Short Communication

A paradox of restoration: prey habitat engineering for an introduced, threatened carnivore can support native biodiversity

Liina Remm, Asko Lõhmus and Tiit Maran

Abstract Conservation of charismatic vertebrates in modern landscapes often includes habitat engineering, which is well supported by the public but lacks a consideration of wider conservation consequences. We analysed a pond management project for an introduced island population of captive-bred, Critically Endangered European mink *Mustela lutreola*. Ponds were excavated near watercourses in hydrologically impoverished forests to support the main prey of the mink (brown frogs *Rana temporaria* and *Rana arvalis*). A comparison of these ponds with other, natural, water bodies revealed that the (re)constructed ponds could reduce food shortages for the mink. Moreover, the ponds provided habitat for macroinvertebrates that were uncommon in the managed forests in the study area, including some species of conservation concern. The cost-effectiveness of the management of charismatic species can be increased by explicitly including wider conservation targets at both the planning and assessment stages.

Keywords Amphibians, Estonia, focal species, habitat degradation, macroinvertebrates, *Mustela lutreola*, Odonata, pond management

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Habitat management for charismatic threatened species is a common conservation activity, and it is important to understand the contribution this makes to wider biodiversity conservation at the scale of species and ecosystems. In addition, the consequences of species-oriented habitat management can inform debates on the efficacy of surrogate species (Caro, 2010) and realistic goal-setting in restoration ecology. The concept of surrogate species was linked explicitly with habitat management for threatened species by Lambeck (1997), who suggested that the conservation or reconstruction of habitats be based on a suite of focal species sensitive to each threat. Hobbs et al. (2011) suggested that traditional habitat restoration needs to be replaced by an approach that maintains ecosystem services in human-impacted environments by means of various interventions. Thus, if sustaining a threatened species is desirable either for its surrogate or public-perceived values, it may be acceptable to engineer critical characteristics of its degraded habitat beyond the natural range of variability. It is less clear, however, to what extent such practices support the wider aims of biodiversity conservation.

Here we explore a situation in which management for a threatened flagship species has gone beyond conventional habitat restoration. The target species, the European mink *Mustela lutreola*, is a Critically Endangered mustelid threatened by habitat loss and the impact of the alien American mink *Neovison vison* (Maran et al., 2011). Balancing these threats, the Foundation Lutreola and Tallinn Zoo established a mink population in 2000, using captive-bred individuals, on the remote Estonian island of Hiiumaa (989 km^2, 68% forest cover; Fig. 1). The island has no historical records of this species but the abundance of farm-escaped American mink (now eradicated and the farm closed), combined with field assessments of riparian areas, suggested a potential carrying capacity for 88–105 European mink (Macdonald et al., 2002; Maran & Põdra, 2009). The main limiting factor is the sparse network of natural streams and a severe reduction of lakes and pools as a result of artificial drainage and lowering of the water level for forestry and agriculture (Veering, 1976). Riparian areas are the main habitat of the European mink, which normally stays within 100 m of streams (Danilov & Tumanov, 1976). Although larger ditches could provide alternative habitat, drainage has presumably reduced the mink's prey base, notably the brown frogs *Rana temporaria* and *Rana arvalis* (Suislepp et al., 2011; Põdra et al., 2013). Improving the prey base via large-scale hydrological restoration would have been complicated, and artificial ponds were therefore constructed. Here, we explore whether these artificial ponds supported not only the mink's prey but also other native macroinvertebrates.

Twenty-three small (24–1,700 m^2) ponds were constructed or reconstructed in forests and meadows. The ponds were c. 1 m deep, to provide an environment suitable for amphibian tadpoles up to the completion of

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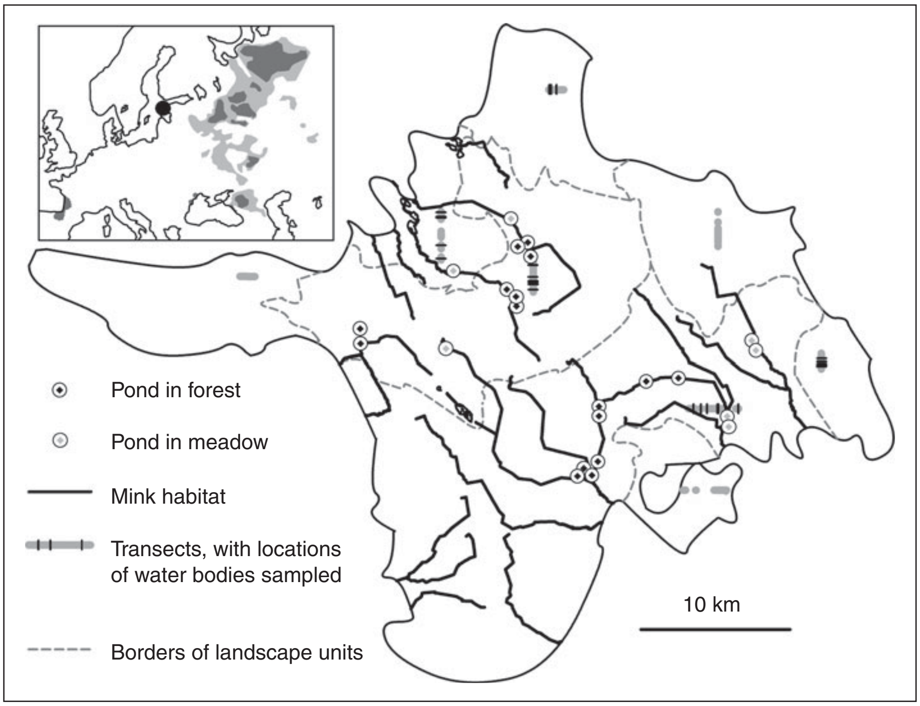

Fig. 1 Locations of (re)constructed ponds and other water bodies and of water bodies suitable for the European mink *Mustela lutreola* on Hiiumaa island (Põdra & Maran, 2003). The landscape units were differentiated based on types of relief, dominant soils, vegetation, movement of water and land use (Arold, 1993). On the inset the location of Hiiumaa island is indicated by the black circle, the areas shaded dark grey depict where wild European mink may still survive and the areas shaded light grey where the species possibly went extinct in recent times in Europe (modified from Maran et al., 2011).

metamorphosis, with a shallow northern bank to provide sun-warmed water. The ponds were <1 km (usually much closer) from the streams suitable for the mink (Fig. 1), to aggregate its prey and facilitate movement of *R. temporaria* to winter habitat in stream bottoms. We focus on 16 forest ponds, excavated during 2002–2003. In late spring 2011 we determined the presence of amphibian larvae (with 10 sweeps of a triangular net of 40 cm side and 1.5 mm mesh), sampled macroinvertebrates (3×5 seconds in different parts of the pond, using a 17×19 cm, 0.5 mm mesh D-frame net) and determined the characteristics of the ponds. In addition, 8–10 of these ponds were surveyed for amphibian spawn in April of 2010–2012. We measured water depth in the middle (mean of three measurements), pH (using a Lutron PH-212 meter), and proportions of surface in shade and of different bottom substrates (estimated visually by the same person).

Similar procedures were used for other, natural, water bodies, some of which were artificial but not created specifically as wildlife habitat, sampled in May 2012 along 10 km of transects (eight transects, stratified by landscape units, with random starting points and in cardinal directions; Fig. 1). We mapped all water bodies that were >1 m^2 on a 4-m wide transect strip or >3 m^2 on a 10-m wide transect, and dip-netted in each of them for amphibians. In water bodies ≥ 15 cm deep or ≥ 100 m^2 in size we also dip-netted for macroinvertebrates. To avoid pseudoreplication we treated similar adjacent water bodies as one and collected no more than five samples per km; this resulted in a total sample of 13 water bodies along five transects. As for the (re)constructed ponds there was a total of 15 seconds of sampling in each.

We used a rapid assessment strategy for identification of macroinvertebrates. We determined all species of Clitellata, Gastropoda, Araneae, Amphipoda and Odonata of later developmental stages; remaining individuals were identified to family. We tested for difference in family-level composition between the (re)constructed ponds and other water bodies using multi-response permutation procedures (Sørensen dissimilarity), and distinguished the taxon groups contributing to that difference using indicator species analysis (Dufrêne & Legendre, 1997) in *PC-ORD v. 6.07* (McCune & Mefford, 2011). To establish differences in habitat characteristics we used Mann–Whitney *U* tests with the Bonferroni correction.

All 10 (re)constructed ponds surveyed in April were used by brown frogs for breeding at least once during 2010–2012. Mean average occupancy was 82% for *R. temporaria* and 10% for *R. arvalis*. In nine of the ponds we found tadpoles during late spring searches in 2011. Other breeding amphibians included common newt *Lissotriton vulgaris* (in six ponds; adults additionally in five ponds) and common toad *Bufo bufo* (in one pond). We found brown frogs breeding in only two of the other water bodies (a ditch and a wheel-rut pool).

The (re)constructed ponds contained more sand/clay on the bottom and were deeper, less acidic and less shaded than

TABLE 1 Characteristics of the 16 (re)constructed ponds and 13 other water bodies (Fig. 1), and Mann–Whitney *U* tests for differences.

Water body characteristics	Mean, (re)constructed ponds	Mean, other water bodies[1]	*U*	P
Peat & mud (% of bottom)	21	32	75	0.215
Sand & clay (% of bottom)	44	6	34.5	0.001*
pH	6.9	5.9	42	0.006*
% surface in shade	33	60	49	0.015*
Depth (cm)	98	17	8	<0.001*

[1] Weighted by macroinvertebrate sampling duration.
*Statistically significant after Bonferroni correction.

the other water bodies (Table 1). Macroinvertebrate assemblages differed significantly between the (re)constructed ponds and other water bodies (multi-response permutation procedure: $A = 0.09$, $P < 0.001$). Twenty-three families recorded in the (re)constructed ponds were not found in the other water bodies, and eleven families were significantly more common in the (re)constructed ponds (indicator species analysis; Supplementary Table S1). Dragonflies and damselflies were found only in the (re)constructed ponds, including two species of European conservation concern: *Aeshna viridis* (Sahlén, 2006) and *Nehalennia speciosa* (Bernard & Wildermuth, 2006). (Re)constructed ponds appeared generally more suitable for the taxa requiring semi-permanent or permanent water, such as the water spider *Argyroneta aquatica*, hemipterans, and several species of pulmonate water snails. The assemblages in the other water bodies contained more hydrophilous terrestrial taxa, such as land snails (some of which were possibly captured from emergent vegetation) and mosquito larvae (Culicidae).

These observations suggest that habitat engineering for a threatened charismatic carnivore also created habitat for less conspicuous species. The taxon groups that appeared to benefit from the creation of ponds were uncommon in the surrounding forest landscape, which had been impoverished by long-term drainage, and some of these species are of wider conservation significance. Although the (re)constructed ponds served their primary aim (concentrating amphibians near mink habitat and thus probably improving critical winter food for mink) there were probably too few of them to significantly increase amphibian numbers at the scale of the island. However, the functioning of the ponds as novel habitat for macroinvertebrates of semi-permanent water bodies provides additional motivation for such conservation activity. The few other studies of this issue suggest that a range of other techniques can support biodiversity in anthropogenic landscapes: supplementary feeding (Martín-Vega & Baz, 2011), nest-site provisioning (Heneberg, 2012) and, possibly, the control of exotic predators (O'Donnell & Hoare, 2012) and diseases.

The cost-effectiveness of the management of charismatic species can be increased by explicitly and routinely considering positive and negative impacts on wider conservation targets at both the planning and assessment stages. In addition to monitoring, this should include a critical assessment of the management techniques used and of the alternatives (see also Koper & Schmiegelow, 2006). For example, a habitat-based alternative to increase the amphibian populations in Hiiumaa would have been large-scale blocking of artificial drainage (H. Drews, pers. comm.), with possibly even wider benefits for other aquatic biota, including the European mink (Fournier et al., 2007).

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Biographical sketches

Liina Remm studies the impacts of forest drainage and logging on biodiversity, especially on snails and other macroinvertebrates. Asko Lõhmus has a wide range of research interests in conservation biology, sustainable forest management and wildlife–habitat relationships. Tiit Maran has been leading in situ and ex situ European mink conservation projects for more than 2 decades.