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Spatiotemporally variable management by grazing and burning increases marsh diversity and benefits amphibians: A field experiment

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ABSTRACT

Ecosystem management often aims to maintain a diversity of habitats to benefit a large number of species within a landscape. We studied the effects of wetland management by low-intensity cattle-grazing and late-summer burning on marsh vegetation and globally declining anuran amphibians (frogs and toads) in a previously homogeneous reedbed. Burning effectively removed old reed and increased the variability of reed cover and marsh vegetation by the next spring. However, reed grew back strong in areas burned 2 or 3 years before the study, indicating that fire rejuvenates reedbeds. In contrast, cattle-grazing kept reed cover homogeneously low and created open water surfaces. The number of amphibian species and individuals decreased with mean reed cover and old reed density, and increased with variability in reed cover. Correspondingly, amphibian richness and counts were greatest in newly burned areas the next spring. In contrast, a year later, richness and counts were greatest in grazed-only areas, with large decreases in newly burned and control areas. Our results suggest that combined management with grazing and burning can create different habitat patches, some of which will be optimal for amphibians in one year, whereas other patches may become suitable in a subsequent year when successional changes alter previously optimal patches. To maximise optimal habitats, mosaic management should repeat burning once every 2 or 3 years in a rotational manner, and also maintain low-intensity cattle-grazing, which controls reeds and benefits amphibians more sustainably. Our study supports spatiotemporally varied management to facilitate habitat heterogeneity and complexity in dynamic landscapes.

1. Introduction

One of the most important principles of ecosystem management is to create and maintain a diversity of habitat types within the landscape to maximise species diversity (Christensen, 1997). Ideal ecosystem management should mimic natural disturbance regimes as far as possible because these enable the maintenance of ecological integrity and near-natural ecological processes in dynamic ecosystems (Mori, 2011). Management, when considered as disturbance, can be characterised by its type, temporal frequency, duration, spatial extent and local intensity or specificity (White et al., 1999). The optimal implementation of management requires knowledge of the necessary intensity of disturbance in time and space in light of the resiliency of the ecosystem to be managed (Groom et al., 2006). Ecological theory suggests that species diversity is maximised when ecological disturbance is at intermediate levels in terms of temporal frequency, spatial extent and local intensity (intermediate disturbance hypothesis or IDH, Connell, 1978). Despite the overall relevance of the IDH to ecosystem management (e.g. McCabe and Gotelli, 2000; Schwilk et al., 1997), intermediate levels of disturbance are rarely known. It is therefore essential that we know the optimal levels of frequency and spatial extent of habitat management if we are to increase habitat diversity to provide for as many species as possible and to mimic natural ecosystems as far as possible. When ecological disturbance is at low levels compared to historically occurring natural disturbances, biotic homogenisation occurs, leading to decreasing species diversity (Lockwood and McKinney, 2001). For instance, in many temperate wetlands, when disturbance by grazing/trampling, mowing, cutting, flooding or burning is absent, habitats often become homogeneous in character and physiognomy due to the spread of Common Reed (*Phragmites australis*), a process that can be detected both at the local and landscape scales (Lougheed et al., 2008). In such cases, management should be directed at mimicking natural disturbances. Spatiotemporally variable management may break up habitat homogeneity, leading to more heterogeneous habitat structure and a range of habitat types accessible for a wider pool of species (Christensen, 1997; Wiens, 1997). Spatiotemporally variable management by grazing and prescribed fire leads to heterogeneous habitats in

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temperate grasslands (Fuhlendorf and Engle, 2001; Hartnett et al., 1996; Vinton et al., 1993) and in wetlands (Mérő et al., 2015).

The global decline of amphibians presents a major challenge in conservation and natural resource management (Nyström et al., 2007; Pittman et al., 2014; Stuart et al., 2004). One of the main reasons for the decline is the loss, fragmentation and degradation or pollution of freshwater wetlands (Cushman, 2006; Dodd and Smith, 2003; Van Den Bos and Bakker, 1990), which also are important centres of biodiversity for plants and animals other than amphibians (Zedler and Kercher, 2005). The restoration and management of freshwater wetlands have thus become an urgent and global priority in conservation (Bobbink et al., 2006; Schweiger et al., 2002). Despite the increasing attention to the restoration and management of freshwater wetlands (Wagner et al., 2008), we know little of the appropriate spatiotemporal allocation of management (Ausden et al., 2005; Perry et al., 2012) and of the impact of such management on amphibians (Smith and Sutherland, 2014). Habitat management for amphibians includes creating or restoring breeding ponds, increasing the connectivity between ponds, and establishing and maintaining shallow open water habitats by grazing or fire management (Bisson et al., 2003; Hazell et al., 2004; Pilliod et al., 2003). Although there is a growing body of knowledge on how controlled and natural fires affect amphibian communities, the issue is far from settled due to the complexity of species-specific effects that depend on the local habitat structure and populations (Hossack and Corn, 2007). Short-term negative effects include increased solar and UV-B radiation, high surface temperatures, aridification, and increased predation (Pilliod et al., 2003). In contrast, some studies reported minor negative effects, mostly at mid to long-term time intervals, such as the maintenance of mosaic habitat structure and landscape heterogeneity (Perry et al., 2012; Russell et al., 1999). Amphibians have various behavioural and physiological adaptations that enable them to survive the direct effects of burning in wet habitats. Open water surfaces and unburned wet patches provide refuges for amphibians during burning, whereas underground burrows can also protect them from fires (Pilliod et al., 2003; Roznik and Johnson, 2007; Russell et al., 1999). Bufonids and Pelobatids also may show an evolutionary adaptation to escape fire by digging burrows (Nomura et al., 2009), whereas hylid frogs are known to avoid an approaching headfire by detecting its crackling sounds (Grafe et al., 2002).

Although livestock grazing can benefit amphibians by removing vegetation from shallow waters, several studies found that amphibians are negatively affected by grazing (Burton et al., 2009; Hoverman et al., 2012; Jansen and Healey, 2003). However, these studies were conducted in forest and grassland ponds and we know little about the separate or combined effects of grazing and fire management on amphibians in marshes and reedbeds. The combined effects of grazing and burning have been studied only in grasslands of northern Argentina (Cano and Leynaud, 2009). All other studies of wetlands followed only one management action and focused on plants or invertebrates (Ausden et al., 2005; Ditlhogo et al., 1992; Hardman et al., 2012; Schmidt et al., 2005), likely because the restored/managed areas were too small (under 1 ha) to evaluate the impacts of disturbance on taxonomic groups such as vertebrates (Wagner et al., 2008). It is thus not surprising that a recent meta-analysis of European studies on the effects of reedbed management on wildlife found no study of amphibians (Valkama et al., 2008).

In this study we examine whether and how spatiotemporally variable management by low-intensity cattle-grazing and prescribed late-summer burning of reedbeds affect reed habitats and anuran amphibians (frogs and toads). Grazing and burning were conducted to increase the diversity of marshes that had become homogeneously overgrown by Common Reed due to invariable management (constant water supply and winter reed harvesting) in the past. In a unique large-scale field experiment (Mérő et al., 2015), we quantified reed cover, plant species richness, anuran species richness and counts over two years to address five questions: (i) Does management reduce reed cover, influence vegetation structure and increase the diversity of habitats? (ii) Do changes in reedbed properties due to management benefit anuran amphibians? (iii) Is there a direct link between management and benefits to the amphibian community? (iv) Do grazing and burning differ in their impacts on the reed habitats and on amphibians? (v) Does management intensity influence anuran species richness and counts?

2. Materials and methods

2.1. Study area

The experiment was implemented in Fekete-rét (N47°33′38.60″, E20°56′4.07″; 88 m a.s.l.), the largest (600 ha) alkali marsh in the Egyek-Pusztakócs marsh and grassland system (EPMS, 4073 ha). The entire EPMS is included in the Natura 2000 network, is an Important Bird Area in Europe, is listed in the Ramsar Convention on Wetlands of International Importance and is a World Heritage Site as part of Hortobágy National Park (E-Hungary) (Aradi et al., 2003). Paleoecological studies indicate that the region was frequently burned by wildfires in pre-human times and that these fires were important in maintaining the open steppe and wooded steppe landscape prior to the appearance of pastoralism c. 1000 yrs B.C., which led to a further increase in open habitats (Magyari et al., 2010). The area was an active floodplain of the Tisza river until its regulation in the 1850s. Military maps from 1855 to 1866 and aerial photographs from 1959 to 1965 (Fig. S1) show the marsh as a complex of open water surfaces, bare alkali shorelines, and small patches of bulrushes (*Typha* spp.) and reed in the lower-lying parts of the marsh (Aradi et al., 2003). Low vegetation cover was maintained by extensive grazing by cattle and sheep. For example, in the eastern Hortobágy region, the area covered by reed was 0.04% in 1892, which increased to more than 2% by 1975 with the decline of grazing (Tóth, 2003). The marshes were drained and became completely dry by the early 1970s. In the first and largest (>4000-ha) habitat restoration programme in Hungary (1976–1997), a new water supply system was built that again brought water from the Tisza river to the marshes, which have recovered spectacularly. However, a constant water supply and intensive winter reed-harvesting led to the establishment of homogeneous reedbeds by the mid-2000s. Reed management by cattle-grazing and burning was implemented between 2006 and 2009 as part of a landscape-scale rehabilitation project (Lengyel et al., 2012) (http://life2004.hnp.hu).

2.2. Marsh management by cattle-grazing and prescribed burning

Management aimed to increase the diversity of marsh habitats by creating openings in homogeneous reedbeds to ultimately recover the mosaic structure of habitats that once characterised the area. Based on historical land use and previous experience elsewhere (Aradi et al., 2003; Kelemen, 2002), cattle-grazing and burning were chosen for reedbed management. Paleoecological studies and accounts from shorter time scales indicate that both these disturbances were part of the ecosystem's evolutionary history (see above). To mimic natural disturbances (grazing by large herbivores and wildfire) as closely as possible, cattle were free to roam and fire was not contained within the southern half of the marsh (Fig. S2). Grazing infrastructure was established in the SW part of the marsh in early 2006. Grazing was conducted between April and November each year between 2006 and 2011 by 180 head of Hungarian grey cattle, an ancient breed highly suitable for marsh management as they consume reed even in deep (up to 1.5 m) water (Kelemen, 2002). Cattle regularly used 200 ha of the marsh and c. 100 ha of meadows and grasslands surrounding the marsh; grazing pressure was thus 0.6 livestock units (LUs) per hectare.

Prescribed burning was implemented by professional firefighters and national park rangers early in September 2007 and 2009 (Fig. S3). This is the peak flowering period of the reed plant, and we predicted