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An answer to Campbell

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R.D. Campbell (2006) in his paper argues on the inconsistency of data and statistics as well as disagrees on the blaming of European beaver *Castor fiber* in the decline of freshwater pearl mussel *Margaritifera margaritifera*. We thank Campbell for his comments on beavers. In addition, we must apologise on a mistake in the article (Rudzīte 2005). In the chapter "Results", labels A and B were in reverse places in Fig. 1.

Campbell (2006) does not use any information on the beaver population in Latvia. His arguments are partly based on the literature on the behaviour of Canadian beaver *Castor canadensis*. However, Canadian beaver has never been found in Latvia (Balodis 1990).

Why do we argue that beaver is a threat for freshwater pearl mussel in Latvia? The freshwater pearl mussel is a highly threatened bivalve. A 85 to 100 % decline in known populations in Central and Southern Europe has been estimated, which may be due to a number of factors, including increasing siltation and eutrophication of rivers, and also the recent declines in migratory salmonids upon which the larvae depend (Skinner et al. 2003). Most pearl mussel populations have lacked successful reproduction for 30 to 50 years. Formerly dense and connected populations have often become fragmented. However, a potential for recovery is offered by the longevity of this species, i.e. a lifespan of more than 100 years, together with the high reproductive potential of adult pearl mussels even in polluted rivers and in extreme old age (Geist 2005).

Freshwater pearl mussels live almost buried in coarse sand and fine gravel in clean, fast flowing and preferably unpolluted rivers and streams. For the successful reproduction of this mussel, the very specific requirements for juveniles are critical. For example, the nitrate level should not exceed 1.0 mg l^{-1}, phosphates 0.03 mg l^{-1} (Skinner et al. 2003), dissolved oxygen 6 mg l^{-1}, water temperature 21 °C, or 10 °C during the breeding period in spring; interstitial water chemistry should resemble the free running water nutrient levels (Moorkens et al. 2000).

Currently, there are only five rivers with viable pearl mussel populations in Latvia. The total number of individuals has been estimated up to 12 000 to 25 000 (Rudzīte 2004). More or less, beavers inhabit all these rivers.

When evaluating the impact of beavers on the pearl mussels, the following factors should be considered: the habitat quality in beaver dams; the water quality below the dams, as well the size and number of dams, and the changes of their locations.

On small rivers, beavers build dams. In floodplain areas, even a low dam can flood a large area. This is especially typically for Latvia where plain landscapes are characteristic. Beaver ponds store significant amounts of nitrogen in sediments. The organic matter is increased also with fallen wood, which is a long-term source of nutrients to the pond water and outflow. Even anaerobic conditions can be reached in beaver ponds (Rosell et al. 1995). Such conditions are incompatible with the recruitment of young pearl mussels, but

the oldest pearl mussels can survive also in dams; this is seen also in Fig. 1 of the discussed paper (Rudzīte 2005).

The influence of beaver dam continues also in areas downstream of the beaver dams where high total organic nitrogen and total phosphorus, and high water temperature can be observed (Rosell et al. 2005). As a result, species composition of downstream sections differs from upstream sections – the macroinvertebrate fauna downstream of the beaver dam is quite similar to the dam itself (Hering et al. 2001). These effects are site-dependent and decrease shortly after the dam (Rosell et al. 2005). A longer-lasting effect is the reduced water discharge because the evaporation in the summer is enhanced by the enlargement of the open water area. This situation can be observed in hot summers in Latvia when beaver-inhabited small rivers become a chain of ponds with no stream connecting them (Rudzīte, unpublished data).

Often, a series of dams are built on small streams. The location of dams changes with the time – old dams become abandoned and beavers build dams in previously intact sites. So, there is no asylum for pearl mussels in areas between the dams.

The above has been observed in River Pērļupe, where one of the most well known and monitored populations of freshwater pearl mussels in Latvia is located. The pearl mussel population in whole river was estimated as 2000 in year 1977 (number based on calculations and not on direct counting; Krišāns 1977), 1400 in year 1984 (here and further – direct countings). Beavers settled in this river between the years 1987 and 1992. Currently, there are no beavers in Pērļupe, the number of pearl mussels is estimated up to 400, and they all are aged. It is expected that this population will die-out within five to ten years because of lack of juveniles (Rudzīte 2001).

Here we give additional information on the studied rivers and pearl mussel populations. River Rauza ir 56 km long, it's inclination is 144 m (2.6 m per km). The catchment area including tributaries is 263 km^2 (Zīverts 1997) Here, 200 to 250 beavers were counted in 2005 (Valka Forestry, unpublished data). There are no beaver dams on the Rauza but beavers live in riverbanks and in tributaries. Along the river, there are a few rural settlements and one small swine farm. Pearl mussel was found in one 7800 m long section of this river; the number of individuals is approx. 3000 (Rudzīte 2005).

River Ludze (tributary of Rauza) is 24 km long, catchment area 80 km^2 (Zīverts 1998), 66 km^2 forests (Rudzīte, unpublished). Upstream in the river there is a section of 17 km with almost a continuous chain of beaver dams. This area is mainly open, and a river has a wide floodplain. The downstream area is beaver-free, relatively pristine, and generally covered with coniferous forests. In this part 20 000 pearl mussel individuals are located. This is considered as the largest and most vital pearl mussel population in Latvia, and this is the only one location where young pearl mussels are found.

R.D. Campbell (2006) argues that pearl mussels and beavers can live together as they did in ancient times. In ancient times, European pearl mussel was one of the most abundant bivalve in rivers (Skinner et al. 2003). Later, both beavers and pearl mussels suffered from overexploitation because of hunting (Rosell et al. 2005) and pearl fishing (Skinner et al. 2003). In 20th century, reintroduction of beavers was started in Europe (Rosell et al., 2005) and also in Latvia where the first beavers were released in 1927 (Balodis 1990). The number of beavers reached 37 000 in 1990 (Balodis 1990), and now their number is estimated at 72 000 according to the monitoring of State forest service, but only forested areas were surveyed for beavers (State forest service, unpublished data).

However, pearl mussels did not recover because their colonies were small, and in the 20th century the continuous eutrophication of rivers due to agricultural development was ongoing.

Currently, there are very many beavers in Latvia, and they are not threatened. However, there are very few pearl mussel populations, and they are small and threatened mainly by river eutrophication, which is partly caused also by beaver. Considering that there are only a few kilometre-long sections of pearl mussel populations, there is a high probability, that beavers can dam these sections just by chance, and therefore the control of beavers is advised in these areas.

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