Is it possible to use beaver building activity to reduce lake sedimentation?

Dmitry Gorshkov

Volga-Kama National Nature Preserve, Sadovy, P.O. Raifa, Zelenodolsk District, Tatarstan, 422537 Russia,
e-mail: raifa@online.kzn.ru

Abstract: Erosion processes and lake sedimentation are among the major environmental problems in Tatarstan Republic. Ploughed soils from the agricultural lands are easily washed away from the fields during flooding, and carried through rivers and relief depressions to lakes and bogs, which then fill with the sediment. Raifa Lake is an example of such lake degradation. Due to erosion from agricultural lands upstream from the lake its length has decreased from 6 to 1.3 km since 1650, its maximum depth has decreased from 36 to 19 m, and its area has decreased from 150 to 32 ha. The possibility of "harnessing" beavers (*Castor fiber*) to stop sedimentation by building dams is of great interest. We hoped that dams constructed by beavers would reduce the volume of solid particles that flow into Raifa Lake. With this objective in mind, we reintroduced 21 beavers between 1996 and 2000 on the Sumka River, which runs through Raifa Lake. Investigation was done during the annual flooding periods of 1999-2001 when 115 water samples were taken. The main factor that affects sedimentation is the volume of water that can be stopped by beaver ponds. During the flooding period of 2001, 4,250 tons of solid particles were stopped by three beaver dams in the settlement on Sumka River amounting to a cumulative area of 5.2 ha. Sediment mass per litre of water decreased by 53% (from 0.49 to 0.26 g/l) after water had passed the cascade of three dams.

Keywords: beaver, *Castor fiber*, Volga-Kama Nature Preserve, water quality, sedimentation, reintroduction, dams, building activity.

Introduction

Today the role of the beaver (*Castor fiber*) as a hunting-trade species has largely disappeared, at least in the Tatarstan Republic, and emphasis is now placed on researching its landscape-creation role in planning the restoration of riparian zones disturbed by humans. Landscapes in the Tatarstan Republic are influenced by intensive economic activity, such as agriculture (cereals, grain crops, root crops and fodder crops), oil production and cattle grazing. In particular, there is a high anthropogenic pressure on the hydrological system because of the development of erosive processes that cause sedimentation in lakes and bogs.

Detailed research of this problem was carried out in the Raifa portion of Volga-Kama National Nature Preserve (VKNNP). No human settlements were present, and the watershed was covered by forest until 1660, when a monastery was built on the bank of Raifa Lake. Settlements appeared and the forest was cleared for agricultural lands. A reduction in the percentage of land covered by forest and irrational agricultural practices (ploughing up slopes and territories near rivers) have resulted in intensive soil erosion on land upstream of the preserve. Sediment that is washed away from fields during spring flooding enters the Sumka River and is carried to lakes and bogs of the preserve, which has decreased their area. For example, the area of Raifa Lake has decreased from 150 ha to 32 ha during the last 400 years. Without in the introduction of less erosive agricultural techniques in the Sumka River basin, some lakes will disappear or turn to bogs (Taisin 1969, Taisin 1996).

We have attacked the problem on two fronts. One involves the re-establishment of beavers, whose dams may catch sediment and lengthen the life of lakes and bogs. Beaver dams affect sedimentation through (1) reducing sediment loads per cubic metre, and (2) stopping big volumes of water thereby causing a reduction in the absolute amount of sediment carried downstream. Later water evaporates and soaks into the ground and sediment accumulates on the bottom of the pond. The last of the beavers in the Tatarstan Republic were killed in 1802. Beginning in 1949, beavers were reintroduced to many parts of the region and now number about 3,000. But only 16% of the republic is forested and the island of forest in which the preserve is located would take a long time to recolonise, if it happened at all, without human intervention. So, our first step was to reintroduce beavers to the preserve (Gorshkov et al. 1999, Gorshkov et al. 2002). A second and longer-term front on which to solve the erosion problem is to find the sources of sediment and implement less erosive agricultural practices in those areas. Our long-term tactic is to work directly on sediment sources, as beaver ponds will only hold a finite quantity of sediment.

Study area

The Raifa part (5,921 ha) of the VKNNP is located 800 km east of Moscow and 600 km west of the Ural Mountains near the city of Kazan, Tatarstan Republic, Russian Federation. Much of the VKNNP forest is 250-300 years old. Western and eastern sections of the preserve are bordered by forests; the northern and southern sections border agricultural lands (figure 1).

The Sumka River (length 37.5 km) and its main tributary, the Ser-Bulak River (length 11.5 km; figure 1), are connected to ten lakes. The Sumka River watershed contains 46% forest in a patch distribution. The upper part of the Sumka River is agricultural land which causes intensive

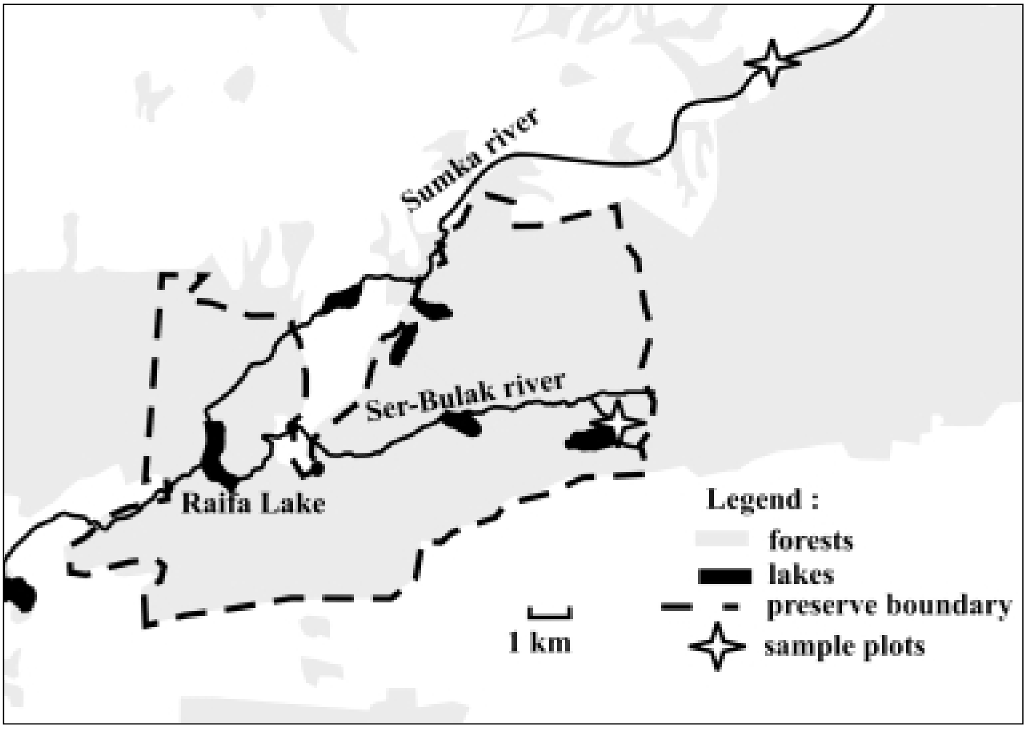


Figure 1. Map of Raifa, part of Volga-Kama National Nature Preserve.

erosion. The watershed of the Ser-Bulak River is almost completely covered by forest. Both rivers flow intermittently, with 80% of the annual runoff in April (Unkovskaia et al. 2002).

Methods and materials

Beavers were relocated from tributaries of the Vyatka River to the Raifa portion of the VKNNP. Animals were released in 1996, 1997, 1999, and 2000, and numbered 6, 7, 3 and 5 individuals, respectively. To study the role of beaver dams in sediment retention, we took water samples during the spring floods of 1999-2001. To perform the investigation we chose two beaver settlements: A and B. Site A, with three dams, was located in the upper part of the Sumka River, in the preserve's buffer zone. Plot A1 was a control plot upstream of all the ponds (figure 2). Plot A2 was in the upper pond and A3 was in the middle pond 50 metres below the upper dam. Plot A4 was downstream from the whole cascade of dams. Site B was located at a beaver settlement in the Ser-Bulak River, which contained plots B1, B2, and B3, respectively above, in and below a single beaver pond (figure 2). Settlements were active throughout the study and the location of the dams did not change.

If the depth was less than 50 cm we took a water sample at half the depth. If the depth was more than 50 cm we took a water sample 20 cm from the bottom and 20 cm from the surface of the river. Water samples were filtered to determine the mass of sediment per litre. We calculated water flow using water velocity and area of wetted cross-section, which were measured using standard methods (Potapova 1975, Luchsheva 1983). Using the amount of sediment per litre and water flow rates, we calculated the amount of sediment that passed through the stream projection in a time period. The difference between total amounts of sediment that passed through plots A1 and A4 during spring flood was the amount of sediment that was retained by beaver dams during flooding.

Using these methods, 115 water samples were collected on the Sumka River and 48 on the Ser-Bulak River. Water samples were taken around midday at each plot (time of sampling was recorded to within a minute accuracy), once every 2-4 days depending on the intensity of flooding.

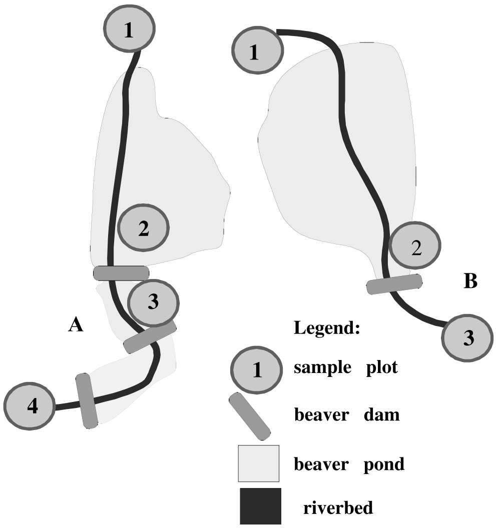


Figure 2. Scheme of hydrometric plots on an observation site on the Sumka River (A) and the Ser-Bulak River (B).

Results

Beavers built 26 dams during the seven years they occupied the Raifa portion of VKNNP and its buffer zone. Dam height varied from 0.3 to 1.6 m, and maximum length was 8 m. The total area of active beaver ponds in the Raifa portion of the preserve was about 14 ha, and 0.54 ha on average (table 1).

The Sumka River within site A (figure 1) was 1-2 m wide during mean flow rates of a year and about 6-8 m during the flooding period. The depth varied from 0.15-0.20 up to 1 m. During the spring flooding of 2001 the total sediment mass at site A reached 4,600 tons (figure 3). The dams decreased the amount of sediment in a litre of water (there was 53% less (reduced from 0.49 to 0.26 g/l) below the cascade of ponds) and also

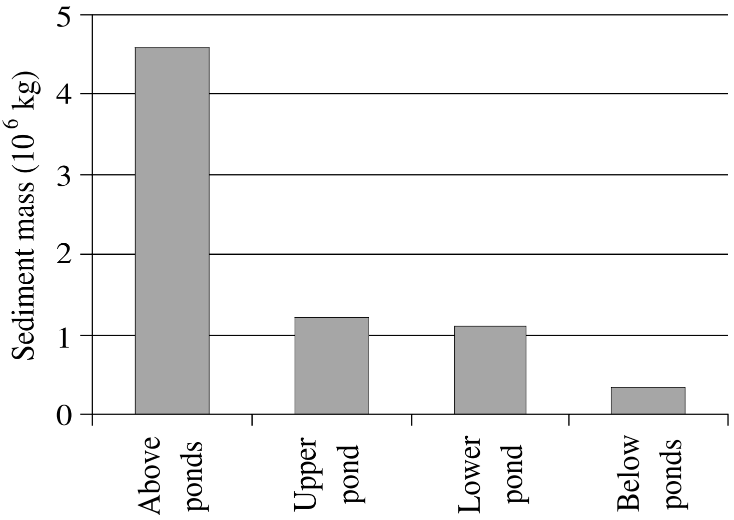


Figure 3. Sediment mass characteristics at hydrometric plots above, in and below beaver ponds on the Sumka River during a spring flooding of 2001.

stopped water that contained sediment. The difference of the parameters of plots A1 and A4 (figure 3) shows that during the flooding period the system of three dams retained about 4,250 tons of sediment. The greatest volume of sediment was filtrated by beaver ponds during the peak of flooding in April 16-18, 2001 (figure 4).

The Ser-Bulak River at site B (figure 2) has a mean width of 0.5 m during low water and about 2 m during flooding. The depth varies from 0.05 to 1 m. During the spring flooding of 2001 the total sediment mass at site B on the Ser-Bulak reached 26.9 tons (figure 5). Because of low mass of sediment per litre (about 0.025 g/l), the weight of sediment retained by a pond (20.6 tons) is only one-hundredth of the amount

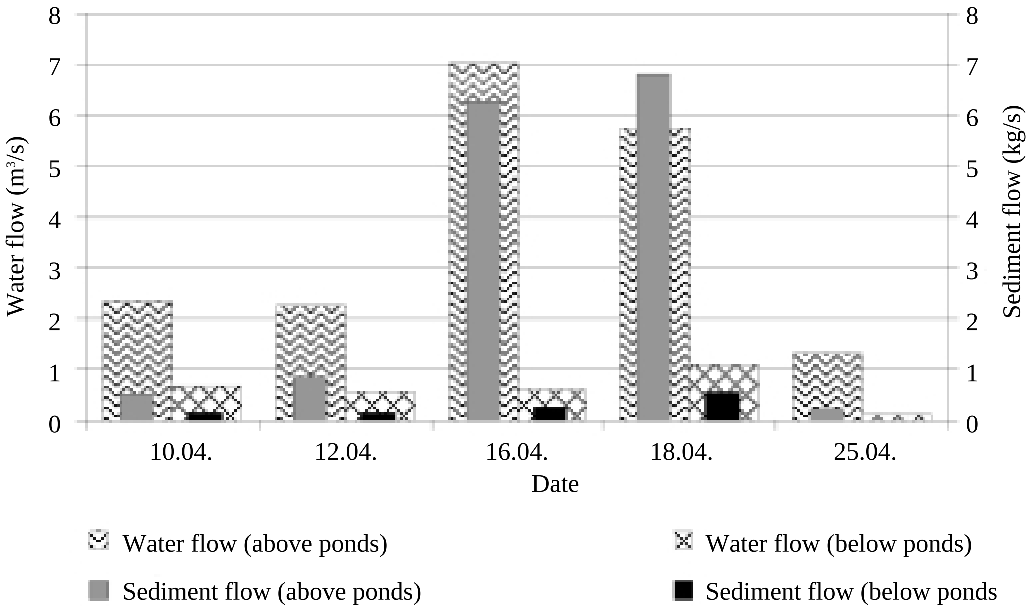
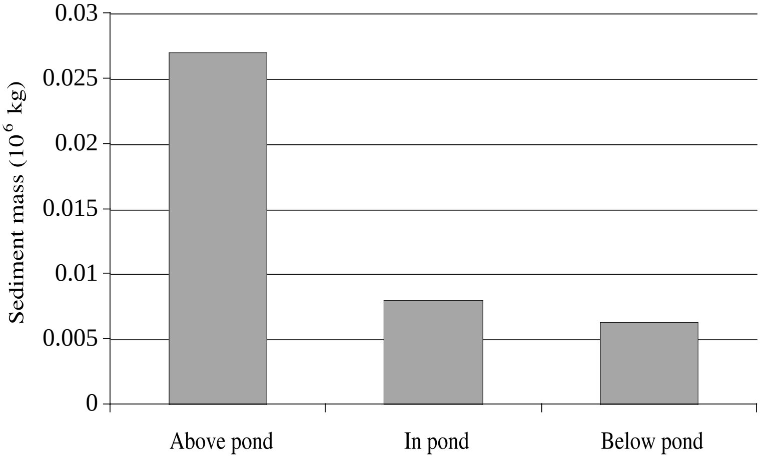


Figure 4. Dynamics of water and sediment flow rate of plots above and below beaver ponds on the Sumka River during a spring flooding of 2001.

Figure 5. Sediment mass characteristics at hydrometric plots above, in and below a beaver pond on the Ser-Bulak River during a spring flooding in 2001.



retained by a pond on the Sumka River. There was no significant difference in the mass of sediment per litre of water in the samples from plots B1 and B3, and all the sediment was retained due to the slowing of much of the water. The beaver pond on the Ser-Bulak River was 6.8 ha. There was a gradual increase of the water and sediment mass, which reached a maximum by April 23, 2001, the date of peak flooding (figure 6).

Discussion

The amount of the sediment stopped by beaver dams depends on the width of a dam, geological conditions and stream velocity (Bruzuski & Kulczycka 1999). According to the data of Naiman et al. (1986, 1988), an amount of between 1,000 and 6,500 m^3 of sediment accumulated per beaver pond in one year, and according to the data from Czech & Prior (2001), an amount of between 1,000 m^3 up to 10,000 m^3 of sediment accumulated. Brayton (1984), mentions that the daily sediment mass on Current Creek (Wyoming, USA) was reduced from 33 to 4 tons.

In total, at site A on the Sumka River during the flooding period, 4,250 tons of sediment was retained (4,700 m^3). The thickness of the sediment layer that was accumulated in the pond on the Sumka River (area 5.21 ha) during the flooding period of 2001 was about 9 cm. With time, sediment of up to two metres in depth can accumulate (Rasmussen 1940, Call 1966).

A large amount of sediment was stopped during the peak of flooding, when big volumes of water were filtrated by beaver ponds. The mass of sediment per litre of water after it had passed through all dams at the peak of flooding had been reduced by 55%. That is comparable with the data received by Parker (1986). In his research the water sample below beaver dams had 50-75% less sediment. Before and after the peak of a flooding, when the level of water was low, the mass of sediment per litre was reduced by only 8%. The percentage of the sediment that was stopped by dams is highly correlated with the level of water (r=0,94).

Unlike the Sumka River, the watershed of the Ser-Bulak River is covered by forest. It is also the reason for low mass of sediment in a litre of water during flooding. And as a consequence, the mass of retained sediment is hundreds of times less than on the Sumka River.

There was no significant difference in mass of sediment per litre of water between hydrometric plots on the Ser-Bulak River. All sediment was retained because the large volume of water with sediment was stopped by a dam.

Because of the increased number of beavers in the preserve, some of them were forced to move

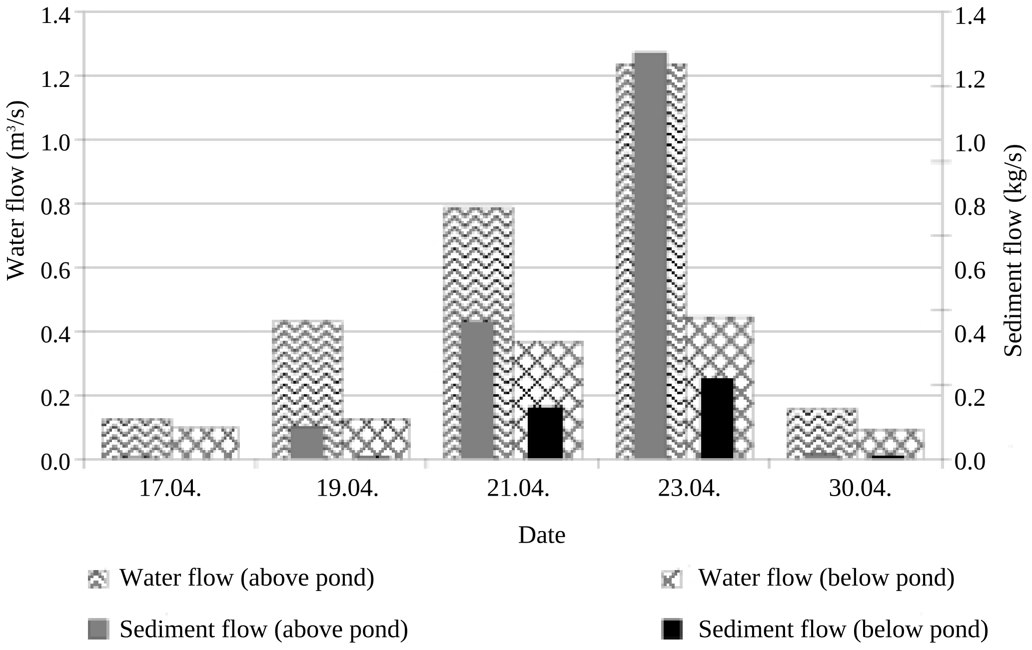


Figure 6. Dynamics of water and sediment flow rate of plots above and below beaver pond on the Ser-Bulak River during a spring flooding in 2001.

to suboptimal conditions where dam building was a necessity to survive. That is why the dams in the preserve were only constructed in the last few years (table 1). Since beavers have been present in the preserve the average amount of dams per settlement has increased from 0 (1996) to 3.3 (2002). As the number of beavers increases in the future, their building activity in the preserve will be more intensive for several reasons. First of all, beavers have constructed dams in those places where there was an opportunity to maximize the area of a pond (table 1). Secondly, the hydrological consequences of beavers are inversely proportional to river discharge (Legeyda 1992). This is the reason that the majority of beaver settlements with dams are in the upper part of the rivers. Stable water flow during the year with the low water discharge gives beavers an opportunity to adjust the level of water according to their needs. Secondly, the area of the flooded pond depends not so much on the size of a dam, but on the local relief (Legeyda 1992). Therefore, the average size of beaver ponds in Raifa portion of VKNNP is small (0.54 ha). The floodplain landscape only allows beavers to make big ponds in a few places. In the majority of cases, after construction of a dam there is only a small increase of width and depth of a pond. In different conditions the area of beaver ponds varied by 0.47 ha in one study

Table 1. Numbers of beaver dams and the size of beaver ponds on rivers of Raifa portion of the preserve and its buffer zone. From the time of reintroduction (1996) till 2002 all the beaver settlements with dams were active.

	1996	1997	1998	1999	2000	2001	2002	Total
Area of new ponds (ha)	0	6.9	3.1	1.8	1.6	0.3	0.4	14.1
Average size of a pond (ha)	0	2.3	1.03	0.9	0.8	0.05	0.04	0.54
Number of new constructed dams	0	3	3	2	2	6	10	26
Average number of dams per settlement	0	0.5	1	1.3	1.4	2.3	3.3	3.3

(Sinitsin 1994), ranged from 0.08 up to 15 ha, making an average of 3.3 ±0.57 ha in a second study (Zavyalov 1999), and ranged from 0.5 up to 10 ha in a third study (Czech & Prior 2001).

Most of the dams (20) were constructed on the Sumka River, which is the main supplier of the sediment entering Raifa Lake. As the beaver population increases, some of their numbers should move close to Raifa Lake, which should lead to a greater reduction in sediment volumes filling the lake.

Conclusions

Beaver ponds are able to retain a significant mass of sediment (4,250 tons). The mass of the sediment retained by beaver dams depends on the volume of water that was filtrated and stopped by dams. The greatest amount of sediment is retained during the peak of flooding when the biggest volumes of water are filtrated by beaver ponds. During this time the decrease of sediment mass per litre due to beaver ponds can reach more than 50% in a river with high sediment content.

Building activity of beavers becomes more intensive as the beaver numbers increase in a preserve. At first beavers constructed dams in those places where there was an opportunity to maximise the area of a pond. That is the reason why the average size of the pond decreases while average number of dams per settlement increases with the growth of a beaver population. As the beaver pond areas increase, the volumes of sediment filling the lake will decrease.

Acknowledgements: The author wishes to express special thanks to the head of the Volga-Kama National Nature Preserve, Dr. Yurii Gorshkov and to Prof. Leonid Baskin. I am also grateful to foreign friends and colleagues Prof. Andrea Easter-Pilcher and Prof. Brian Pilcher from the University of Montana – Western (USA) for the overall guidance of the project and for reviewing the paper. Thanks to my colleagues from VKNNP, O.V. Bakin, E.N. Unkovskaya and A.S. Sarvarov for help in the research. Part of the study was sponsored by a grant, INTAS - 01-168.

References

Brayton, S.D. 1984. The beaver and the stream. Journal of Soil and Water Conservation 39: 108-114.

Bruzuski, P. & A. Kulczycka 1999. Beaver – symbol of a return to nature. Warszawa, Polski Zwiazek Lowiecki, Poland.

Call, M.W. 1966. Beaver pond ecology and beaver-trout relationships in southeastern Wyoming. PhD thesis. University of Wyoming, Laramie, USA.

Czech, A. & S. Prior 2001. Ecological effects of beaver reintroduction in the Carpathian mountains. In: A. Czech & G. Schwab (eds.). The European beaver in a new millennium. Abstracts of 2nd European Beaver Symposium: 143. Carpathian Heritage Society, Krakow, Poland.

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

Gorshkov, Y.A., D.Y. Gorshkov, A.L. Easter-Pilcher & B.K. Pilcher 2002. First results of beaver (*Castor fiber*) reintroduction in Volga-Kama National Nature Zapovednik. Folia Zoologica 51: 67-74.

Legeyda, I.S. 1992. Beavers landscape creative activity and the protection of bank phytocoenosis of Ukraine. PhD thesis. Institute of Ecology and Evolution, Moscow, Russia. (In Russian)

Luchsheva, A.A. 1983. Practice on hydrometry. Hydrometizdat, Leningrad, Russia. (In Russian)

Naiman, R.J., J.M. Melillo & J.E. Hobbie 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). Ecology 67: 1254-1269.

Naiman, R.J., C. Johnston & J. Kelley 1988. Alteration of North American streams by beaver. Bioscience 38: 755-762.

Parker, M. 1986. Beaver, water quality, and riparian systems. In: D.J. Brosz & J.D. Rodgers (eds.). Proceedings of Wyoming Water 1986 and Streamside Zone Conference: 88-94. Wyoming Water Research Center and UW Agricultural Extension Service, University of Wyoming, Casper, USA.

Potapova, O.N. 1975. Instructions for hydrometric plots. Hydrometizdat, Leningrad, Russia. (In Russian)

Rasmussen, D.I. 1940. Beaver-trout relationship. Transactions of the North American Wildlife Conference 55: 256-263.

Sinitsin, M.G. 1994. Analysis of landscape creative

beaver activity and evaluation of beaver habitat using remote sensing. PhD thesis. Institute of Ecology and Evolution, Moscow, Russia. (In Russian)
Taisin, A.S. 1969. Relief and waters. In: V.I. Garanin (ed.). Proceedings of Volga-Kama National Nature Preserve: 26-51. Tatknigoizdat, Kazan, Russia. (In Russian)
Taisin, A.S. 1996. Anthropogenic activation of erosion processes and dynamics of lakes in Tatarstan. PhD thesis. Kazan pedagogic Institute, Kazan, Russia. (In Russian)
Unkovskaia, E.N., N.M. Mingazova & L.R. Pavlova 2002. Hydrological and hydrochemical peculiarities of Raifa basins. In: Y.A. Gorshkov & O.V. Bakin (eds.). Proceedings of Volga-Kama National Nature Preserve: 9-37. Tatknigoizdat, Kazan, Russia. (In Russian)
Zavyalov, N.A. 1999. Dynamics and landscape creative activity of beavers in Darwinsky Preserve. PhD thesis. Institute of Ecology and Evolution, Moscow, Russia. (In Russian)

Samenvatting

Is het mogelijk om bouwactiviteiten van bevers te gebruiken om sedimentatie in een meer te verminderen?

Erosie en sedimentatie in meren behoren tot de grote milieuproblemen in de Republiek Tatarstan. De omgeploegde gronden in het agrarisch gebied worden tijdens overstromingen gemakkelijk weggespoeld van de velden en via rivieren en laaggelegen gedeelten afgevoerd naar meertjes en moerassen, die zich vervolgens vullen met het sediment. De Sumka Rivier, met zijn grootste zijrivier de Ser-Bulak, stroomt door het Raifa Meer en vormt een voorbeeld van zo'n erosie- en sedimentatieproces. Sinds 1650 verkortte erosie door agrarisch gebruik van land bovenstrooms van het meer de lengte van het meer van 6 tot 1,3 km, de maximale diepte verminderde van 36 tot 19 m, en het oppervlak kromp van 150 tot 32 ha. De mogelijkheid om bevers te gebruiken om sedimentering te stoppen door het bouwen van dammen is een interessante optie. Gehoopt werd dat beverdammen het volume van vaste deeltjes die het Raifa Meer instromen zou beperken.

Met dit doel werden tussen 1996 en 2000 21 bevers uitgezet in de Sumka Rivier, die door het Raifa Meer stroomt. Gedurende de jaarlijkse overstromingen van 1999-2001 werd op twee plaatsen onderzoek uitgevoerd: aan de rivier Sumka en zijn zijrivier de Ser-Bulak, waarbij in totaal 115 respectievelijk 48 watermonsters werden genomen. De hoofdfactor die de sedimentatie beïnvloedt is het volume water dat door de bevervijvers gestopt kan worden. Tijdens de overstromingsperiode van 2001 werd 4.250 ton aan vaste deeltjes gestopt door drie beverdammen bij de bevervijvers van de Sumka Rivier, die bij elkaar een oppervlak hadden van 5,21 ha. De sediment-massa per liter water verminderde met 53% (van 0,49 tot 0,26 g/l) nadat het water de cascade van drie dammen passeerde.

Received: 27 October 2003
Accepted: 20 February 2004