Limnologica 50 (2015) 84–91

Contents lists available at ScienceDirect

Limnologica

journal homepage: www.elsevier.com/locate/limno

Impact of deforestation on pearl mussel habitats in the Russian section of the Baltic Sea basin☆

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ARTICLE INFO

Article history:
Received 13 March 2014
Received in revised form 23 October 2014
Accepted 23 October 2014
Available online 1 November 2014

Keywords:
Pearl mussel
Extinction
Deforestation
Survival

ABSTRACT

Changes in the vegetation cover associated with intensive forest extermination may have a strong effect on the riverine environment, including the chances of survival for bivalve mollusc populations in small streams and rivers. In order to check this hypothesis, drainage area properties of the rivers with extinct and existing pearl mussel populations in the Russian section of the Baltic Sea basin were compared. Preservation of forest vegetation along the river banks of the studied rivers was correlated with the presence of pearl mussel populations. Traditional agriculture turned out to be, in some cases, more harmful for river ecosystems than urbanization and industrialization.

Introduction

Water pollution, pearl fishing, construction of dams, eutrophication and numerous other processes negatively influence pearl mussels (*Margaritifera margaritifera*) in Europe (Araujo and Ramos, 2001; Degerman et al., 2009). However, it is not always clear which factor is the most essential and what conservation measure would be the most urgent. This problem arose during the "rediscovery" of pearl mussel populations in the Russian sector of the Baltic Sea basin. A strange fact was observed: most populations in areas close to the large city of Saint Petersburg had survived (although decreasing in numbers down to the minimum), but almost all populations in remote, supposedly "wilderness" areas had become extinct. Former pearl mussel habitats are inhabited by other bivalves (*Unio crassus*, *Unio tumidus*, *Anodonta anatina*) or there are no bivalves there at all. In one case pearl mussels coexisted with thick-shelled mussels (Popov and Ostrovsky, 2013).

In order to explain these observations, the following hypothesis was stated: the disappearance of pearl mussels may be associated with the deterioration of land habitats along the rivers, for instance, as a result of deforestation and agricultural activities (Popov and Ostrovsky, 2012). Some other negative influences may result in a decrease in the numbers of pearl mussels but not necessarily in their extinction. When trees are exterminated along the rivers, the soil is washed out of the banks and the rivers become shallow and silted. Some pearl mussels may persist under such conditions, but the microhabitats for juveniles are destroyed. (Young pearl mussels spend several years burrowing into the ground needing good aeration of their environment (Hastie et al., 2000; Österling, 2006; Geist and Auerswald, 2007)). As siltation intensifies, a succession may take place: pearl mussels give way to other bivalves, they coexist for some time and then pearl mussels disappear. Eventually, the other bivalves may disappear too. The hypothesis was prompted by historical considerations (extinct populations were located in the areas of ancient human settlements) and general speculations of anthropogenic nature transformation (the longer people live in an area, the fewer trees are there) (Popov, 2013). To test this hypothesis, pearl mussel habitats from different rivers of the Russian section of the Baltic Sea basin were compared. This paper presents the results of this comparison.

Materials and methods

Investigated rivers. "Rediscovery" of pearl mussels

Until recently, pearl mussels in the Baltic Sea basin of Russia had remained almost unexplored. There is, however, much historical evidence of pearl fishing in this area. About 30 rivers were considered as pearl fishing locations (Yakunina, 1955; Makhrov, 2009) (Exact calculation is impossible because of toponymical confusion: there may be rivers with the same name, one and the same river may be named differently in its different parts, some rivers can-

☆ This article is part of a special issue entitled "The current status and future challenges for the preservation and conservation of freshwater pearl mussel habitats".

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http://dx.doi.org/10.1016/j.limno.2014.10.003
0075-9511/

not be identified on modern maps). They mostly flow through the Russian territory now referred to as "Novgorodskaya oblast"[1], that is, the south-eastern part of the Baltic Sea basin. Pearl mussel habitats used to concentrate mainly in the upper reaches of the rivers close to the watershed between the Caspian and the Baltic Sea basins. However, during a recent survey of 23 rivers only one small pearl mussel population was found there (Popov and Ostrovsky, 2013). Fifteen rivers were populated by *U. crassus*, one river by *U. crassus* and *U. tumidus* and one river by *U. crassus* and *A. anatina*. In the other rivers no bivalves were found.

The only extant pearl mussel population (in the Khorinka river) now numbers about 5000–6000 individuals. The riffles in this river are populated either by *U. crassus* or *M. margaritifera* or both.

Novgorodskaya oblast is a mostly rural area. Its administrative centre, Veliky Novgorod, has a population of 200,000. The region is a popular recreational and touristic destination. A large Valdaysky national park (1580 km^2), partly covering former pearl mussel habitats, and several other protected areas are situated there. So, the conditions for river conservation seem favourable.

Leningradskaya oblast[2], lying to the north of Novgorodskaya oblast, is much more densely populated. Saint Petersburg, its administrative centre, has a population of ca. 5 million. Though one might expect various negative impacts of a megapolis on the surrounding territory, seven pearl mussel populations were found in the region. Four of the rivers with pearl mussels are close to Saint Petersburg (Okhta, Sestra, Gladyshevka, Roshinka), one of them (Okhta) flowing in its low reaches through an urban area. Some mussels were found within the administrative border of the city, although not in urban areas. All these seven rivers were mentioned in some sources (either in archives or in scientific collections) as pearl mussel habitats. In addition to them 50 small rivers of Leningradskaya oblast were studied for the presence of bivalves. Pearl mussels were not found, and neither were any indications of their past existence there (Popov, 2014).

The total number of pearl mussels of Leningradskaya oblast is about 45,000, with 40,000 occurring in one small brook (Table 1). This largest population is characterized by an unusually high density of mussels: up to 1000 individuals per 1 m^2. Other populations are sparse but all of them contain young individuals. In four rivers (Yanega, Shotkusa, Sestra, Okhta) pearl mussel habitats are located only in the upper reaches, while in the others (Gladyshevka, Roshinka, Peipia) they are distributed along the main part of the stream (Ostrovsky and Popov, 2011; Popov and Ostrovsky, 2013).

Four pearl mussel populations probably existed and might still exist in the Baltic Sea basin in the Republic of Karelia, just northwards from Leningradskaya oblast (Makhrov et al., 2013).

Though the details of pearl mussel distribution over the Baltic Sea basin need verification, the general situation is clear: almost all populations in Novgorodskaya oblast have become extinct, while most, if not all the populations in Leningradskaya oblast survived. This is intriguing considering that the conditions in the rivers in the two regions are often quite similar (Fig. 1).

To reveal the causes of pearl mussel extinction, 11 rivers of Novgorodskaya oblast, where there are no pearl mussels, were compared with the rivers with extant pearl mussel populations (1 in Novgorodskaya oblast and 7 in Leningradskaya oblast) (Table 1, Fig. 2). The 11 rivers chosen for comparison could be easily matched

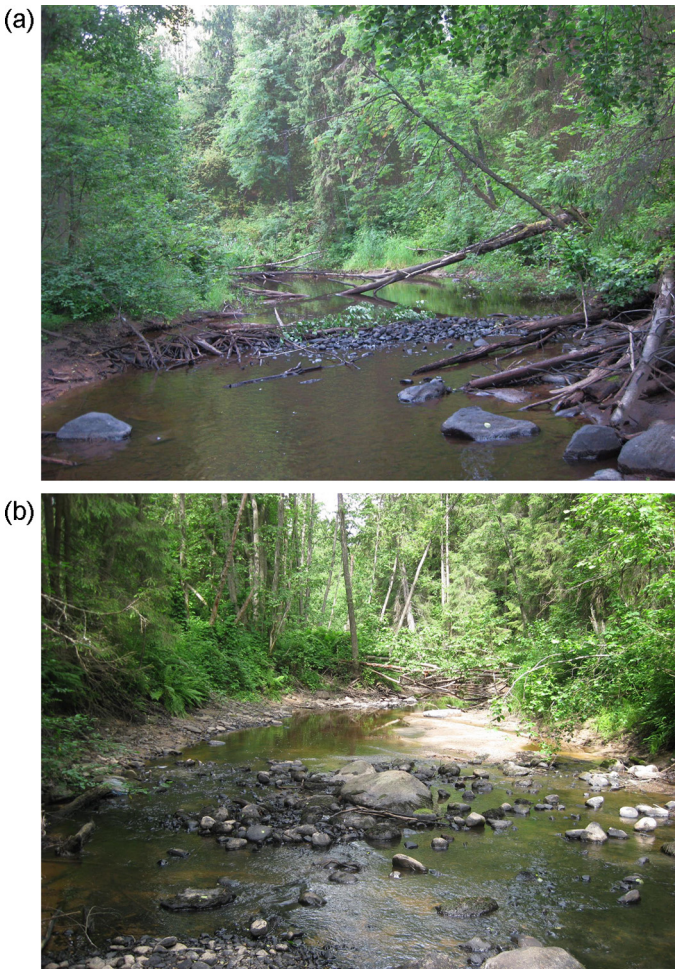

Fig. 1. The pearl mussel habitat on the Shotkusa River, Leningradskaya oblast (a), and the former location of an extinct pearl mussel population of Krenichno River, Novgorodskaya oblast (b).

with the rivers mentioned in the archives and resemble pearl mussel habitats of Leningradskaya oblast with respect to hydrology. They are usually 3-8 meters wide and not more than 80 cm deep in the middle reaches.

Cartographic analysis

River sections with riffles (that is, potential pearl mussel habitats) were indicated in maps using GIS and their drainage basin was outlined. Woodlands, farmlands and settlements were then identified within the basins. Farmlands and settlements were considered mutually, because the borders between them are unclear: most of the settlements consist of small houses surrounded by gardens and fields. The length of the sections, where farmlands and settlements border on river banks, was also determined. The percentage of deforestated areas of the drainage area and that of deforestated banks was determined for each river. These percentages were used as indices for comparing the rivers of Novgorodskaya and Leningradskaya oblast.

In order to outline the basins, aerial photographs (GoogleEarth, GoogleMaps, YandexMaps) and topographic maps (Karpova, 2011; Lindholm et al., 2013) were used. To reveal farmlands, settlements and woodlands the "public cadastre map" was used, an Internet resource showing land categories (http://maps.rosreestr.ru/PortalOnline/).

[1] ""Oblast", meaning "region", is an administrative division of the Russian Federation. "Novgorodskaya oblast" is a region with the administrative centre in the city of Veliky Novgorod.

[2] Saint Petersburg was called Leningrad in 1921–1991, and the administrative region around it is still called "Leningradskaya oblast".