr, skupiając się na oddziaływaniu gryzonia na środowisko przyrodnicze oraz sposobie jego przekształcania, a także zagrożeniach, stratach i korzyściach wynikających z działalności bobrów.
Wnioski. Dzięki budowanym tamom bóbr jest w stanie zmagazynować kilka milionów metrów sześciennych wody w ekosystemach, w których funkcjonuje. Zwierzę jest dużo skuteczniejsze w retencjonowaniu wody niż wszystkie krajowe programy retencji wody. Ilość wody zgromadzonej w stawie bobrowym jest wypadkową rozmiarów zapór i lokalnej geomorfologii terenu, zwłaszcza profilu i nachylenia przekroju doliny. Bóbr wpływa niemalże na wszystkie składniki ekosystemów zarówno abiotycznych, jak i biotycznych. Pozytywne zmiany przyrodnicze wynikające z działalności bobrów nie zawsze pokrywają się z oczekiwaniami rolników czy leśników. Jedną z najbardziej efektywnych metod zapobiegania ich szkodom są przesiedlenia całych rodzin za pomocą pułapek żywiołowych.

Słowa kluczowe: bóbr europejski, bóbr kanadyjski, środowisko, woda