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Amphibian diversity in farmlands: Combined influences of breeding-site and landscape attributes in western France

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ABSTRACT

Agricultural intensification is responsible for major habitat degradation and is a primary cause of biodiversity loss. Amphibians are currently facing a global decline induced by multiple pressures, including notably habitat degradation and land conversion. In western Europe, traditional farming systems involve a dense hedgerows network with a mosaic of pastures, cultivated fields, ponds, and small woods. These heterogeneous landscapes are particularly favorable for biodiversity but their role for amphibian conservation remain understudied.

We studied the amphibian community (15 species) of a hedgerow network landscape in western France. We described 79 cattle ponds and tested the influence of ponds characteristics as well as the surrounding landscape composition on species occurrence. Amphibian diversity was positively influenced by breeding site vegetation and also ponds density in the surrounding landscape. We also found positive effects of wood patches and hedgerow linear at a small spatial scale. In turn, crop cover and road linear negatively influences amphibian richness at a large spatial scales. Important variation were detected among species reflecting contrasted life history traits. Our results underline that traditional pastoral landscapes provide a high density of breeding site and habitats favorable for a diversity of amphibian species.

1. Introduction

Habitat loss and degradation are the primary causes of biodiversity decline associated to the Anthropocene (Potts et al., 2010; Tscharntke et al., 2005; Vitousek et al., 1997). Understanding the impact of land use on biodiversity is therefore a key conservation issue (Foley et al., 2005; Newbold et al., 2016). A major impact of human land use results in habitat fragmentation and the altered functional connectivity between habitat patches (Wiens, 2009). Reduced connectivity is known to alter organisms movements, gene flows, and in turn affects population dynamics (Crawford et al., 2016). Landscape heterogeneity is important and recent studies have demonstrated that biodiversity responds to both landscape composition and configuration (Collins and Fahrig, 2017; Duflot et al., 2017). Meanwhile, biological functions such as reproduction may depend on specific microhabitat features that condition species persistence (Botzat et al., 2013; Smith et al., 2017). Therefore it is critical to combine multiple spatial scales (from microhabitat to landscape) to understand the effects of anthropic disturbance on biodiversity patterns (Humphrey et al., 2015; Razgour et al., 2011).

Farmlands represent a vast surface area of the planet, and agricultural landscapes consist of a variety of land uses where natural and anthropized habitats are interspersed. The intensification of agricultural practices is observed at a global scale (Foley et al., 2005; Matson et al., 1997) translating to habitat loss, reduced landscape heterogeneity, and altered connectivity (Stoate et al., 2001). A massive decline in farmland biodiversity has been reported (Krauss et al., 2010; Robinson and Sutherland, 2002) and understanding the role of agrosystems for biodiversity conservation is now of critical importance (Fahrig et al., 2011). Amphibians are currently facing a global decline both in natural and anthropized habitats (Collins and Storfer, 2003; Stuart et al., 2004). Most amphibian species depend on aquatic habitats for breeding and larval development but also on the surrounding landscape for the terrestrial phase (Quesnelle et al., 2015). Due to this dual life cycle, amphibians are particularly sensitive to habitat structure and thereby offer a relevant group for studying the impact farming practices intensification on biodiversity (Collins and Fahrig, 2017).

In western Europe, traditional hedgerow landscapes consist of networks of linear structures (i.e. hedgerows) and mosaic of pastures, cultivated fields, ponds, and small woods (Burel and Baudry, 1995). These landscapes offer an extreme level of imbrication between natural

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and anthropized habitats and diversity of contact zones (ecotones) and corridors (Baudry et al., 2000; Bennett, 1998). Hedgerow landscapes are favorable to a vast diversity of organisms with contrasting ecological affinities including both vertebrates and invertebrates (Boughey et al., 2011; Hinsley and Bellamy, 2000; Michel et al., 2007; Ouin and Burel, 2002). However, they have been profoundly affected by the intensification in land use since World War II (Robinson and Sutherland, 2002). Changes in farming practices have resulted in a dramatic increase in field size (Tscharntke et al., 2005), the replacement of permanent pastures with croplands (Robinson and Sutherland, 2002), the removal of wetlands and ponds (Wood et al., 2003), and increased pollutions (Stoate et al., 2001). A synchronic decline has been reported in biodiversity and notably birds population, in relation with hedgerow loss (Chamberlain et al., 2000; Cornulier et al., 2011). Heretofore only few studies have investigated the impact of hedgerow network landscape degradation in amphibians (Boissinot, 2009).

The determinants of amphibians richness attracted considerable interest either in natural (Quesnelle et al., 2015), agricultural (Collins and Fahrig, 2017) or urban landscapes (Hamer et al., 2015). The quality of breeding sites is a critical aspect because it directly supports reproduction (Arntzen et al., 2017; Wells, 2007). Because of limited ground mobility, surrounding habitat structure will constraint amphibians movements and activity (Semlitsch and Bodie, 2003) with important variation among species depending on their vagility (Hillman et al., 2014; Koumaris and Fahrig, 2016). The density of breeding habitat is also essential because it is related to functional the connectivity with terrestrial habitat (Ribeiro et al., 2011; Wells, 2007). A number of studies demonstrated that species richness is influenced by both breeding habitat and landscape structure (Cushman, 2006; Van Buskirk, 2005). These effects are not restricted to species richness, but also involve population dynamics and gene flow (Angelone et al., 2011; Cushman, 2006). Overall, increasing human activities have multiple impacts on amphibians including habitat loss, altered connectivity but also increased mortality from road traffic or pesticide use (Arntzen et al., 2017; Bokony et al., 2018; Jackson and Fahrig, 2011).

We studied amphibian occurrence in 79 ponds in western France in a traditional hedgerow farmland landscape characterized by a mosaic of habitat and land use. Given the importance of aquatic habitat for reproduction and because the study site is still well preserved, we hypothesize that species richness should primarily depend on breeding-site attributes (Hartel et al., 2010). A progressive transition towards crop farming is occurring in the area (Gamache, 2006). Therefore the occurrence of amphibians should also depend on landscapes attributes and notably be favored by typical hedgerow landscape features that reflect high habitat connectivity and breeding site availability. The structure of each pond (depth, surface, vegetation cover, mud depth) as well as the surrounding landscape (8 concentric buffers from 100 to 3000 m) were described to test the following predictions:

1) Species richness should be positively influenced by pond vegetation cover that provides multiples benefits for reproduction and against predation
2) Hedgerow landscape features (high pond density, wood cover and hedge linear) should positively influence species richness. In turn crop farming and road density should have a negative impact on amphibian diversity
3) The contribution of local (breeding site) and landscape attributes should vary among taxa reflecting contrasted breeding requirements and mobility.

2. Materials and methods

2.1. Study area

The study was conducted in Gâtine Poitevine, in the northern part of Deux-Sèvres department in western France. This area is mainly composed of traditional hedgerow farmlands (54% of land use). The landscape is a mosaic of pasture for cattle and sheep grazing and cultivated fields delimited by hedges. The most distinctive aspect of this agrosystem is a dense network of hedgerows (average density of 140 m/ha) that are connected by wood patches (surface ranging from 0.01 to 416 ha) and a high density of cattle ponds (total number > 5000, average density 3.5/km^2) (Boissinot, 2009). This traditional landscape has been affected by the intensification in land use (Gamache, 2006) and 27.5% of hedgerows were removed between 1950 and 2002 in this region (Boissinot, 2009). In the study area, 15 amphibian species (10 Anurans and 5 Urodeles, see Table 1) are present (Thirion et al., 2002).

Table 1
Species distribution in the 79 agricultural ponds.

Species	Number of positive ponds	Proportion (%)
Anourans:		
Alytes obstetricans	2	2.53
Bufo spinosus	7	8.86
Epidalea calamita	0	–
Hyla arborea arborea	59	74.68
Pelodytes punctatus	0	
Pelophylax kl. *esculentus*	48	60.76
Pelophylax lessonae	10	12.66
Pelophylax ridibundus	47	59.49
Rana dalmatina	66	83.54
Rana temporaria	0	–
Urodeles:		
Salamanda salamandra terrestris	17	21.52
Triturus marmoratus	59	74.68
Triturus cristatus	5	6.33
Hybrid marmoratus x cristatus	1	1.27
Lissotrition helveticus	74	93.67

2.2. Pond selection and sampling method

We selected 79 cattle ponds with contrasted structural features (4 descriptors) and landscape attributes (5 variables). Pond surfaces area varied from 37.84 to 537.6 m^2 (mean = 217.46 m^2) and the water depth from 0.5 to 2 m (mean = 1.44 m). The ponds were selected without previous information on the presence of amphibians. We excluded ponds harboring fishes as they negatively affect the amphibians community (Denoël et al., 2005; Hartel et al., 2007; Hecnar and M'Closkey, 1997). We monitored each pond over three nocturnal surveys between March and June 2007, which encompassed most species breeding period. Each survey was separated by one month on average and combined three methods to detect amphibians. First, an acoustic monitoring was conducted over 5 min at a distance of 5 m from the pond. This method is effective for detecting most male Anurans species through their breeding calls (Pellet and Schmidt, 2005). Second, a close visual inspection of the pond banks was carried out using an halogen light (100 W). The number of observed individuals was recorded for each species, as well as the presence of Anuran egg masses. Finally, we carried out direct sampling using a fishing net with a 4-mm mesh size, allowing to capture adults as well as larvae and tadpoles of the different species. For each visit, a total of 15 consecutive net sweeps were carried out per pond. The combination of these three methods is widely used to study amphibian communities (Ficetola and De Bernardi, 2004; Petitot et al., 2014). The three sampling visits allow detecting all species of a given pond with a high degree of confidence (Petitot et al., 2014; Sewell et al., 2010).

2.3. Breeding sites description

We considered four pond descriptors that show important variation in the area and therefore possibly influence the presence of amphibians as well as species richness. They included: a) percentage of aquatic