Planning, coordination and realization of Northern European beaver management, based on the experience of 50 years of beaver restoration in Russia, Finland, and Scandinavia

Leonid Baskin[1] & Göran Sjöberg[2*]

[1] Institute of Ecology and Evolution, Russian Academy of Sciences, Leninsky prospect 33, Moscow, 117071, Russia

[2] Department of Animal Ecology, Swedish University of Agricultural Sciences, SE-90183 Umeå, Sweden, e-mail: goran.sjoberg@szooek.slu.se

Abstract: By 1900 the beaver (*Castor fiber*) had disappeared from many parts of Northern Europe. Beaver population restoration started during the 1930s, and mass releasings of animals took place after the 1950s. The extinction and reintroduction of the beaver can thus be seen as a giant field experiment in landscape ecology and ecological engineering. A general evaluation of this experiment, however, has not been made yet. It is argued here that two main natural causes of beaver population fluctuations should be studied: 1. The carrying capacity of the environment, where food resources at northern sites are expected to be exhausted within some years. 2. Control from predators, which has led to the evolution of the beavers' complicated constructing behaviour. A cost–benefit analysis of beaver reintroduction, which could result in management policies, needs to be made.

Keywords: beaver, *Castor fiber*, *Castor canadensis*, reintroduction, restoration, carrying capacity, predation refuge, ecological engineering, landscape modification.

Introduction

Until the 19th century, beavers (*Castor fiber*) occurred in large areas of Northern Europe, from the west coast of Norway to the Ural Mountains. By 1900 the species was extinct in large parts of its former range of distribution, as a result of hunting and habitat change. It was, however, still present in a few areas of central Russia, Belarus and Ukraine, as well as in small areas of Norway, Germany and France. Since the restoration of beaver populations in north-eastern Europe started, researchers have reported on the status of the newly established populations (Segal' & Orlova 1961, Lavrov 1965, Zharkov 1969, Zaripov & Yushina 1973, D'yakov 1975, Danilov 1992, Hartman 1994, Baskin 1998). In Russia the first small numbers of beavers were caught in the central parts of the country and released in northern areas already in the years 1936-1938, although most animals were released after the 1950s (Pavlov et al. 1973). After 30 years of reintroduction, beavers had occupied all suitable habitats. Nowadays we observe the highest beaver densities in small forest streams where they are able to transform the environment according to their needs. Events in human society have also been favourable for the beaver. Since the market for beaver fur has declined, hunters have lost interest in trapping more beavers.

In Finland and Russian Karelia the American beaver (*Castor canadensis*) was released, in addition to the European beaver, resulting in established populations (Lahti & Helminen 1974). American beavers are now distributed in areas close to those occupied by European beavers. The two species inhabit the same streams and lakes of Karelia and Finland (Danilov & Kan'shiev 1983, Danilov et al. 1999,

* Corresponding author

Fyodorov 2003). From the modern point of view the introduction of American beaver in Europe was a mistake that contradicts principles of conservation of fauna diversity (Sjöberg & Hokkanen 1996, Nummi 2001). The question is whether or not this introduction threatens the existence of the aboriginal European beaver populations.

The beaver is a keystone species and its activities have important consequences for the landscape (Naiman et al. 1988, Johnston 1994, Jones et al. 1994). The extinction and reintroduction of the beaver can thus be seen as a giant field experiment in landscape ecology and ecological engineering. A general review of this experiment has, however, not been made. The dynamics of the beaver population have not been analysed, nor have the beavers' ecological niche, the limiting factors, or the carrying capacity of the environment been sufficiently studied. There is a significant gap also in the knowledge of landscape changes during the last 50 years as a result of the return of the beavers.

The experiment has been replicated in areas of widely differing ecological, climatic and edaphic characteristics. Seven teams of researchers (four teams from Russia, along with Finnish, Norwegian and Swedish teams) intend to use this diversity in reintroduction areas for a study (see: http://www.szooek.slu.se/eng/projekt/projekt.cfm?ID=104). The research is being conducted in flowing and standing reservoirs, in streams and large rivers, in very shallow and quite deep waters, and in natural as well as artificial water reservoirs. The little-known swamp populations of the beaver, inhabiting floating peat islands, will also be studied. The teams will work in areas dominated by forests, as well as in the Republic of Tatarstan where 70% of the area is occupied by arable land. In Tatarstan most beaver settlements are situated in rivers straightened by humans, where the animals browse sparse willow shrubs growing along the water edge. Furthermore, in the Scandinavian countries and Finland, beavers have existed in an environment without large predators (Rosell et al. 1996), while these have been present in large parts of Russia. The aim of the researchers working under different environmental conditions is to find general as well as specific answers to a number of questions.

Questions and hypotheses

There are some questions that should be addressed in an evaluation of the beaver "experiment" as described above: 1. How does the beaver change the landscape conditions, species composition and biomass in aquatic and riparian environments in different relief and soil conditions of different vegetation zones? 2. How important is predation in determining the engineering activities of beavers? What is the current role of predators, e.g. wolf (*Canis lupus*), brown bear (*Ursus arctos*), lynx (*Lynx lynx*), and other species? 3. What influence does the beaver have on vegetation in poor northern conditions, and how long does it take for beavers to return to places previously deserted by them? 4. What different kinds of beaver-human conflicts occur? 5. How do new conditions created by beavers correspond to pristine conditions? Introducing beavers as a method of restoring primeval landscapes is practised more and more often, and it needs to be developed more.

A number of hypotheses can be made based on ecological theory and results of previous studies on interactions of European and American beavers with their environment: 1. Population densities of beavers should be higher in more productive areas, i.e. warmer and more humid regions. Turnover time of beaver settlements should also be longer in more productive areas. 2. Locations of beaver settlements are strongly determined by relief. It is possible to predict positions of the localities using map information and parameters that are necessary for beaver survival (D'yakov 1975, Dezhkin et al. 1986). 3. Successions of all kinds of biotic communities should differ significantly in areas with beavers compared to areas where the species is absent, and they should follow different paths in time (Naiman et al. 1988). These changes are ex-

pected to last long after beavers have deserted areas, and these effects should be more pronounced in harsh than in more productive areas. 4. Biodiversity of all biotic communities is expected to increase as a consequence of the beavers' activities. Species adapted to wetland conditions are expected to benefit from the effects of beavers on the landscape (cf. Medin & Clary 1990). 5. The effects on beaver populations of the presence of wolves is expected to be significant, as a result of the risk of predation and changes in beaver behaviour (Basey & Jenkins 1995). 6. Differences in construction activity of the two beaver species depend on environmental conditions more than on innate species differences (Danilov et al. 1999, Fyodorov 2003). Also a competitive advantage of the respective species is expected to vary with environmental conditions.

Proposed research fields

An estimate of the large-scale results of the reintroduction of beavers in Northern Europe
A general review should be made of beaver population densities, geographic distribution and habitat occupation after 50 years of reintroductions and restoration of populations. A comparative study should be made along east-west and north-south gradients. Data on beaver populations advancing in Northern Europe should be compiled. Mapping of fresh waters occupied by beavers in the second half of the 20th century should be done.

The starting conditions of the different beaver restoration projects varied. The population growth depended on many factors, e.g. abundance of fresh water, number of released animals, number of years since the first group of animals was released, and predator density. A comparison of beaver status of 32 populations in Eastern Europe in 1972 demonstrated that the beaver densities in northern areas had been growing much more slowly than in central areas. However, a comparison of the same populations in 2000 showed that beaver densities in the areas south of 57°N had, on average, doubled only, while numbers of populations northwards from 57°N had increased by seven times (figure 1).

Predators and beaver construction activities
To our knowledge there are no studies emphasizing that predators were the stimulus for the evolution of a specific protective behaviour of the beaver. We suggest that predators are the most important factor determining that beavers can only survive if they have a water refuge. In the areas of on-going investigations, the wolf, the brown bear and the lynx are the main beaver predators. Predation is most obvious in March-April, when beavers are forced to come out of their ice hole to find food. In spring about 20% of wolf excrements contain beaver hairs. The vulnerability of beavers in winter is supported by an anecdotal observation. Once in spring we found an unsuspecting beaver browsing an aspen (*Populus tremula*) and were able to be ahead of it near its ice hole. We observed the desperate attempts of the beaver to push off the human from the hole as the only refuge (L. Baskin, personal observation).

According to Dezhkin et al. (1986), the minimum size of a water reservoir for the survival of at least one animal is 1 m by 10 m and 1-1.5 m deep. We observed, however, that one animal survived for a month in a pond 2 by 2 m and 0.5 m deep. The principal question here is what the minimum depth is of waters where beavers can survive. We studied the depth of streams where beaver presence was obvious, e.g. there were fresh exits at shores or fresh browsing marks. The depth in these places fluctuated between 15 and 150 cm. However, in 90% of the occasions it was 35 cm or more (L. Baskin, unpublished data).

Another limiting factor is the distance to safe feeding. In southern boreal forests, 90% of the browsed trees are found not further than 13 m from a water refuge (L. Baskin, unpublished data). Only 1% of the browsed trees were more than 20 m removed from a water refuge. The maximum was 26 m, not taking into account the trees browsed during spring flood. The hypothesis that a significant part of landscape modifica-

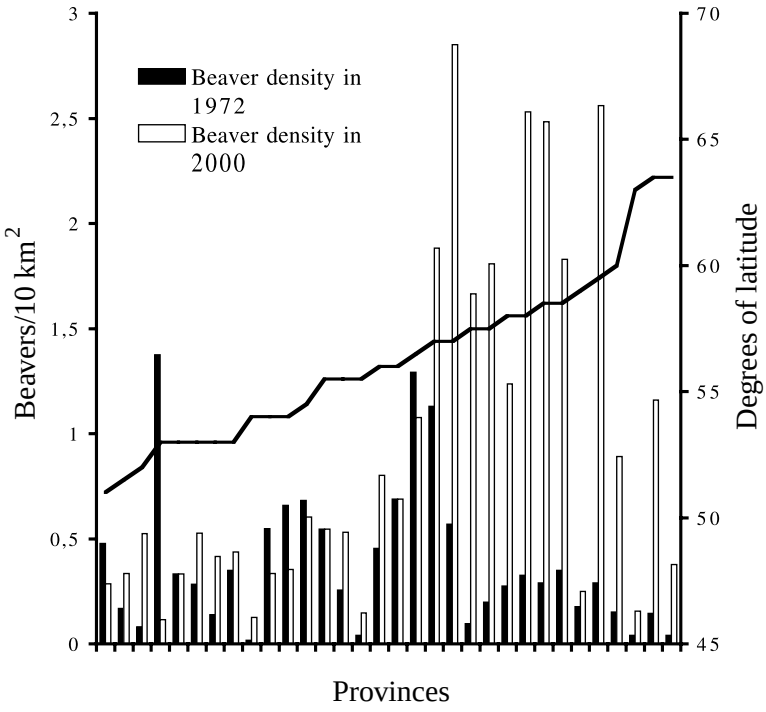

Figure 1. Beaver numbers since their reintroduction in 32 provinces, listed from south to north, of European Russia in 1972 and in 2000.

tion activities by beavers are an anti-predator strategy needs to be tested and developed. We need to know the exact parameters of water refuges. The risk of predation also needs to be estimated more correctly.

Testing models for predicting beaver population density and the time of existence of settlements

Thirty-eight species of trees and shrubs were found to be used by beavers. However, only twelve of these are found in all areas of northern Russia (Makarov & Tkachenko 1957, Solov'ev & Tyurnina 1971, D'yakov 1975). In southern boreal forest from 1977-2003, 43% of the 4,900 browsed trees were aspen, 30% were birch (*Betula* spp.), 11% were alder (*Alnus* spp.), 8% were willow (*Salix* spp.), 6% were lime tree (*Tilia* spp.), and additional trees included cherry tree (*Padus racemosa*), mountain ash (*Sorbus aucuparia*), buckthorn (*Frangula alnus*) and currant (*Ribes pubescens*) (L. Baskin, unpublished data).

The number of years required for beavers to exhaust the carrying capacity of northern habitats is an important problem. In a river that has been under investigation since 1977 the proportion of aspen among browsed trees was 88% in 1977, but only 27% in 2003 (L. Baskin, unpublished data). After the depletion of local food resources, the next stage of environmental exploitation was to build a dam to elevate the water level and thus have access to food resources situated at higher elevations. In 1977, along 22 km of the river, we observed nine large dams, but in 2003 only one. The beavers left the river and settled in small tributaries. Along the main river, strips of meadow stretched out along the water and only willows and birches were able to occupy those sites in the short term, while aspen needed more years for re-growth. Re-settling of beavers in these sites, which have been used in the past, now takes place in essentially worse conditions. We need to describe this cycle of exhaustion and recovery under different conditions.

Mapping of environmental variables, including the impact of humans and food availability, should be made. Models need to be devel-

oped for assessing beaver population density and duration of settlements. This can be done using GIS to take into account characteristics of landscape and climate. Already collected data sets should be compared to newly collected data upon which to base more reliable models and predictions.

Predicting landscape changes after reintroduction of beavers in various vegetation zones

Where there is a flood plain, building a dam leads to the creation of a pond. Then the beavers can safely reach feeding places situated further away from the main stream. Also after spring flood beavers dig canals to transport stumps of wood and tree branches.

The first beaver meadows occurred 20 years after the first reintroduction of beavers (L. Baskin, unpublished data). Nowadays, after 50 years of beaver restoration in Northern Europe, the meadows stretch along most of the rivers and streams where beaver settlements have existed and where beavers have elevated water levels by dam constructions. It is an interesting task to determine the areas of beaver meadows and their dependence on topographic conditions and forest type. A helpful tool would be a model to predict the appearance of beaver meadows. The next step would then be to validate these predictions in the field. The width of beaver meadows depend on the elevation of flood plains. In lowlands, beavers can flood much larger areas. We will use maps to predict which sites are more suitable for the creation of beaver ponds, and which will later develop into beaver meadows. By using large-scale topographic maps it should be possible to find sites where beavers can create water refuges. With maps (scale 1:10,000), and assuming 0.5 m as a minimum acceptable depth of a beaver refuge, we can point out sections of streams where dams of different height (e.g. 0.5, 1, 1.5, or 2 m) will keep a sufficient water level. Dam influence reaches 200 m and more upstream. This value may fluctuate depending on the depth and width of the stream. A simple example from a drainage system is presented in figure 2.

Studying the role of beavers in aquatic and riparian communities, and determining the role of predators as a factor limiting beaver populations

The effects of beaver reintroductions on biodiversity, community composition and biomass (vegetation, vertebrates, and invertebrates) in aquatic and riparian environments should be estimated. The following studies need to be done: 1. Changes of bank vegetation resulting from beaver grazing and other activities. 2. Vegetation, plankton, benthos and fish communities in habitats with and without beaver (cf. McDowell & Naiman 1986). 3. Land vertebrates in habitats with and without beavers, especially beaver-predator relationships (cf. Potvin et al. 1992, Rosell et al. 1996). 4. Breeding success of ducks in habitats with and without beavers, and the role of invertebrates in this (cf. Nummi 1992). As a result, beaver ponds, irrigated meadows, and water canals create an environment with new conditions favourable for other animals including moose (*Alces alces*), rodents, and various species of birds.

Identifying long-term consequences of the introduction of the American beaver in Northern Europe

The importance of interactions between beaver species (*Castor fiber* and *Castor canadensis*) when co-occurring should be assessed, and predictions should be made of their long-term consequences. It should be studied what species currently is the strongest competitor where they coexist. Maps of European and American beaver settlements should be prepared, data should be collected for comparison of habitats and characteristics, and dynamics of numbers and distribution of American and European beavers during the last 50 years should be estimated.

Production of a cost–benefit analysis of beaver reintroduction, to be used in management policies

In the past centuries, the beaver has been important to humans mainly for its fur. Nowadays there is no longer a good market for beaver skins

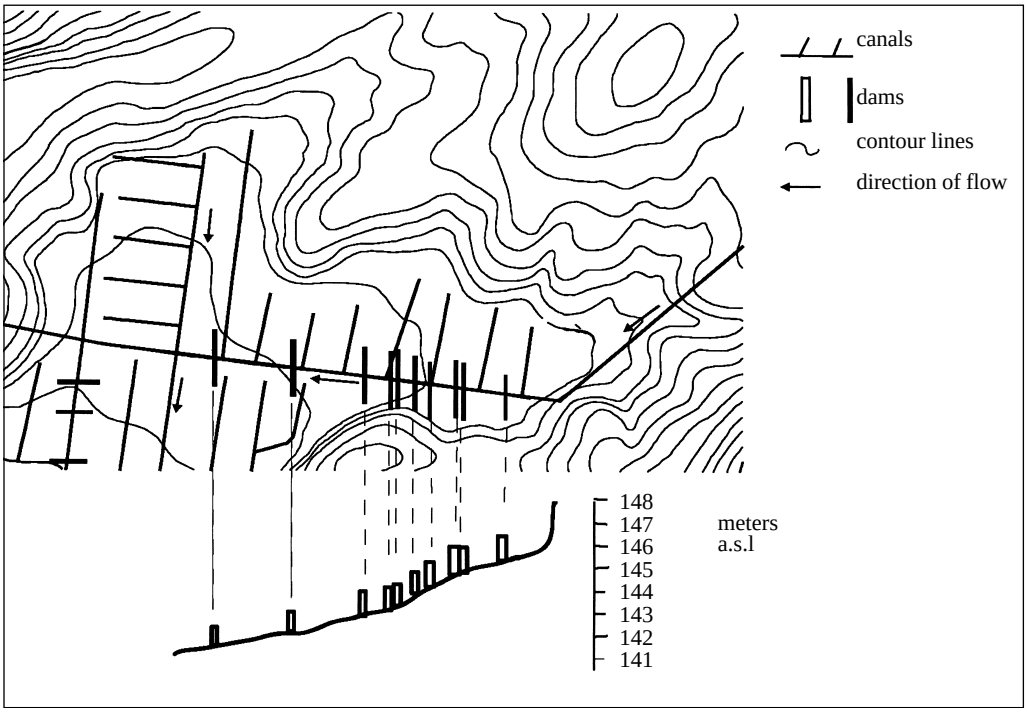

Figure 2. An example of a system of beaver dams from a drainage system in the Kostroma Province, Manturovo District, Russia (58.2654 °N, 44.4538 °E). The upper part shows a view from above and the lower part of the picture shows a profile.

and a decline of beaver harvest is observed. As a consequence the necessity for special measures to protect the species has disappeared. The browsing activity of the beaver is of limited importance to humans since the species generally uses trees and shrubs of little value. Dam construction is the most harmful beaver activity, since significant areas of forest, hay fields and roads can be flooded (Fyodorov 2003). Drainage systems can be partly paralysed by beaver dams. However, in our studies we found that after some period the beavers abandon the drainage canals after having exhausted the food resources within a 20 m distance from the canals (L. Baskin, unpublished data). Some damage may remain, however, as old dams may survive for over ten years. Water flow may wash out one of the shores in passing beside the dam. Beaver burrows may also destroy canal banks.

The landscape modification role of the beaver is positive in areas where agriculture, straightening of streams and drying up of swamps have led to loss of biodiversity and natural communities. Human activities have simplified the aquatic environment (straight canals instead of naturally winding streams, more or less dead waters instead of complicated ecosystems of water plants and animals). The importance of the role of the beaver for restoration of an environment disturbed by humans has been confirmed (Balodis 1990, Gorshkov et al. 1999), but it is still unknown whether the new conditions created by beavers correspond to pristine conditions. An introduction of beavers as a method of restoration of primeval landscapes is more commonly practised, and it needs to be further developed.

Conclusion

Large-scale field experiments investigating the extinction and restoration of beaver populations

should be a valuable tool for understanding processes in landscape ecology. To reach this aim teams working in different parts of Northern Europe have been involved. These teams use different methods and approaches. Coordination of their activities, directions and methods is necessary. Preference will be given to long-term data on populations and landscape changes.

Acknowledgements: The work on this paper was supported by the INTAS project 01-0164 "Landscape-creative beaver activity in Northern Europe: a review of the 50-years species-restoration". We thank two anonymous referees for helpful comments on earlier drafts of the paper.

References

Balodis, M.M. 1990. Beaver. Biology and role in nature and economy of the Latvian republic. Riga, Zinatne, Latvia. (In Russian)

Basey, J.M. & S.H. Jenkins 1995. Influences of predation risk and energy maximization on food selection by beavers (*Castor canadensis*). Canadian Journal of Zoology 73: 2197-2208.

Baskin, L.M. 1998. Hunting of game mammals in the Soviet Union. In: E.J. Milner-Gulland & R. Mace (eds.). Conservation of biological resources: 331-345. Blackwell Science, London, UK.

D'yakov, Y.V. 1975. Beavers of the European part of the USSR. Moskovsky Rabochii, Moscow, Russia. (In Russian)

Danilov, P.I. 1992. Introduction of North American semi-aquatic mammals in Karelia and consequences of it for aboriginal species. Semiaquatische Säugetiere. Wissenschaftliche Beiträge Universität Halle: 267-276.

Danilov, P.I. & V.Y. Kan'shiev 1983. Some peculiarities of morphology and ecology of European and Canadian beavers in NW USSR. In: E.V. Ivanter (ed.). Ekologiya ptits I mlekopitayushchikh Severo-Zapada SSSR: 109-122. Karel'skoe knizhnoe izdatel'stvo, Petrozavodsk, Russia. (In Russian)

Danilov, P.I., V.Y. Kan'shiev & F.V. Fyodorov 1999. Modern distribution and number of beaver (*Castor fiber* L. and *C. canadensis* Kuhl.) in Karelia. Abstracts of the International scientific conference "Biological fundamentals of studies, use and conservation of soil cover in Eastern Fennoscandia": 77-78. Petrozavodsk, Russia.

Dezhkin, V.V., Y.V. D'yakov & V.G. Safonov 1986. Beaver. Agropromizdat, Moscow, Russia. (In Russian)

Fyodorov, F.V. 2003. Modern status of beaver populations in Karelia and their role in biocenosis. PhD thesis. Institute of biology, Petrozavodsk, Russia. (In Russian)

Gorshkov, Y.A., A.L. Easter-Pilcher, B.K. Pilcher & D.Y. Gorshkov 1999. Ecological restoration by harnessing the work of beaver. Beaver protection, management, and utilization in Europe and North America: 67-77. Kluwer Academic/Plenum Publishers, New York, USA.

Hartman, G. 1994. Long-term population development of a reintroduced beaver (*Castor fiber*) population in Sweden. Conservation Biology 8: 713-717.

Johnston, C.A. 1994. Ecological engineering of wetlands by beavers. In: W.J. Mitsch (ed.). Global Wetlands: Old world and new: 379-384. Elsevier, Amsterdam, The Netherlands.

Jones, C.G., J.H. Lawton & M. Shachak 1994. Organisms as ecosystem engineers. Oikos 69: 373-386.

Lahti, S. & M. Helminen 1974. The beaver *Castor fiber* (L.) and *Castor canadensis* (Kuhl) in Finland. Acta Theriologica 19: 177-189.

Lavrov, L.S. 1965. River beavers. Izdatelstvo Voronezhskogo Universiteta, Voronezh, Russia. (In Russian)

Makarov, V.V. & A.A. Tkachenko 1957. Some features of river beaver biology in Pechora River basin. Uchenue zapiski Moskovskogo Gosudarstvennogo Pedagogicheskogo Instituta by Potemkina, vol. 65. (In Russian)

McDowell, D.M. & R.J. Naiman 1986. Structure and function of a benthic invertebrate stream community as influenced by beaver (*Castor canadensis*). Oecologia 68: 481-489.

Medin, D.E. & W.P. Clary 1990. Bird populations in and adjacent to a beaver pond ecosystem in Idaho. Research paper INT-432. Intermountain Research Station, Forest Service, US Department of Agriculture, Ogden, Utah, USA.

Naiman, R.J., C.A. Johnston & J.C. Kelley 1988. Alteration of North American streams by beaver. Bioscience 38: 753-762.

Nummi, P. 1992. The importance of beaver ponds to waterfowl broods: an experiment and natural tests. Annales Zoologici Fennici 29: 47-55.

Nummi, P. 2001. Alien species in Finland. The Finnish Environment 466. Ministry of the Environment, Helsinki, Finland.

Pavlov, M.P., I.B. Korsakova, V.V. Timofeev & V.G. Safonov 1973. Acclimatization of game mammals and birds in the USSR, part 1. Vyatskoe knizhnoe izdatelstvo, Kirov, Russia. (In Russian)

Potvin, F., L. Breton, C. Pilon & M. Macquart 1992. Impact of an experimental wolf reduction on beaver in Papineau-Labelle Reserve, Quebec. Canadian Journal of Zoology 70: 180-183.
Rosell, F., H. Parker & N.B. Kile 1996. Causes of mortality in beaver (*Castor fiber* & *canadensis*). Fauna 49: 34-46. (In Norwegian with English summary)
Segal', A.N. & S.A. Orlova 1961. Appearance of Canadian beavers in Karelia. Zoologicheskii zhurnal 40(10): 987-995. (In Russian)
Sjöberg, G. & H.M.T. Hokkanen 1996. Conclusions and recommendations of the OECD workshop on the ecology of introduced, exotic wildlife: Fundamental and economic aspects. Wildlife Biology 2: 131-133.
Solov'ev, V.A. & B.N. Tyurnina 1971. Some features of river beaver biology in some northern populations. Uchenye zapiski Ryazanskogo Gosudarstvennogo Pedagogicheskogo Instituta 105: 95-109. (In Russian)
Zaripov, R.Z. & N.G. Yushina 1973. Study of beaver feeding in Mariiskaya SSR. Ratsional'noe ispol'zovanie zapasov rechnogo bobra v SSSR. Voronezh: 111-113. (In Russian)
Zharkov, I.V. 1969. Results of reintroduction of river beavers in the USSR. Trudy Voronezhskogo gos. Zapovednika 16: 10-51. (In Russian)

Samenvatting

Planning, coördinatie en realisatie van een beheersplan voor de bever in Noord-Europa, gebaseerd op 50 jaar ervaring met herstel van beverpopulaties in Rusland, Finland en Scandinavië

Rond 1900 was de bever uit grote delen van Noord-Europa verdwenen. De eerste bescheiden herintroducties in Rusland vonden plaats in de jaren '30, maar pas vanaf de jaren '50 werd de bever op grotere schaal in Noord-Europa uitgezet. Naast de Europese bever (*Castor fiber*), ging het in delen van het gebied ook om de Amerikaanse bever (*Castor canadensis*).

De geslaagde poging om de bijna uitgestorven bever weer terug te brengen in Noord-Europa, kan worden gezien als een enorm veldexperiment. Een gedegen evaluatie van dit experiment, is echter niet voorhanden. Bovendien wordt het enorme potentieel aan onderzoeksmogelijkheden onvoldoende benut. Dit artikel presenteert plannen voor samenwerking tussen onderzoekers uit Noorwegen, Zweden, Finland en Rusland. Er worden vragen geformuleerd, uitmondend in een aantal belangrijke onderzoeksvelden. Argumenten hiervoor komen uit de literatuur, en worden deels ook ondersteund door eigen waarnemingen. Speciale aandacht moet uitgaan naar twee onderwerpen: 1. de draagkracht van noordelijke biotopen voor de bever, en 2. de invloed van predatoren op het gedrag en de ecologie van bevers. Daarnaast zouden de herintroducties onderworpen moeten worden aan een kosten-batenanalyse. De resultaten van het onderzoek kunnen worden toegepast in de ontwikkeling van toekomstig beleid voor en het beheer van beverpopulaties.

Received: 7 October 2003
Accepted: 30 January 2004