Monitoring of reintroduced beavers (*Castor fiber*) in Denmark

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Abstract: The European beaver (*Castor fiber*) returned to Denmark in 1999 when 18 beavers were released in Klosterheden State Forest District in the northwestern part of the country. A monitoring programme was initiated to trace the population and distribution of the beavers, beaver-human conflicts, and effects on flora and fauna. The status of flora and fauna in the reintroduction area was systematically investigated prior to the beaver reintroduction. By 2003, beavers inhabited the entire catchment basin in which they were released and had dispersed to a neighbouring river system 25-30 km away. Beaver kits were observed every year and the population was estimated at 51 individuals in 2003. The beavers mainly fed on willow scrubs during the winter season and non-woody plants in the summer. No damage was reported in forests or agricultural production areas but the beavers caused minor problems by flooding an arable field, gardens, meadows, and forest roads and by blocking inlets to a fish farm. Few significant alterations of water flow were recorded but the diversity of the wetland biotopes increased. The only negative effects appeared to be a restriction of spawning migration of sea trout (*Salmo trutta*) by beaver dams in brooks. Other fish species were thought to benefit from the beaver ponds. Ponds enhanced spawning potentials for amphibians and enabled new species of birds to breed in the area. Bats profited by more suitable hunting sites. Occurrence of otters (*Lutra lutra*) increased but no clear relationship with beaver distribution was demonstrated.

Keywords: reintroduction, European beaver, *Castor fiber*, population development, management problems, ecological effects.

Introduction

Beavers (*Castor fiber* L., 1758) became extinct in Denmark more than one thousand years ago. In the late 1990s the Danish Forest and Nature Agency initiated a plan to reintroduce beavers in Denmark to recreate natural dynamics and enhance diversity in wetland ecosystems (Skov- og Naturstyrelsen 1998). The reintroduction of beavers in Denmark resulted in widespread public discussions. Anglers were particularly concerned. The Danish National Environmental Research Institute (NERI) was commissioned to carry out a five-year monitoring programme to follow the development of the beaver population and its influence on flora and fauna (table 1). Four annual progress reports and a preliminary evaluation of the reintroduction have been published (Berthelsen 2000, Berthelsen et al. 2001, Madsen et al. 2001, Berthelsen & Madsen 2002, Berthelsen & Madsen 2003). This paper describes the monitoring programme and its provisional conclusions and makes predictions of likely future developments.

Reintroduction, distribution and population development

Eighteen beavers, originating from the Elbe River in Germany, were released at six sites in Klosterheden State Forest District (KLS) in the north-western part of Denmark in October 1999 (figure 1). The beavers were introduced into upstream parts of the Flynder stream catchment

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Table 1. Parameters surveyed in the monitoring programme for reintroduced beavers.

Parameters	1999	2000	2001	2002	2003
Distribution and population development	x	x	x	x	x
Habitat descriptions	x	x	x	x	x
Food analysis			x	x	
Management problems	x	x	x	x	x
Vegetation in streams and valleys	x				x
Vegetation and abiotic parameters in lakes	x				x
Fish populations	x				x
Fish spawning grounds		x			x
Fish passage at beaver dams			x	x	x
Aquatic invertebrates	x				x
Insects in dead wood		x			x
Breeding birds		x			x
Amphibians		x			x
Bats		x			x
Otters	x	x		x	x

area in the KLS. The KLS consists of coniferous forests, heath lands and wetlands with small artificial lakes. It contains brooks and streams up to 4 m wide. The valleys around the watercourses and lakes are dominated by purple moor grass (*Molinia caerulea*), bog myrtle (*Myrica gale*), and willow scrubs (*Salix* sp.).

The distribution of beavers was determined by regular observations and identification of beaver lodges and core areas. A few weeks after the release, beavers had explored approximately 20 km downstream from the reintroduction areas. Beavers abandoned most release sites within months. Two beavers dispersed to a site approximately 10 km downstream of the reintroduction area and two pairs settled in the immediate vicinity of the reintroduction area. By 2003 beavers occupied most of the Flynder stream catchment basin and had established 13 territories. Signs of beaver activity were observed in a neighbouring catchment basin at a site approximately 25-30 km away from the reintroduction area (figure 1).

Population development was estimated from observations during regular work in the reintroduction area and two annual counts in spring and autumn. Beavers were counted at dawn and dusk in two days at all active lodges and in core areas by several observers primarily to record number of beaver kits. Beaver kits were observed each year. Some young beavers born in 2001 and 2002 were not registered until spring 2003. Seven new kits were registered in the autumn of 2003. One dead kit was found in 2001, one in 2002 and a fully-grown beaver was found dead in 2003. Assuming that all mortalities have been recorded, the population size was estimated to be 51 individuals in autumn 2003 (figure 2). The beavers are restricted to a small catchment basin in which the whole population can still be monitored, although no beavers have been tagged to enable individual identification. Adult mortality rates are low amongst beavers (Nolet & Baveco 1996) and we assume that the annual recruitment was underestimated more than the annual mortality rate. Thus, the population size estimate is assumed to be a conservative one.

Diet of beavers

The beavers' feeding habits were investigated by analyses of 400 excrement samples collected at three study sites in 2001 and 2002 (Borglykke 2002). Content of the excrement was sorted into woody and non-woody plants. The degradation of non-woody plants, which included herbs, grasses, aquatic plants, and deciduous leaves, was too advanced for more detailed analysis. Woody species were identified from different

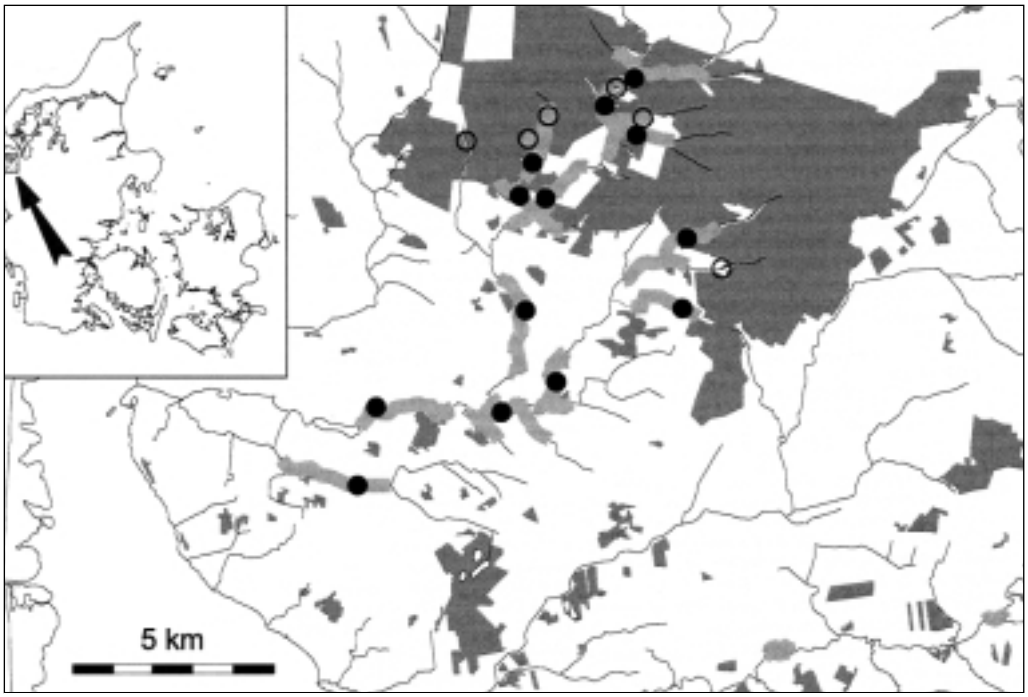

Figure 1. Reintroduction area in the north-western part of Denmark. Circles indicate release sites in 1999. Dots indicate locations of active beaver lodges in 2003. Medium grey areas indicate beaver territories along watercourses (thin black lines). Dark shaded areas indicate forests.

anatomic characteristics, e.g. rays and perforation of vessel elements. The prevalence of different woody plant species was evaluated according to Jacobs (1974). Feeding experiments with captive beavers have shown this method to be reliable (Borglykke 2002).

Seasonal utilisation of woody and non-woody plants varied (figure 3). Beavers foraged primarily on non-woody plants from June to September (69.6 ± 2.7%) and on woody plants (89.0 ± 2.6%) from November to May. Willow was the most important woody species (90.7 ± 1.6%) and was the only woody species positively selected by beavers. Spatial variations in the diet and utilisation of woody plants reflected differences in availability between study sites. The temporal variations in beavers' utilisation of plant species are governed by seasonal availability, changes in nutrient content and digestibility of the plants (Nolet et al. 1994). Roberts and Arner (1984) have reported similar seasonal variations between woody and non-woody plants in beavers' food habits.

Beaver-human conflicts, impact on biotopes, and production areas

Beavers had considerable impact on areas adjacent to watercourses by the damming of small streams. Dams built on streams less than 2 m wide created wetland areas larger than 1 ha. Ninety-five percent of beaver-cut trees were recorded less than 5 m from water. However, in coniferous stands, a few deciduous trees were collected from more than 25 m away from streams. At eight locations beavers have established lodges and territories on privately owned lands. Beaver activity on private land was concentrated in undisturbed semi-natural bogs and fens.

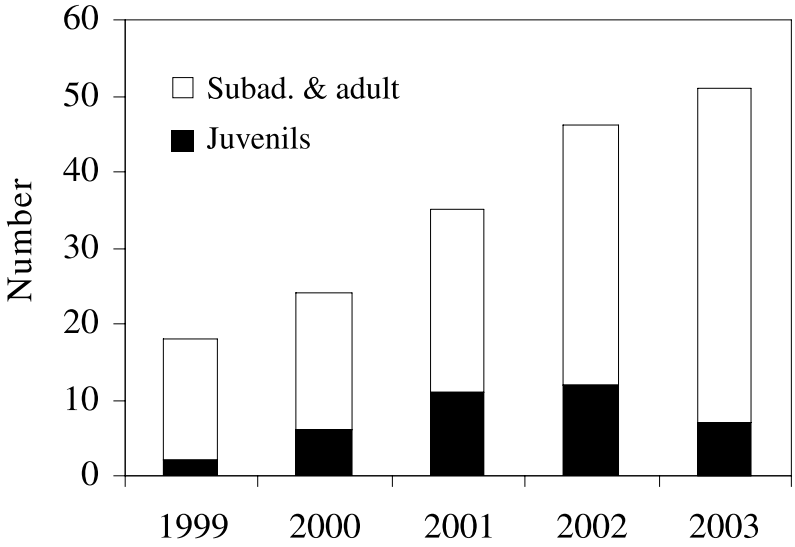

Figure 2. Estimated annual population size of reintroduced beavers in Denmark. Dead kits were found in 2001 and 2002, and a fully-grown beaver was found dead in 2003.

Beavers have not exploited resources in productive areas in forests or farmlands, but minor management problems have been encountered. At two privately owned locations significant numbers of birch (*Betula* sp.) and alder (*Alnus* sp.) were felled and a few trees had to be protected by chicken wire around the stems. Two meadows have been flooded. At one of these sites a pipe was installed in the dam to control the water level. At two other locations, dams in brooks have been repeatedly removed to prevent flooding of an arable field and gardens in a village. Beaver-cut sticks and aquatic plants have blocked the inlet gate on a fish farm at several occasions. Clogged culverts on forest roads have been cleared to prevent flooding at three locations. Despite these minor problems the private landowners have generally responded favourably towards the beavers.

Vegetation, aquatic invertebrates and dead wood insects

Prior to the reintroduction some semi-qualitative baseline studies of the vegetation in selected plots in meadows, streams and lakes, and of aquatic invertebrate fauna in streams were carried out (Miljøstyrelsen 1998). Beaver-cut wood was examined to analyse the insect fauna associated with dead wood. However, detailed assessments of effects of beavers on vegetation and aquatic invertebrates were hampered as the beavers abandoned most release sites and the sites that they did eventually settle, and most heavily alter, were not covered in the pre-reintroduction surveys.

The abundance of willow and bog myrtle scrubs increased in the reintroduction area, although the extra growth was restricted at sites with beaver activity (table 2). No overall change in the abundance of aquatic vegetation in the streams was recorded. The abundance of scrub only decreased very locally at a few sites with heavy beaver activity. At these, previously shaded, sites herbaceous vegetation started to develop and the abundance and diversity of aquatic vegetation increased. The vegetation in new beaver ponds was poorly developed, probably because the sediment consists of detritus, which is a poor substrate for plant growth. Only negligible changes, attributable to natural variations, were recorded in abundance of vegetation in lakes.

Overall, the number of aquatic invertebrate species/taxa increased from 71 in the 1999-survey to 81 in the 2003-survey. The most com-

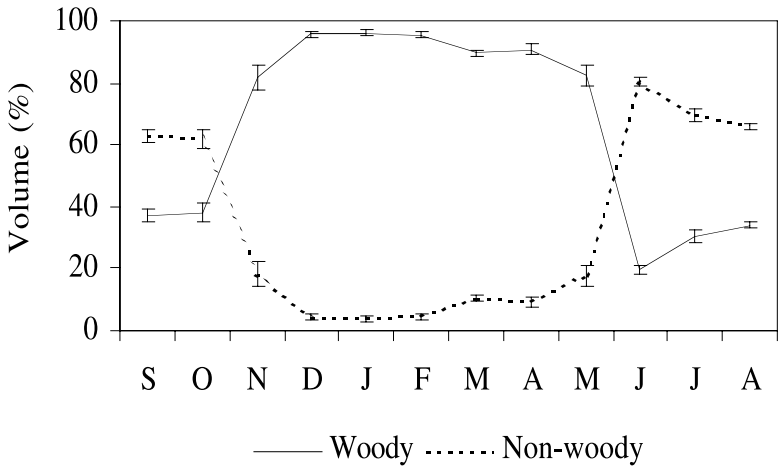

Figure 3. Seasonal food choice (volume % ± S.E.) of beavers in Denmark.

mon groups in both surveys were dipterans (*Diptera*), caddis flies (*Trichoptera*), and beetles (*Coleoptera*). Species living in running water disappeared at sites where impoundments changed a stream habitat to a pond habitat. Oxygen levels may drop in new beaver ponds and the diversity of invertebrates may decrease (Dgebuadze, unpublished data), although it may be expected to increase again later (Rosell & Pedersen 1999, Collen & Gibson 2001). The effects of the beavers' alterations of stream habitats are limited to small areas and insect species that disappear from these sites are assumed to exist in unaffected streams elsewhere in the reintroduction area. No notable changes in the diversity of dead wood insects in beaver-cut wood were recorded.

Impact on fish populations

The structure of fish communities was determined prior to the reintroduction and again in 2003 by electro-fishing streams (Bohlin et al. 1989). Brown and sea trout (*Salmo trutta*), roach (*Rutilus rutilus*), three-spined stickleback (*Gasterosteus aculeatus*), nine-spined stickleback (*Pungitius pungitius*), brook lamprey (*Lampetra planeri*), and eel (*Anguilla anguilla*) were the most common species recorded in both surveys. A few individual rainbow trout (*Oncorhynchus mykiss*) were registered prior to the beaver release, and a few dace (*Leuciscus leuciscus*) and pike (*Esox lucius*) were registered in the post-introduction survey. Trout was only recorded at substantial densities at two localities in the largest watercourses, where anglers regularly restock trout populations. The observed variations in the fish community structure and population sizes were attributable to natural variations in small populations and restocking.

The substrate of the riverbed was mapped in selected stretches of watercourses in the reintroduction area and the occurrence of spawning areas and spawning activities of trout was evaluated. The stretches of stream most heavily

Table 2. Percentage cover of willow and bog myrtle scrubs and aquatic vegetation at sites with beavers and reference sites along neighbouring streams with no beaver activity.

		1999	2003
Scrubs	Beaver sites (*n*=16)	32	32
	Reference sites (*n*=3)	33	45
Aquatic vegetation	Beaver sites (*n*=18)	46	44
	Reference sites (*n*=3)	42	40

altered by beavers, were surveyed four years after the reintroduction. As in the pre-reintroduction survey, none of the observed gravel banks showed any indication of trout spawning. Beaver dams may increase sedimentation on upstream spawning areas (Collen & Gibson 2001). However, they are not thought to cause a significant reduction in the spawning potential of brown and sea trout in the watercourses in the KLS. Rather, the absence of spawning activities, and natural recruitment of brown and sea trout, were attributed to the poor physical conditions of the watercourses.

Long-persisting beaver dams on streams and brooks were examined regularly to assess whether fish were able to pass the dams, and to assess the possible effects of the damming of the watercourses on various fish populations. Most dams were situated on streams less than 2 m wide. It was considered that eels would be able to pass all the dams and that brown and sea trout would be able to pass dams in the main watercourses during periods of high water flow. Only a few dams had a small pool immediately downstream. The absence of such a feature was considered as a constraint on the spawning migration of sea trout to more upstream stretches. Dams acted as total barriers for roach, sticklebacks and brook lamprey. However, small bypasses, formed around some dams, would enable these small fish to migrate upstream of the dam.

Table 3. Egg clusters from common frog at locations for spawning amphibians. The impoundments at Hestbæk, Flynder Å I, and Risbæk II had created wetlands, which were not available for spawning amphibians in 2000. Depotsøen is located near Risbæk I. Øvre Sø & Nedre Sø, and Døjbæk are located near Risbæk II.

Location	2000	2003
Hestbæk	–	11
Flynder Å I	–	451
Flynder Å II	10	0
Risbæk I	30	400
Depotsøen	164	50
Risbæk II	–	443
Øvre Sø & Nedre Sø	300	100
Døjbæk	4	5
Unnamed lake near Risbæk	225	3

Salmonids may negotiate beaver dams under some conditions and juveniles have been recorded upstream of dams (Collen & Gibson 2001, Halley & Lamberg 2001). Brown trout may eventually profit by small beaver ponds (Collen & Gibson 2001). The dams are not expected to have a negative impact on populations of eel or brook lamprey. Populations of roach and sticklebacks are expected to benefit from the beaver dams when the new ponds eventually develop into productive lake biotopes (Collen & Gibson 2001).

Amphibian surveys

Occurrence of spawning amphibians was determined in the reintroduction area and at active beaver sites in spring in 2000 and 2003. Lakes and ponds were surveyed for amphibians, egg clusters, egg strings and croaking males. Only common frog (*Rana temporaria)*, moor frog (*Rana arvalis*) and common toad (*Bufo bufo*) were recorded in both surveys. Spawning activity of common frog in the artificial lakes decreased (table 3: Depotsøen, Øvre Sø & Nedre Sø, and the unnamed lake near Risbæk II). However, numerous egg clusters from the common frog were found in nearby shallow waters in new wetlands created by the beavers at Risbæk I and Risbæk II. Egg strings of the common toad were only found at one location in 2003. However, the 2003 survey was performed at the beginning of the spawning season for common toads. Several common toads were recorded in beaver ponds and upstream stretches at Hestbæk, Risbæk I, and Risbæk II. The common toad may use the deeper parts of the larger beaver ponds for spawning. Moor frogs were only recorded at one of the release sites in both surveys, a site that the beavers quickly abandoned.

The ponds and wetlands created by beavers were assumed to have increased the numbers of suitable spawning areas for amphibians in the KLS. Flooded meadows with shallow waters and tussocks are a favourable habitat for moor frog. The distribution of moor frog is

expected to increase due to the changes induced by beavers.

Breeding bird surveys

The occurrence of breeding birds was surveyed in valleys along watercourses and lakes each spring and during beaver counts. Species composition and numbers of breeding pairs were determined visually and aurally (Enemar 1959).

The development of breeding bird species at locations with beavers differed (table 4), although the number of species tended to increase. A total of 36 breeding species were recorded in 2003. Nine species recorded in low numbers in previous surveys had disappeared, but this was attributed to natural variations in small populations. The species were all breeding in forest or on heath lands (e.g. at Risbæk II). As scrubs along the watercourses became flooded, passerines abandoned the scrubs and started to breed in the nearby forest edges. An overall decline in the breeding population of whitethroat (*Sylvia communis*) was registered. The largest beaver ponds have improved the habitat for kingfisher (*Alcedo atthis*) and water birds, such as water rail (*Rallus aquaticus*). The number of breeding water birds is expected to increase in the future.

Bat surveys

The occurrence of bats was surveyed in the summers of 2000 and 2003, using ultrasound detection (Ahlén & Baagøe 1999). Daubenton's bat (*Myotis daubentonii*) was the only species detected in both surveys. They were detected at more locations in 2003, and there was a higher rate of activity near potential roost sites. Serotine (*Eptesicus serotinus*), pond bat (*Myotis dasycneme*), noctule (*Nyctalus noctula*), and Nathusius' pipistrelle (*Pipistrellus nathusii*) also occurred in the area (Baagøe 2001). The oligotrophic lakes in the forest support small insect biomasses. The low occurrence of bats in the forest and at beaver sites outside the reintroduction area is attributed to a low availability of prey and a shortage of suitable old trees and buildings for day hides and breeding sites. The landscape changes caused by the beavers have not significantly affected the occurrence of bats, but the 2003 survey indicates that larger ponds with open water surfaces have resulted in more suitable hunting grounds for Daubenton's bats.

Otter surveys

Otters leave spraints at conspicuous sites along the waterside to mark their territories and access to resources, e.g. food (Kruuk 1995). The banks and shores of watercourses and lakes were searched for otter spraints to record occurrence of otters (Anonymous 1984) and, in 2003 otter tracks were surveyed at the larger dams to investigate the relationship between beaver activity and otters.

Otter spraints were recorded at, or near, all beaver dams, which may represent conspicuous

Table 4. Number of breeding bird species at seven locations surveyed repeatedly during the monitoring programme. The beavers' alterations of the habitat at Risbæk I had created a large wetland area. Habitats at Møllesøen, Øvre Sø & Nedre Sø, and Døjbæk were relatively unaffected by the occurrence of beavers.

Location	2000	2001	2002	2003
Hestbæk		14	14	11
Møllesøen	22		16	21
Flynder Å II	7		8	12
Risbæk I	11	14	18	19
Risbæk II		13	21	11
Øvre Sø & Nedre Sø	13		13	
Døjbæk			8	9

sites in the stream habitats. During the monitoring period the occurrence of otters increased throughout the whole catchment basin (table 5). The increased site occupancy of otter also occurred on watercourses without beavers. A positive development of the otter population has occurred throughout the country (Elmeros & Madsen, unpublished data). The increased site occupancy of otters in the beaver reintroduction area was less pronounced when the results from national survey stations were compared with earlier national surveys (Madsen et al. 1992, Hammershøj et al. 1996).

Otters occurred in most parts of the Flynder stream catchment basin. Relatively stable food resources are probably found in the artificial lakes but the streams hold only small fish stocks. Otters have large home ranges (Kruuk 1995) and their occurrence in the upstream stretches of the Flynder probably fluctuates. The biomass of fish in new beaver ponds is low (Dgebuadze, unpublished data), but these ponds may eventually supply stable food resources for otters (Collen & Gibson 2001). It is uncertain whether the reintroduction of beavers has had a significant influence on the increased occurrence of otters in this part of Flynder stream catchment basin.

Conclusion

Beavers were reintroduced to recreate natural dynamics and variability in wetland ecosystems. The reintroduction was successful and the beavers are thriving. The population has nearly tripled in four years and beavers now occupy the whole freshwater system in which they were reintroduced. Only minor management problems have been encountered. Few significant changes in biodiversity and occurrences of the various flora and fauna groups were recorded. A longer post-reintroduction survey period would probably show more significant effects on flora and fauna, as beavers have extensively modified wetland biotopes at some locations and, as a result the diversity at various levels of the ecosystem can be expected to increase.

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Table 5. Percentage of positive stations for otters in the beaver monitoring programme. Seven of the stations were also surveyed in the previous national otter surveys (NERI stations) in 1991 and 1996.

	1991	1996	1999	2000	2002
Beaver monitoring stations			43	57	89
NERI stations (*n*=7)	71	86	71	71	100

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Samenvatting

Monitoring van geherintroduceerde bevers (*Castor fiber*) in Denemarken

Na een afwezigheid van meer dan 1000 jaar, vond in 1999 een herintroductie plaats van de bever (*Castor fiber*) in Denemarken. Achttien bevers werden uitgezet in Klosterheden State Forest District, in het noordwesten van het land. Een monitoring-programma werd opgezet om de populatie-ontwikkeling te beschrijven, alsmede de effecten op de flora en fauna, en de eventuele conflicten met menselijke activiteiten. Vooraf-gaand aan de uitzetting was reeds een uitvoerige studie gemaakt van de flora en fauna in het herintroductiegebied. Bevers bleken het gehele stroomgebied van de rivier waar zij waren uitgezet, te hebben bevolkt. Daarnaast hadden zij zich gevestigd in een naburige rivier, 25-30 km vanaf de plek waar zij waren uitgezet. De populatie groeide jaarlijks. Volgens de meest recente telling in 2003, bestaat de populatie uit 51 dieren.

De bevers eten vooral wilgen en kruidachtige planten die dicht bij het water groeien. Schade door vraat in landbouw- en bosgebieden werd niet gemeld. Kleine problemen ontstonden door ondergelopen akkers, tuinen, graslanden en boswegen, en doordat de inlaten van een viskwekerij werden geblokkeerd. In de relatief korte onderzoeksperiode werden slechts kleine veranderingen in de flora en fauna geconstateerd. Toch nam de algehele biodiversiteit van de natte biotopen in het gebied toe, een effect dat naar verwachting in de komende jaren duidelijker zal worden. Op de forel (*Salmo trutta*) na, zullen alle vissoorten naar verwachting in de toekomst populatiegroei te zien geven. Ook de voortplantingsmogelijkheden voor amfibieën namen toe. Een aantal nieuwe vogelsoorten vestigde zich in het gebied. Vleermuizen profiteerden, doordat nieuwe foerageergebieden werden gecreëerd. Het aantal otters (*Lutra lutra*) steeg, maar een verband met de toename van bevers kon niet worden aangetoond.

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