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ECOLOGICAL IMPACT OF EUROPEAN BEAVER, *CASTOR FIBER*

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Abstract

Beavers are large, semiaquatic rodents in the genus Castor native to the temperate Northern Hemisphere. The European beaver (Castor fiber) has an undoubtedly positive impact on the environment: it is a key species, which means that it plays a critical role in the biodiversity of ecosystems and that many species, some endangered or threatened, rely on beavers and the landscapes they build. In this way, there are many benefits that humans and other animal species can get from beavers. Also, dam construction has the potential to alter the hydrology, geomorphology, biogeochemistry, and ecosystems of river corridors and the feedbacks between them, thus the beaver is also recognized as an 'ecosystem engineer'. However, beavers can also generate conflict situations because not all watercourses can withstand the intense construction of dams. Thus, in many contexts, the engineering activities of the beaver may come into direct conflict with other priorities: agriculture, urban land use, forestry, irrigation. Beavers occasionally damage selected trees, but the worst damage is caused by their burrows, which raise water levels in streams, ponds or lakes, flooding the ground and frequently killing large areas of valuable trees in the forest. There are proven costs to agriculture that result from the impact of beavers, and these will have to be fully taken into account in future decisions to manage the beaver population. The ecological impact of the Eurasian beaver on habitat structure has been little investigated in Europe and includes in particular the changes that take place during dam construction activities. The purpose of this study was to summarize the publications that analyse the ecological impact of beaver (Castor fiber).

***Key words**: beaver, dam, ecological, impact.*

INTRODUCTION

Beavers have the ability to profoundly modify ecosystems to satisfy their ecological needs, with significant associated hydrological, geomorphological, ecological and societal impacts (Brazier et al., 2021). In some areas of Romania, the complaints of the owners of agricultural lands flooded due to the dams built by beavers are multiplying from year to year and claiming hundreds of hectares transformed into swamp. Experts say the solution could only come from amending and supplementing existing legislation.
The European beaver, *Castor fiber*, is the largest rodent mammal in Europe. It is a semi-aquatic animal with multiple anatomical adaptations that allow it to successfully explore the aquatic environment.
The beaver is a nocturnal and twilight animal that is particularly prudent and suspicious of the presence of predators and humans.
The species *Castor fiber* is included in Annex II of the Habitats Directive, respectively Annex 3 of GEO no. 57/2007, which includes species of wild fauna and flora of Community interest, the conservation of which requires the declaration of Special Areas of Conservation forming the Natura 2000 Network.
The species is also included in the list of species of Annex IV of the Habitats Directive, respectively Annex 4 A of GEO no. 57/2007, as a species of community interest that requires strict protection. The obligations arising from the Habitats Directive include: maintaining the favorable conservation status of the beaver population, monitoring and regularly reporting the conservation status of the species to the European Commission.
Also, the *Castor fiber* species is included in Annex II (Strictly protected wildlife species) of the Convention on the Conservation of European Wildlife and Natural Habitats, adopted in Bern on September 19, 1979, to which Romania acceded by Law no. 13/1993 (Pașca et al., 2020). Known to us as the sheep, the beaver is nicknamed the "ecosystem engineer" for its ingenuity in building a mosaic of natural surfaces where it retains water and expands wetlands, so necessary in the current

conditions of climate change and prolonged droughts (https://www.carpathia.org/ro/castorul-revine-in-sud-estul-muntilor-fagaras/).

The beaver was declared extinct in Romania in 1824. After more than a century and a half, in 1998, a study on the repopulation of the beaver in Romania materialized with the bringing of some specimens from Germany (https://blog.cosmeanu.ro/presa-a-semnalat-recent-prezenta-castorilor-in-delta-aflati-cum-si-prin-cine-au-ajuns-insa-simpaticele-animale-in-romania/).

The size of the beaver population in our country has undergone great variations in the last 200 years, mainly due to anthropogenic pressure.

After the reintroduction, the beaver population at national level had a slightly upward trend, in the first years, after which it increased exponentially reaching in 2017 to 2145-2250 specimens (Pașca et al., 2020).

The growing trend of the population at national level and the continuous expansion of the area of *Castor fiber* brings to the fore the need to move to another level in terms of management measures applied to the species.

If in the previous period the main concern was the monitoring of the species in the context of reintroduction, at present the success of the reintroduction project is as obvious as possible and it is necessary to establish other monitoring criteria that are essential in the long-term sustainable management of the species.

One of these directions is to determine the reasonable maximum limit of population development that allows maintaining an acceptable level of conflict.

Significant areas within protected natural areas of the NATURA 2000 network overlap with the network of flood dams in the custody of the Water Management System and the National Agency for Land Improvement.

Through their activity, beavers often contradict the interests and activities of the two institutions listed above, by creating dams, plugging riverbeds.

Although previous projects have addressed these issues in an attempt to find solutions, and at the institutional level SGA and ANIF agree with the protection and conservation of the species, maintenance work on the flood protection system must be carried out periodic.

Thus, a high anthropogenic pressure is exerted on the species, the impact being special if we refer to the works of regularization, clearing, recalibration of the riverbed or cutting of the woody vegetation on the banks.

All these have direct and indirect effects on beavers, some incompatible with the presence of the species in the area affected by works for periods between 1 and 5 years (necessary for the natural restoration of the affected habitat).

Under these conditions, the designation of new protected areas in species-friendly areas where conflict levels would be lower would be a solution to ensure a favourable conservation status of the species in areas where the system of dams and drainage channels is particularly extensive.

Also, analysing the trend of beaver populations reintroduced at European level, it is observed that most of them have reached a particularly high number.

In this context, to which is added the low degree of acceptance of the human population as a whole, it is necessary to take more drastic management measures, including questioning the introduction of a hunting intervention quota. This action will be based on studies to assess the conservation status of the species (population size, quality and habitat size), but also simulations that will show the impact on the species. It is intended that the introduction of the harvest quota be introduced as a management tool in the event that the support capacity is reached, the damage caused by the beaver is significant and relocations are no longer possible.

MATERIALS AND METHODS

In this review, the scientific literature consists on a series of specific articles which were found to have useful information about the ecological impact of beaver, from different databases. The journals were selected through the analysis of previous data studies that classified and ranked the most significant key publications.

All the scientific research papers used within present review are indexed in GS data based, 76.47% of them are also indexed Web of Science (WOS) database and a percentage of the 23.52% are indexed in Scopus. Considering WOS scientific articles used in present study, a percentage of 17.64% are placed in red zone, 35.3% in yellow zone and 47.06 % in white zone.

The journals were selected through the analysis of previous studies that classified and ranked the most significant key journals. According to Simionov et al., the searching was considered to perform better if using a variety of search methods (electronic and manual) and by searching multiple possibly overlapping resources. In order to offer complete view of the analysed subject, papers published within a wide time period were considered (between years 1998 and 2021). The researches which have the highest visibility are priority. As a limited factor in the process of scientific papers selection, the extent of searching is determined by the research keywords and resources available to the research team.

RESULTS AND DISCUSSIONS

The impact of the beaver on the invertebrates

Bush & Wissinger (2016) suggest that beaver wetland complexes support a wealth of invertebrate taxa, mainly due to high habitat heterogeneity. Beavers create wetlands with a variety of small habitats, and the barring of streams or the construction of canals by the beaver creates a mosaic of slow and lotic hydrology that provides habitat for semi-aquatic invertebrates.

The beaver also creates and maintains new wetlands and improves existing ones, helping to maintain invertebrate wetland habitat in the face of climate change and habitat destruction. Beaver ponds turn lotus habitats into slow habitats. In ponds, the aquatic invertebrate community is changing to reflect the newly created lentic habitat. Under such circumstances, shredders and scrapers become less abundant, while collectors and predators become more abundant (McDowell & Naiman, 1986). Beavers can also create unique aquatic habitats, such as canals, that support taxa not found in other wetland habitats (Hood & Larson, 2015).

Beaver dams can support a wide variety of invertebrates (Rolauffs et al., 2001).

Hering et al. (2001) reviewed in detail the literature on the aquatic invertebrate community in beaver-captured streams and uncaptured streams. They reported that on a landscape scale, beaver basins have a positive impact on the abundance and diversity of aquatic invertebrates.

Beaver activities can lead to a considerable change in the morphology and composition of the community in floodplains, in particular by creating additional habitat types, two of which can be very abundant:

1. beaver ponds, which are characterized by stagnation and a different composition of the substrate compared to the unconstituted sections;
2. beaver dams, which can have an average density of 10 dams / km section of stream in habitats suitable for beavers. They are frequently destroyed by floods, but their remains can remain for decades (Rolauffs et al., 2001).

When building dams, beavers change the ways of streams and rivers, allowing the creation of extensive wetland habitats. In one study, beavers were associated with large increases in open water areas. When beavers returned to an area, 160% more open water was available during the drought than in previous years, when they were absent. Beaver dams tend to lift the groundwater, both in mineral soils and in wet areas such as peat bogs. Especially in peatlands, their dams can stabilize the often fluctuating groundwater table, which controls both carbon and water levels. Ponds colonized by beavers offer a supportive environment even for the smallest aquatic organisms - the plankton.

Plankton play an essential function in the food chain of every aquatic habitat (Janiszewski et al., 2014).

Beaver activity has an impact on aquatic invertebrate communities.

Damage usually leads to an increase in lentil-dependent species (slow or still water), such as dragonflies, oligochaetes, snails and mussels, to the detriment of lotic species (fast water) such as blackflies, stoneflies and flies that they spin in the net.

Beaver floods create a growth of dead trees that benefit terrestrial invertebrates such as *Drosophila* flies and bark beetles, which live on dead wood (https://wikipredia.net/ro/Beaver).

Dams create places for insects to lay eggs, such as dragonflies (https://wikicro.icu/wiki/Reintroduction_of_beavers_to_Europe).

Invertebrate communities in aquatic habitats associated with beaver activities can be divided into two general groups:

(1) those with a distinct "running water perspective", which focuses on how beaver dams change invertebrate communities in the river on multiple scales, and

(2) those with a distinct wetland / pond perspective on plant and animal life living in the many types of shallow slow habitats outside river channels (Bush & Wissinger, 2016).

The influence of the beaver on the invertebrate communities derives from the modification of the physico-chemical aspects of the water: chemistry, carbon reserves, nutrient spiral, flow regimes, physical substrate, rotation of organic matter.

Beaver pond hydrology is dominated by flow inputs and outputs, and dams can reduce the peak flow of the canal by temporarily storing water and maneuvering it to the adjacent riparian zone / floodplain.

Invertebrate biomass is much higher (1.3–11.1 g m^{-2}) in the basins behind beaver dams than in adjacent ones (0.01–0.6 g m^{-2}), but taxonomic diversity between habitats is similar (McDowelland & Naiman, 1986). Large patches of wood debris associated with dams can house unique sets of invertebrate species. Rolauffs et al. (2001) found a higher diversity of invertebrates and a higher secondary productivity on the coarse woody substrates of dams than in rivers or dam-created basins.

The macroinvertebrate communities in beaver ponds are reported to be considerably different from those in unimpounded sections (Pliūraitė & Kesminas, 2012).

The impact of the beaver on the vertebrates

Studies show many positive effects of beavers on frog populations. Beaver activity can also increase the connectivity between ponds, due to the increased density of the lentic habitat, but also due to the creation of channels by beavers.

Beaver huts and dams can provide valuable habitat for amphibians that can be used to avoid predators, to provide and develop larval food, or as hibernation sites. It has been suggested that a higher abundance of predatory fish in beaver ponds may reduce the abundance of amphibians. However, Dalbeck et al. (2007) reported that the increase in habitat heterogeneity caused by beaver activity means that *Salmo trutta*, a key predator, does not eradicate amphibians from upstream streams.

Beaver activity has been shown to have a positive impact on abundance or biodiversity in four studies of salamanders and newts.

The impact of beavers on newt and salamander species is variable.

Many salamander species prefer running water and cannot use beaver ponds. A number of researchers have observed reptiles using the habitat created by beavers. The older a beaver pond is, the greater the diversity and abundance of reptiles. In two studies, the usefulness of beaver ponds as a habitat for reptiles was investigated. One showed that beaver ponds had a greater abundance of reptiles and greater biodiversity than streams. In particular, the creation of slow habitat and open habitats around ponds due to the roaring of beavers has been considered important for reptiles.

The effects on snakes have been shown to be mixed (Stringer & Gaywood, 2016). Most papers have shown that bird species use beaver ponds or beaver-created habitats, but this use has not been compared to the use of unaffected areas by beavers. Numerous mechanisms have been cited as reasons for increasing the abundance or diversity of birds.

The increase in wetland area caused by beaver catches is a key factor in avian biodiversity. Beaver dams often flood and kill trees in the waterfront. It attracts woodpeckers (Picinae), as standing wood is an important habitat for nesting and feeding. Woodpeckers are often classified as ecosystem engineers themselves, due to the use of woodpecker holes by a number of secondary species that nest in the cavity.

Beaver habitats provide a more abundant supply of bird food. Beaver ponds contain an abundant aquatic ensemble, including a diverse range of macronevertebrates, which are an excellent source of food for ducks. In addition, an increased abundance and diversity of fish and amphibians in beaver basins provide food for species such as herons (Ardeidae) and seagulls.

Studies investigating the impact of beavers on mammalian diversity and abundance have been reviewed. Thus, beaver-created ponds supported a greater abundance of bats than beaver-free ponds. Bats can use, for example, beaver habitat to shelter under the exfoliating bark of beaver-killed beaver trees. Also, following the activity of the beaver, bats benefit from the increase in

the abundance and availability of prey (Ciechanowski et al., 2011).
Otter, *Lutra lutra* is likely to benefit from beaver activity because it increases the habitat suitable for otter by capture. The formed ponds are rich in prey species for otters such as fish, amphibians and invertebrates. Beaver activity does not appear to affect small terrestrial mammals (Suzuki & McComb, 2004). Beavers instead influence large mammals by creating habitats, sources of prey, and because beaver-cut trees can provide food for many ungulates (Rosell et al., 2005).

Environmental impact

One bevear's ecology characteristic is its capacity to build shelters, dams and channels in this way it changes the landscape and increases the capacity/ability to occupy the territory. Their capacity of changing their habitation offers a special significance to beaver as a geomorphic agent and this called them in ecosystem's engineer.
As a result, a direct and significant control on the ecosystem structure, the beavers are considered a key specie/the most important specie. It's important to accept these effects before to reintroduction in order to take an documented decides regarding the feasibility of reintroduction and also the opportunity to restoration of this specie in the actual habitat.
During the vegetation period, the beaver uses dug burrowing on the river bank with the entrance above the water's level. during the cold season, the entrance inside the burrowing is always situated under the water's level. The beavers built their shelters according to environmental – local topography and environmental condition.
Natural wholes who situated /dug in the river's bank can serve/be a place of a burrow. when these natural wholes don't exist, the beavers (especially *Castor fiber*) dug burrows where the bank is tall enough and the soil is stronge enough for the construction of this kind of shelter. At least 50% of their shelters are dug burrows.
When the banks aren't tall enough for digging burrows, the beavers can build shelters under water or on the river's bank, consisting of a bilt (dug) or a masked burrow by pices of wood with an extended channel till the water.
The built shelters usually consist of a vestibular room and a living room situated above the river's level. These are, generally, made of a mixture of wood and ground. Branches and twigs can be used for covering any wholes when / in case the surface is destroyed. The new constructions start to be used as shelters when there is approximately 1 meter of construction material stored above the living room.
The shelters can serve to a family of beavers as a place for sleeping, as a refuge and for growing their babies up. The shelters are of these types:
1. Dug burrows in the tall bank of water where is possible, except the rocky banks- with entrances above the water's level- more or less temporary- in the hot period of the year, and with under water entrances during the winter period. This kind of shelter is usually specific to rivers with hight whole and tall bank.
In the aquatic habitats where the bank of the water is tall enough for digging, the acces is situated under the level of the water. Sometimes, the access in the shelter may be covered (masked) by/with pieces of wood branches, twigs linked between them with ground or mud. The dig burrow in water's bank.
2. If the configuration of the banks doesn't allow the digging of the burrows (one tall bank missing)- narrow rivers, streams, ponds- the beavers build themselves make shelters like huts, situated of linked branches between then with mud or ground, but still with under water access; generally speaking, the beavers build banks for rising the water's level, where the water is not deep enough for allowing an the underwater access in the shelter and , sometimes, the shelter's type is usually specifically for hilly areas.
3. The third type is a combination between tge first two types. There, where the banks allows excavation, but the high of the bank is not enough (<1.5-2 m) and the composition of the soil permits the fitting of a dug burrow, but with the enough distance between ceiling of the living room and the surface of the soil from above, the beavers build the burrow but the ceiling of the shelter isn't realized the bank soil, anymore, but from a similar material with a the ane of the built shelters.
Digged burrow: The structure of the shelter is complex. It can have several levels and consists of several rooms. The burrows dug in the high

shore usually have two or more entrances which continue with a tunnel which may have, in its course, from place to place, feeding chambers or refuges situated at water level, in which the sheep feed in in winter or where he retreats if he feels threatened outside the shelter.

The tunnels end with a larger room where the sheep family spends more time - sleeping, raising chicks, etc. Generally, the rooms have a ventilation chimney at the top.

This type of den can also be of two types: simple - with the entrance uncovered or with the entrance covered with branches, twigs and other woody materials, but without being glued together with mud. The shelters built (on the waterfront) can reach 3.5 m in height. The entrance to this type of den is always located below the water level, dug into the water's edge. The shelter is usually made up of two levels: the vestibular floor is located at the height of the water surface and is the place where the sheep can dry after leaving the water; the second level (round main room - approx. 60/70 cm) is lined with dry wood chips, plants and twigs, the animals using it as a place to sleep, raising chicks, etc. The roof is made of tree bark or branches welded together with mud. The part above the water consists only of branches not welded together, acting as a vent.

Shelters of this type have the shape of a half-sphere, reaching a diameter of 6 m at the base and a height of 1.70 m. It can often be seen that they are anchored by shrubs or even trees.

The shelter can reach up to 50 cm above the ground around it; it has the same shape and dimensions as a dug burrow and its organization is identical (sealed / earthed roof, ventilation chimney).

In this type of shelter, the gloss of the water is close to the feeding chamber, which in turn is very close to the living room. The shelter is usually built from the back, the animal climbing the waterfront through ramps that surround the shelter and meet at the top. Sometimes the tunnels branch in all directions up to a distance of 100 meters. The construction is made of wood materials 5 - 7 cm in diameter and can measure up to 3 m long, notched from the top, the spaces between them being covered with mud or plant debris from the bottom of the watercourse. Maintenance is done by adding a new layer of wood, which will be covered with clay and / or mud afterwards. This is done several times a year, more or less frequently, depending on the weather conditions. At first glance, it looks more like a mass of dead wood from the flood than any other type of construction. Their shape is quite irregular. However, several factors ensure the presence of sheep: their location, much of the wood and bark that make up this structure, show clear traces of bites - including defoliation of bark (bitten by sheep), traces of alleys used by sheep. (at the bottom of the stream). The sheep keep the shelter clean and repair it regularly, with alternating layers of branches, twigs, fresh wood chips, bark and mud. The shelter is constantly being expanded and rebuilt, especially in late autumn, when the sheep are preparing for winter. Both types of shelters consist of one or more tunnels leading up to one or more bedrooms.

Usually the shelter has at least two tunnels from the river to the feeding chambers, sometimes there can be a complex system of tunnels. When the ground is rocky the shelter is built above the ground, the tunnel system being built in the added material.

Human-beaver conflicts

A major challenge for conservation biology is to facilitate coexistence between humans and wildlife. On the other hand, growing beaver populations cause increasing conflicts with man, and population and/or damage control may therefore be required (Nolet & Rosell, 1998).

Human-animal conflicts occur when the activities of wild animals or their presence have a negative influence on humans (Treves et al., 2006). Beaver-man conflicts arise when beavers get close to populated areas and through specific activities affect the interests of the local population.

Thus, conflicts arise in the following cases:

- causing damage to agricultural crops in the immediate vicinity of watercourses;
- felling of valuable trees on the banks of watercourses populated by beavers;
- flooding of certain areas by raising the water level due to the construction of dams;
- damage to the defensive dams by digging burrows.

Beavers' engineering activity has a significant impact on the ecosystem and the economy. The most common alterations are land flooding due

to the construction of dams. Beavers also clog culverts, girdle fruit and garden trees, and also forage on crops (mainly corn, carrots and beets) on a field nearby (Swiecicka, 2014).
Eurasian beavers can be destructive when they cut down trees and flood areas. They may be removed for nuisance behavior. The most numerous nuisance complaints are flooding farm lands and crop destruction from eating and flooding. Eurasian beavers also flood roadways and culverts and can cause extensive timber damage (Nolet, 2000).

CONCLUSIONS

The Eurasian beaver experienced a spectacular comeback in the early 20th century.
The reduction in hunting pressure has made it possible to restore the population and increase the area occupied by the species.
The natural recovery of beaver populations has also been supported by reintroduction projects in many European countries.
The biggest challenge of the future is to adopt certain management measures to help man and beaver coexist. For the repopulation of new territories with beavers, it is necessary to elaborate impact / feasibility studies, which are requested by the environmental authority as a basis for repopulation.
Given that in some areas the density of beavers has increased beyond the optimum and conflicts occur, it is very important to identify areas where repopulation can take place and preparatory steps have been taken so that relocation is as rapid as possible.
As a last resort solution, it is recommended to relocate the "problem" beaver specimens to new territories, without beavers or with very low densities.
The relocation will take place in autumn and spring, avoiding the period of calving and raising the chicks.
This will be done immediately after the installation of beavers in the area at risk.
The important thing is to capture the whole family. During the capture period, the specimens will be kept in the rehabilitation center, until the capture of all its members.
For all conflicting cases in which it is necessary to relocate / extract specimens or the habitat of the species is affected, it is mandatory to obtain a ministerial order regarding the derogation from the profile legislation.
The elaboration of a guide for living with beavers is increasingly important in the conditions in which there is an increase in the number of human-beaver conflicts and the diversification of the issue.

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