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Population viability modelling and potential threats to the beaver in the Vistula River valley, Poland

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Distribution data on beaver populations thriving in central Poland are common. We modelled beaver population viability to assess the current status and threats to the beaver in the 135-km-long section of the Vistula valley. We simulated different densities of expanding beaver populations and evaluated the three most significant scenarios of potential developments in the valley with the LARCH habitat model. The model output indicated higher vulnerability of low density populations to the same environmental changes. At present, suitable habitats sustain a large minimum viable population as part of one sustainable network. Hypothetical construction of two dams and removal of riparian forests within dykes would lead toa 25% reduction in population size. In contrast, river renaturalisation would increase beaver numbers by 42%. Based on the population trends we conclude that scenario analysis is beneficial in helping to evaluate future management decisions.

Introduction

The beaver (*Castor fiber*) was widespread in Poland until the 13th century, however, because of anthropogenic changes in the landscape and in hunting, its numbers decreased, eventually causing its extinction in the entire Vistula River catchment in Poland after 1850 (Pucek 1984). After World War II the species was recorded at only a few localities in northeastern Poland. A successful reintroduction programme in the catchments of the Vistula and Oder Rivers began in the 1970s supported by natural dispersion of beavers; this resulted in a wide range of species occurrence in Poland. Numbers of beavers are presently increasing. The population estimate was 130 individuals in 1958 and approximately 15 000 in 2004 (Żurowski 1992, Borowski 2004). Miller (2005) estimated the 2004 population to be 40 000. The beaver population in the Vistula valley is increasing, as documented by the proportion of sites showing signs of presence recorded during surveys along the Vistula banks from Warsaw to the Narew River outlet: i.e. 20% in 1997, and 100% in 2005 (Goszczyński & Romanowski 2000, Romanowski unpubl. data). A recent increase in the population poses a potential threat to the management of the Vistula river dykes and may result in an increase in the annual rate of state recompensations paid for beaver damages in agriculture and aquaculture (Czech 2005).

The Vistula valley, recognized for its high nature values and biodiversity, is exposed to a

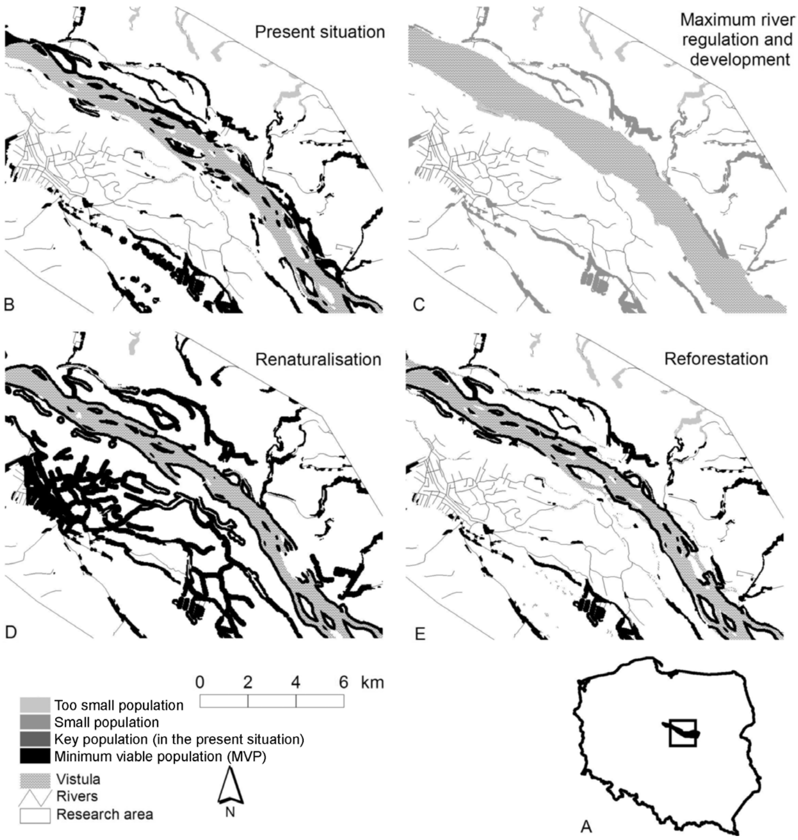

Fig. 1. Viability of local populations of the beaver in the Vistula valley (fragment of the study area) in the present situation and three scenarios, based on LARCH modeling. — **A**: Study area in Poland. — **B**: Present situation. — **C**: Maximum river regulation and development. — **D**: Renaturalisation. — **E**: Reforestation.

range of various environmental stresses. These include hydro-technical measures aimed at flood control and water transport, water pollution, development of build-up areas and roads and intensification in use of agricultural lands, that pose potential threats to viability of many populations in the area. The aim of this paper is to analyse, using the LARCH habitat model, the current status and vulnerability of the beaver population to the potential management strategies in the Vistula valley.

Material and methods

The research area covers a 135-km-long section between Warsaw and Włocławek in central Poland with an area of about 1545 km^2 (Fig. 1A). Arable lands, gardens and orchards cover 33% of the area; forests cover 34% (69% of which are coniferous forests and 31% broad-leaved forests); grasslands (mostly extensive meadows) cover 17% (Matuszkiewicz *et al.* 2005a). The valley includes core areas and ecological corridors of the ECONET Poland concept (Liro *et al.* 1995). There are two areas included in the Natura 2000 Network: the valley of the middle Vistula and the Kampinos Forest (the latter being also a National Park).

Development scenarios

Potential threats and expected or possible management strategies identified for the middle Vistula valley became a part of five scenarios that were developed in consultation with various stakeholders (Matuszkiewicz *et al.* 2005b). Detailed maps were prepared for each of the scenarios, which outlined all spatially explicit elements e.g. changes in the vegetation, hydro-technical regulation of the Vistula and the network of roads in the study area. A review of the LARCH model outputs has shown very limited effects of the two scenarios (Van der Sluis *et al*. 2007), so to further model the beaver population, we considered only the following three scenarios:

- Maximum river regulation and infrastructure development. Main elements: construction of two new dams, removal of all trees inside the dykes, and the development of other infrastructure like roads, dykes, motorways, etc.
- "Brave vision" for the Vistula valley renaturalisation. Main elements: removal of some dykes (where possible), decommissioning of the dam at Włocławek, removal of some of the settlements in the river valley, natural succession within the flood plain.
- Reforestation. Main elements: conversion of low-productivity agricultural fields into forest plantations and natural forest succession.

Modelling

To assess population viability of the beaver we implemented the habitat model LARCH (Landscape Ecological Analysis and Rules for the Configuration of Habitat) (Chardon *et al*. 2000, Verboom *et al*. 2001, Groot Bruinderink *et al*. 2003). LARCH requires input in the form of habitat data (digitalized vegetation or land use map) and ecological parameters (home range, dispersal distance, carrying capacity for optimal, suboptimal and marginal habitats). Based on habitat distribution and carrying capacity, and taking into account barriers such as busy roads, the model evaluates the size and viability of local populations. Viability of the populations is evaluated according to the "model defined" numbers of individuals needed for key and minimum viable populations with the probability of extinction less than 5% in 100 years (Verboom *et al*. 2001). All populations located within dispersal distance belong to one network (metapopulation), for which spatial cohesion analysis provides an estimation of the degree of connectivity and corridor functioning. For the current modelling we used a digital map of 102 vegetation complexes prepared at a scale of 1:25000 (Matuszkiewicz & Solon 1998), as well as several additional topographical maps. Expected changes in vegetation and habitats for each scenario were expressed on the modified digital maps of the 102 vegetation complexes (Matuszkiewicz *et al*. 2005b). We calibrated beaver parameters required by the model to fit the present situation (*see* below), and used the same settings for assessment of the three scenarios.

Model calibration

For the modelling of the beaver populations we selected suitable habitats within a 100-m buffer along all running water. We considered riparian *Salici–Populetum* and *Circaeo–Alnetum* forests, birch and aspen forests and willow scrubs (*Salicetum triandro-viminalis* and *Salicetum pentaendro-cinareae*) as optimal habitats, and other forests and bushes as suboptimal (28 vegetation complexes) and marginal (18 vegetation complexes) habitats. We used the density of 1, 2, 4 and 8 reproductive units (RU) per km^2 of optimal habitats to simulate different numbers of an expanding beaver population. We assumed that the density in suboptimal habitats equals 0.5, and in marginal habitats 0.1 of that in optimal habitat.

Although actual species distribution or abundance data are not required for LARCH since the assessment is based on the habitat potential of the ecological network of the species (Van der Sluis *et al*. 2007), fine adjustments of the parameters were undertaken by comparing the initial model outputs to the distribution and habitat preference of the beaver in the study area, followed by modification of the parameters for the best fit. In addition, field censuses for fresh signs of beaver activity (feeding signs, tracks, lodges and burrows) were conducted in the study area in the spring of 2004 and 2005. A total of 110 sites with signs of beavers were recorded, of which 96 (87%) fitted later into the range of local populations generated by the LARCH model for the present situation. The remaining 14 false negative sites in the model all represented sections of small rivers with open banks and scarce vegetation in early stages of succession (typically young willow scrub), that were most probably visited by dispersing animals. Since such habitats were unlikely to hold resident beavers, these should not influence the LARCH estimates of total number of reproductive units.

Results

Present situation

The LARCH analysis indicated the potential for a large local beaver population in most of the study area, including the Kampinos National Park, the Bzura and section of the Vistula from the Narew outlet to the Włocławek reservoir (Fig. 1B). This population was assessed as a minimum viable population (MVP) for the entire range of beaver densities modelled. The beaver's habitats in the study area were well connected and the spatial cohesion was highest along the Vistula banks and the river's tributaries. Local populations within the study area formed one network, which was assessed as sustainable for the density of 1, 2, and 4 RU km^{-2} of optimal habitats, and as highly sustainable for the density of 8 RU km^{-2} of optimal habitats. The total number of beavers varied depending on the densities used in the model from 74 to 591 RU (Table 1).

Scenarios

The scenario of maximum river regulation resulted in a decrease in beaver population numbers (Table 1). Destruction of optimal habitats resulting from the removal of all riparian forests between the dykes and the flooding of the banks by two reservoirs led to the disappearance of some local populations, which was especially pronounced in the middle section of the Vistula (Fig. 1C). The model output for the density of 1 RU km^{-2} of optimal habitats documented a strong decrease in population viability: all MVP and key populations (in the present situation) were assessed as small. The model outputs for a density of 2 and 4 RU km^{-2} of optimal habitats indicated an intermediate decrease, while the output for the density of 8 RU km^{-2} of optimal habitats showed no change in the viability analysis (Table 1). As compared with the present situation, viability of the entire network of populations decreased (from sustainable to nearly sustainable) in case of the scenario with only the lowest RU density modelled.

Renaturalisation and reforestation resulted in an increase in beaver population numbers, being more pronounced in the renaturalisation scenario (Table 1). The recreation of new riparian habitats that replace the Włocławek reservoir and the overall development of riparian forests and willow shrub resulted in an increase of the minimum viable population in the flood plains of the central section of the Vistula (Fig. 1D and E), and in additional improvements of the viability of populations on the most western section of the Vistula (presently Włocławek reservoir). The viability of the entire network of populations increased as compared with the present situation in both scenarios at a density of 4 RU km^{-2} of optimal habitats modelled (from sustainable to highly sustainable, *see* Table 1).

Discussion

The results of the modelling exercise indicate the potential for a thriving beaver population inhabiting semi-aquatic habitats in most of the

Table 1. Estimated number of reproductive units (RU) and viability of local beaver populations for the different densites in optimal habitats in the present situation and the three scenarios. – nearly sustainable, + sustainable, ++ highly sustainable.

Scenario	Density (RU km^{-2}) and viability							
	1	viability	2	viability	4	viability	8	viability
Present situation	74	+	148	+	295	+	591	++
Maximum river regulation and development	56	–	113	+	226	+	451	++
Renaturalisation	105	+	209	+	418	++	837	++
Reforestation	81	+	163	+	326	++	651	++

study area, as confirmed by the field surveys in 2004–2005. Beavers have occurred in the study area since 1980 (Kowalski *et al*. 2003) and the population is presently increasing (Goszczyński & Romanowski 2000). There are no precise population figures for the wider area although results of the National Park forest service surveys in 2004–2005 indicate a minimum of 20–24 beaver families in the area of the Kampinos National Park (E. Owadowska unpubl. data). These data are intermediate as compared with the model outputs of approximately 17 and 34 families for the same area, generated by LARCH for densities of 1 and 2 RU km^{-2}, respectively, providing an approximate range for the current population of 74–148 RUs in the study area. Considering data on the average size of a beaver family (3.7 individuals) used in a survey in Poland (Żurowski & Kasperczyk 1986), we estimate the present population in the study area to be 274–548 beavers.

The model outputs indicate the potential threats to population numbers and the spatial cohesion of beaver habitats with further regulation of the Vistula River, infrastructure development and the removal of riparian forests in the valley. In contrast, scenarios of the Vistula valley renaturalisation and reforestation are beneficial for the species. Sensitivity testing of density shows a proportional change in beaver population numbers and differentiated viability as a result of each scenario. Higher vulnerability was noted for low density populations as compared with that for high density ones: all minimum viable populations with a density of 1 RU would become small populations (at risk of extinction) as a result of maximum river regulation and infrastructure development, while all minimum viability populations with a density of 8 RU would remain MVP as a result of the same environmental changes (Table 1).

Recent discussions on the threats posed by development such as stream regulation and dam construction focus on bird and fish species (Gacka-Grzesikiewicz 1995, WWF 2001). This study provides evidence that populations of semi-aquatic mammals, such as the beaver are also subjected to the effects of such developments. Although we analysed a single species, our analysis conducted with the habitat model may be indicative for a range of mammals that forage or use shelters in aquatic habitats and riparian forests, such as the otter (*Lutra lutra*), polecat (*Mustela putorius*) and the muskrat (*Ondatra zibethica*).

Population viability models are widely used in nature conservation to compare management strategies and predict the probabilities of extinction (Grimm *et al*. 2004). Habitat modelling is based on ecologically scaled landscape indices (Vos *et al*. 2001, Verboom *et al*. 2001) and can be applied even without exact data on the species' distribution, however in this study field data were used to verify and adjust LARCH parameters used. This approach allows us to assess the potential threats of landscape development even in the case of species that are difficult to census, including the beaver. The scenarios' ranking enables us to indicate how future management decisions will affect probabilities of extinction of the beaver population analysed.

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