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Amphibians in drained forest landscapes: Conservation opportunities for commercial forests and protected sites

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ABSTRACT

Forest drainage has led to the loss of a considerable number of wetlands, especially in the northern hemisphere. In order to find ways to mitigate the loss of biodiversity in drained forests, we investigated two distinct conservation measures: (i) leaving drained peatlands for natural succession, i.e. protecting without active restoration, and (ii) constructing a variety of mitigation pools during ditch maintenance work in commercial forests. We tested the effectiveness of these conservation approaches for wetland biota, selecting brown frogs (*Rana arvalis*, *R. temporaria*) as our focal species. We found that ditches do not substitute natural floods as breeding habitats for brown frogs in protected peatlands. One of the main reasons was the reduction of sun exposure due to drainage-induced forest growth. However, secondary wetlands formed on ditches impounded by Eurasian beaver (*Castor fiber*) offered high quality reproduction sites for brown frogs. In commercial forests, the number of natural pools decreased due to ditch maintenance work, but the colonisation rate of brown frogs increased in cleaned ditches. The reproduction site selection of the two frog species differed – *R. arvalis* bred mainly in natural and constructed pools, while *R. temporaria* bred more frequently in ditches. Among mitigation pools, those with a shallow littoral zone were primarily used for breeding. Thus, the conservation measures are effective only if certain key assumptions are met. The success could stand on the considering of the habitat requirements of target species before creating mitigation habitats or presence of a restoration agent (like beaver) in protected sites modified by human activities.

1. Introduction

Estimates show that as of 2009 at least 33% of global wetlands have been lost (Hu et al., 2017)—primarily due to increased land usage for agriculture (Van Asselen et al., 2013). However, that is not the case for all wetlands. Northern temperate and boreal wetlands have been largely drained for forestry: about 15 million ha; mainly in Fennoscandia, Russia, the British Isles, and in the Baltic States (Paavilainen and Päivänen, 1995). Forest drainage is usually conducted by straightening the natural streams and digging open ditches whereas in agriculture underground drains are used. The aim of the forest drainage is to foster timber production, to enable tree regeneration in harvested sites, and to improve access to the stands. The replacement of open, or semi-open, wetland mosaics with linear ditch-networks leads to the transformation of hydrological and disturbance regimes, a reduction of the area and depth of peat soils, changes in the tree stand structure and composition, and the pollution of downstream waters (Lõhmus et al., 2015; Paavilainen and Päivänen, 1995). In order to halt or prevent the loss of drainage-sensitive biodiversity several approaches have been used: the establishment of protected areas, the restoration of degraded wetlands and streams, the cessation of new ditch networks, and the implementation of sedimentation ponds and overflow fields to capture suspended solids eroded from ditch banks (Remm, 2015).

The scarcity in the number of fully intact wetlands has led to the incorporation of drained or partly drained wetlands into protected areas. For example, in Finland 0.4% or 50,000 ha of currently protected peatlands had been historically drained (National peatland strategy working group, 2011). Secondary succession may seem to offer a low-cost approach for wetland recovery as the deterioration of ditches starts right after digging (Silver and Joensuu, 2005). Despite this, the spontaneous reversion of drained ecosystems back into their original state is improbable due to irreversible changes in soil and biota; they are not favourable habitats for most wetland specialist species (Lõhmus et al., 2015).

Beavers offer another solution, as they are often considered agents of wetland restoration (Law et al., 2017). Their activity in watercourses favour species associated with lentic habitats, while concurrently disfavouring lotic species (Janiszewski et al., 2014; Stevens et al., 2007).

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Forest drainage ditches are highly preferred habitats for Eurasian beaver (*Castor fiber*), presumably because of the abundant woody vegetation (their main winter food) and the shape of the canals, which enables relatively easy creation of deep pools by damming (Ulevičius et al., 2011). In forest drainage ditches we have noticed similar ecosystem engineering impacts, as shown in other watercourses, but detailed biodiversity studies from those systems are lacking to our knowledge. Passive restoration in drained and protected wetlands through beaver populations could optimize the targeting of conservation budgets, but a deeper understanding of this possibility needs to be reached.

In drained commercial forests natural pools and streams have been largely replaced with ditches (Remm et al., 2015b; Suislepp et al., 2011). Periodic ditch maintenance is done to keep the ground water table low (Ahti and Päivänen, 1997). Some studies exploring these effects have shown a decrease in watercourse and the landscape-scale biodiversity of fish (Rosenvald et al., 2014). Studies have also found that amphibians may find these ditches, as well as other novel anthropogenic water bodies, attractive (Johnson et al., 2016; Remm et al., 2015b). Some mitigation measures for wetland biodiversity (e.g., construction of pools and enlargement of ditches) may also be applicable in drained commercial forests (Suislepp et al., 2011; Rosenvald et al., 2014); though, the efficiency of these measures need further testing (Remm et al., 2015a).

In this study we aimed to evaluate the effectiveness of two conservation techniques for drained forest areas: (i) leaving the area for natural succession and (ii) constructing mitigation pools during ditch maintenance work. The first technique was tested in historically drained but currently protected peatlands that encompassed sites with beaver activity. We used the space-for-time method to explore whether the ditches (with or without beaver dams) can substitute natural floods. The second technique was evaluated in commercially managed forests with an experimental study to specifically examine: (i) the impact of ditch maintenance on breeding conditions of brown frogs and (ii) the efficiency of constructed separate pools and ditch enlargements in mitigating the potential negative impact of ditch cleaning. The brown frogs involved two species with similar ecology: the moor frog, *Rana arvalis* and the common frog, *R. temporaria*. We chose brown frogs as the focal species of the study, because they are widespread, wetland dependent anurans that quickly colonize new suitable habitats (Soomets et al., 2017).

2. Methods

2.1. Study area and data collection

Our study was conducted in eastern Estonia, hemiboreal vegetation zone (Ahti et al., 1968), where the mean air temperature is 17 °C in July and −5 °C in January; the average precipitation is 700 mm yr^{-1}. The topography of Estonia is mostly of glacial origin: flat with undulating moraine plains as well as glaciolacustrine plains with abundant clayey deposits and extensive postglacial paludification. A large-scale systematized drainage was carried out between the 1950s and 1980s that resulted in approximately 723,530 ha of drained forestland (Register of the Melioration Systems of Estonia). Today, almost all paludifying forests and 82% of peatland forests have been drained (Ilomets, 2005) and approximately 45% of protected peatlands (including both forested and open mires) have been impacted by drainage (Action plan for protected peatlands, 2015). Although the construction of new drainage systems is prohibited in state forests (Forest Stewardship Council (FSC) certification scheme), existing ditches are periodically cleaned to maintain the growth of the stands. This entails removing brushwood and sediments from old ditches and, if necessary, digging new supplementary ditches. Brown frogs are a nationally protected species in Estonia and are also listed in annexes of the EU Habitats Directive. Nevertheless, both species are still common in Estonia (Adrados et al., 2010), thus restrictions for colonisation are not expected.

This study examined the impact of drainage in protected areas at the margins of four raised bog complexes in north-eastern Estonia (Fig. 1). We surveyed eight flooded sites in natural transitional mires (undrained or very slightly drained) and 13 beaver-impoundments on ditches in former lagg-areas. For these two types of sites we chose comparable sites in drained peatland forest, based on the soil type (undrained mires were situated mostly on mesotrophic; beaver sites on eutrophic peat)

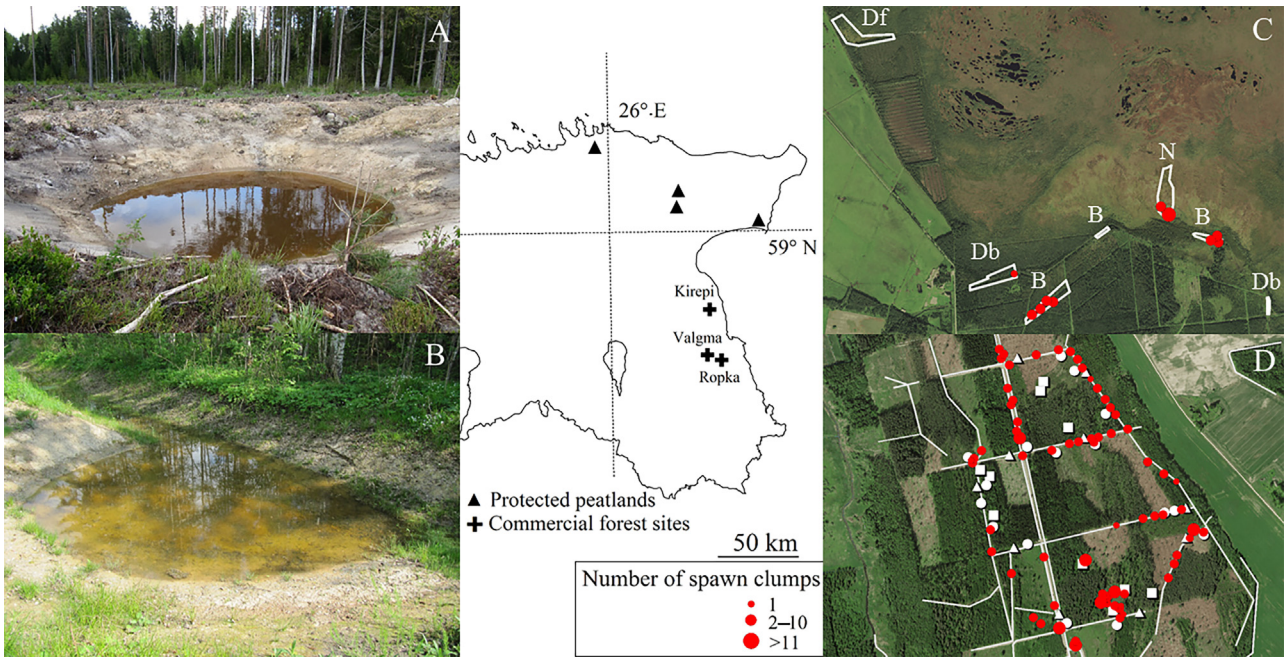

Fig. 1. The location of study areas in Estonia. Examples of mitigation pools (A, B), landscape overview at a bog margin (C), and a commercial forest site (D). A: a pool without a shallow littoral zone where we did not detect amphibian breeding attempts. B: a shallow ditch enlargement, where we detected brown frog and smooth newt breeding. C: the locations of spawn clumps in natural fen (N) and drained fen sites (Df); beaver-impounded ditches at laggs (B) and normal ditches at laggs (Db). D: the location of mitigation pools (white circles), sampling places in natural pools (rectangles), and ditches (triangles on the white lines) in the Valgma study site.