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Small woods positively influence the occurrence and abundance of the common frog (*Rana temporaria*) in a traditional farming landscape

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Abstract. Traditional farming landscape in western Europe is made of a complex mosaic of pastures, cultures, ponds and hedgerows connected with woods. Previous observations in the common frog species suggest that lowland populations are closely associated to wood cover and our aim was to test the validity of this assumption. We studied common frog occurrence and abundance in western central France (*Deux-Sèvres* department) close to the southern margin of lowland distribution. Our results pointed out that the proportion of woods surface around sampled areas (1 ha) was a critical determinant of common frog presence and abundance. Extensive farming, which maintains a mosaic of small woods, may provide a robust conservation tool for this species.

Keywords: agrosystem, amphibians, anuran, forest, habitat.

The intensification of agricultural and industrial practices is responsible for the major habitat loss or degradation currently observed at global scale (Tilman et al., 2001; Tscharntke et al., 2005). Additionally, habitat alteration is now recognized as the primary cause of species decline (Baillie, Hilton-Taylor and Stuart, 2004; Potts et al., 2010), including amphibians (Stuart et al., 2008). In western Europe, traditional farming system mixing livestock and crop has progressively shaped a specific landscape based on a network of linear structures, i.e. hedgerows (Baudry, Bunce and Burel, 2000). This anthropogenic habitat is made of a complex mosaic of small pastures, cultures, ponds, and hedgerows that are connected with small woods (Burel and Baudry, 1995). This spatial complexity and habitat diversity offers favorable conditions for many vertebrates and invertebrates species (Baudry and Jouan, 2003) including amphibians (Boissinot, 2010). Over the last decades, hedgerow landscapes have been strongly impacted by the intensification in agricultural practices resulting in the loss of hedges and scattered trees from farmlands as well as in draining the wet pastures (Pointereau, 2001; Robinson and Sutherland, 2002).

Amphibians are particularly exposed to agriculture intensification because of their complex life cycle that depends on both terrestrial and aquatic habitats quality and also because of their limited dispersion abilities (Smith and Green, 2005) that make them highly sensitive to the loss and fragmentation of the habitats (Stuart et al., 2008). The common frog (*R. temporaria*) has a wide distribution in western Europe (Kuzmin et al., 2009). It uses a wide diversity of habitat including bogs, pastures and woods and can reach high altitudes in the Alps and the Pyrenees (>2500 m). The ecology of the species is well understood including its habitat use (Johansson, Primmer and Merilä, 2006; Ludwig, Sinsch and Pelster, 2013), reproduction (Elmberg, 1991; Lardner and Loman, 2003; Neveu, 2009) and population fluctuation (Loman and Lardner, 2006; Blank, Luoto and Merilä, 2013). Recent works underline population decreases, especially in regions impacted by

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agricultural intensification and loss of woodlands and the increasing use of pesticides (Johansson et al., 2005; Vos et al., 2007; Brühl et al., 2013).

The common frog has been poorly studied at the Southern margin of its lowland distribution. This context is particularly relevant since important environmental constraints, especially in relation with water loss, may occur at this limit of its distribution range that may impact its habitat requirement (Köhler et al., 2011). It has been suggested that lowland populations are dependent on wood cover in western France (Lescure and De Massary, 2012) but this aspect has not been examined thoroughly. We studied the common frog occurrence and abundance in a hedgerow landscape complex in Deux-Sèvres department.

Our study was conducted in 2011 in the Deux-Sèvres department in western Central France. This area is characterized by contrasted agricultural practices based on a mix of livestock (mainly cattle and sheep) and crops (cereals). The study site is characterized by a temperate oceanic climate and the average altitude is 123 m. The most distinctive aspect of this farming landscape is a dense network of hedgerows (average 140 m/ha) that are connected with wood patches and a high number of ponds scattered in the landscape (average 3.5/km^2). The woodlands are typically represented by small patches (i.e. below 4 ha), the largest forest patches having up to 2500 ha. Ponds are very abundant (e.g. more than 15 000 inventoried in Deux-Sèvres, see Boissinot, 2010) and are used for breeding by 5 urodeles and 10 anurans species. However, the common frog uses almost exclusively temporary breeding habitats such as flooded pastures (Boissinot, 2010).

We sampled 96 areas (1 ha each) that were either known to be occupied by the common frog ($n = 56$) or selected from photo interpretation ($n = 40$) based on the presence of wetlands (Bd Ortho® 2008, IGN). Each area was prospected over 1 hour at two occasions in early January and early March, which encompasses the breeding period in our study area (Le Garff, 1998). During each survey we inspected for favorable breeding sites (i.e. temporary flooded pastures, flooded woods, flooded paths, flooded crops, temporary streams, ditches, ruts) were prospected to determine clutch occurrence and clutches number as an index of abundance (Cooke, 1985; Meyer, Schmidt and Grossenbacher, 1998; Loman and Andersson, 2007).

We analyzed the proportion of woods in the periphery of each 96 areas using concentric buffers (Ficetola, Padoa-Schioppa and De Bernardi, 2009; Hartel et al., 2010). We used 10 concentric buffers ranging from 100 to 1000 m radius and thus corresponding to surfaces ranging from 3.1 to 312.6 hectares (fig. 1). The buffer center was defined as the centroid of the prospected site. Maximal distance selected encompasses migratory and colonization displacements known in the species (Tramontano, 1997; Baker and Halliday, 1999). The wood proportion in each concentric buffer was extracted using ArcGIS 9.2® and topographic database BD Topo® 2010 (IGN). We used a Generalized Linear Model (GLM) to test the influence of landscape characteristics (wood proportion in each 10 concentric buffers) on the presence and the number of clutches (Hartel et al., 2010; Ficetola et al., 2011). Wood proportions were transformed (Arc-Sinus) to obtain normality. The probability of presence of the species was modeled using a GLM with binomial distribution (logistic regression). Variation in the number of clutches was analyzed in a GLM using a negative binomial distribution because the number of clutches showed large variation and thus was considered as overdispersed compared to what is expected with a Poisson distribution. We used Akaike's Information Criterion (AIC) to compare models (Burnham and Anderson, 1998) and we calculated Akaike weight (wi) for each model. All analyses were carried out using R 2.14.1 software (R Development Core Team, 2009) and MASS package (Venables and Ripley, 2002).

Clutches were detected in 76 of the 96 sampled areas. When *R. temporaria* was detected at the first visit it was always confirmed at the second one ($n = 68$). In eight areas, clutches were only found the second survey possibly reflecting clutches appearance. Detection probability of at least one clutch was estimated using a generalized linear model with binomial distribution. The modeled variable was the detection of at least one clutch on sites where egg mass was detected at least at one of the two visits. The detection probability was high (estimate = 0.94, CI = 0.89-0.97). The number of clutches per occupied areas greatly vary and ranged from 1 and 1093 (mean ± SD = 121 ± 209). Clutches were found in various breeding microhabitats including temporary flooded pastures (51.4%) but also flooded woods (16%), ditches and temporary streams (12.6% and 12%). These results are consistent with other observations in the west of France (Neveu, 2009; Grosselet, Gouret and Dusoulier, 2011).

We found a significant effect of wood surface on the species probability of occurrence (fig. 1A). Model comparison using AIC weight showed that 400 m radius was the best scale to explain species presence (AICwi = 0.57, table 1). The probability of occurrence was low

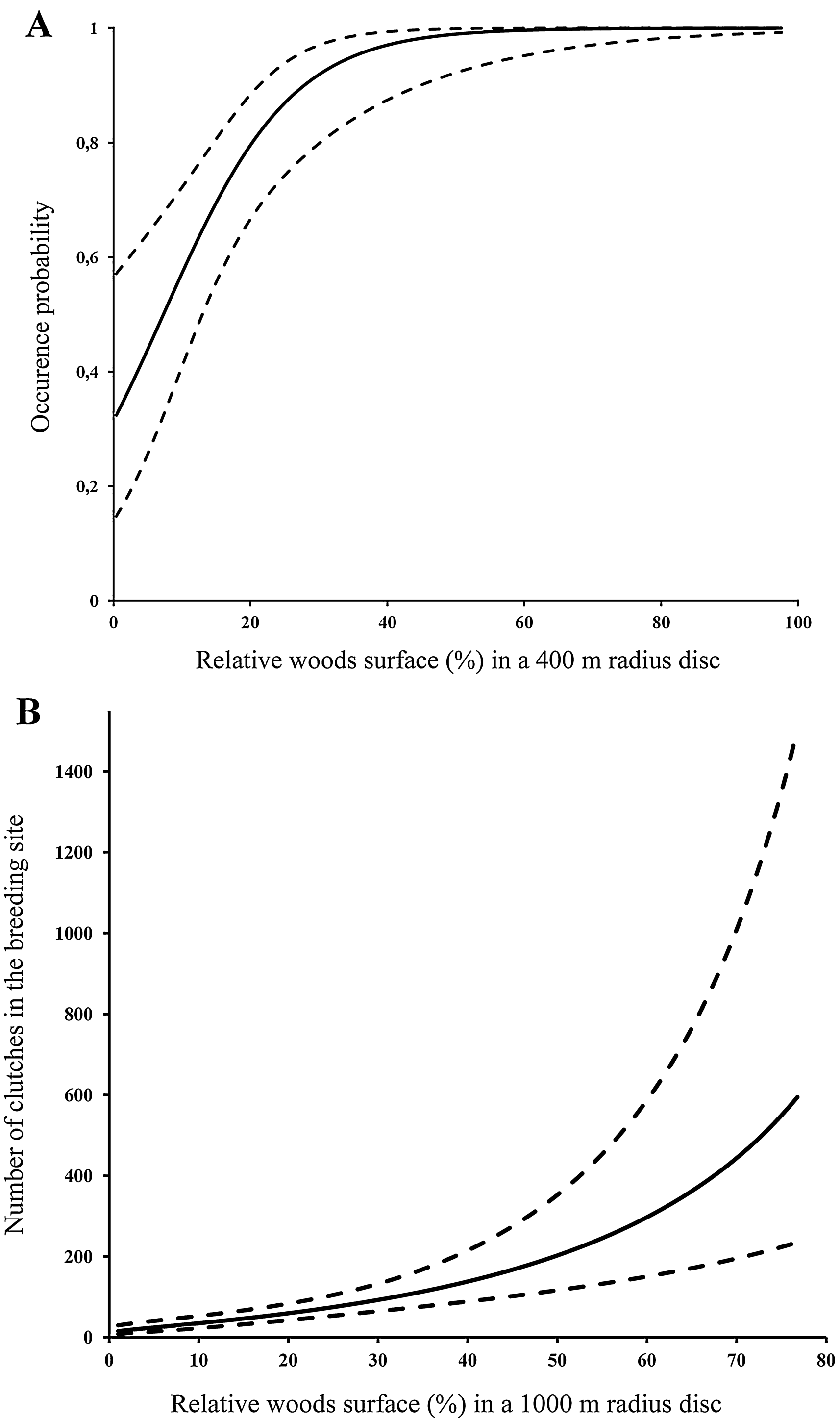

Figure 1. (A) Relation between common frog occurrence and relative woods surface (%) within a 400 m radius buffer from the sampled area. Plain line is the estimated slope; dotted lines are the 95% confidence interval of the estimated slope. (B) Relation between the number of clutches and relative woods surface (%) within a 1000 m radius buffer from the sampled area. Plain line is the estimated slope; dotted lines are the 95% confidence interval of the estimated slope.

Table 1. Models comparison for common frog occurrence and number of clutches depending on the size of the concentric disk (Wood) with radiuses ranging from 100 to 1000 m. The AIC difference (Δ AIC) to the best model and the AIC weights (AICwi) are given.

Occurrence	Δ AIC	AICwi	Estimate	Standard error
Wood_400	0.00	0.57	7.67	2.09
Wood_300	1.61	0.25	6.51	1.79
Wood_500	3.23	0.11	7.26	2.03
Wood_200	5.42	0.04	4.90	1.38
Wood_600	6.69	0.02	6.54	1.87
Wood_700	9.83	0.00	5.97	1.78
Wood_800	12.05	0.00	5.61	1.74
Wood_900	13.33	0.00	5.33	1.70
Wood_100	13.70	0.00	2.66	0.87
Wood_1000	13.71	0.00	5.27	1.69
Clutches number	**Δ AIC**	**AICwi**	**Estimate**	**Standard error**
Wood_1000	0.00	0.23	3.81	0.77
Wood_900	0.64	0.16	3.61	0.74
Wood_400	1.03	0.14	2.70	0.57
Wood_800	1.28	0.12	2.49	0.53
Wood_300	1.46	0.11	3.33	0.69
Wood_700	1.54	0.10	3.06	0.64
Wood_600	2.20	0.08	2.76	0.60
Wood_500	2.84	0.05	2.14	0.48
Wood_200	6.06	0.01	0.80	0.41
Wood_100	18.93	0.00	3.46	0.72

(0.3, CI = 0.15-0.57) when woods were absent in the 400 m radius buffer centered on the sampled area. In turn, the occurrence rapidly increased when wood surfaces was over 30% (i.e. 15 ha, see fig. 1A). When considering the number of clutches, a significant relationship was detected at multiple concentric scales ranging from 200 to 1000 m. Radiuses of 900 and 1000 m accounted for 39% of the AIC weights in the number of clutches (table 1). Model comparison indicated that a 1000 m radius was the best explanatory scale but the relative relevance in terms of AIC weights was closed for several models (table 1). The relation with woods surface was relatively strong (fig. 1B) and clutches number was 6 time higher when relative woods cover was 50% (mean = 208.57; CI = 118.80-366.18) versus 10% (mean = 35.02; CI = 23.09-53.12). Extreme variation in reproduction can occur in a given site (Meyer, Schmidt and Grossenbacher, 1998; Loman and Andersson, 2007) and this source of variability likely alters the quality of model as illustrated by the large confidence intervals of the regressions fitted on clutch abundances. Critical variables associated with the breeding habitats or the landscape may be important to address abundance variation (Denoël and Lehmann, 2006).

Our results underline the impact of wood surface on common frog presence in western France. The species is a cold climate specialist with an extended distribution and uses a high diversity of aquatic and terrestrial habitats (Kuzmin et al., 2009). The Northern and mountain populations are exposed to colder conditions and appear more ubiquitous using different terrestrial habitats, such as grasslands or lowland forests, alluvial valleys, pastures and mountain woodlands, bogs, parks and gardens. Aquatic habitats used are also more diverse in the north, east and the mountain zones including permanent alpine lakes, ponds, bogs and permanent streams for breeding (Kuzmin et al., 2009; Lescure and De Massary, 2012). In western France, the species seems more specialized and dependent on wood cover (Lescure and De Massary, 2012). This observation may reflect a shift of the realized niche along environmental gradient and higher specialization on the edge of the distribution as detected in other taxa (Oliver et al., 2009; Wasof et al., 2013; Silc, Lososova and Vrbnicanin, 2014).

Forest is a critical habitat for amphibians in a diversity of ecological systems including tropical environments or agricultural landscapes (Stuart et al., 2004; Cushman, 2006; Denoël and Ficetola, 2008; Ficetola, Padoa-Schioppa and De Bernardi, 2009). However, important interspecific variation exist and negative responses to woods proximity or surface have been documented as well as nonlinear effects depending on woods predominance or landscape configuration (Guerry and Hunter, 2002). Woods are often critical for foraging, migratory movement, or hibernation (Marty et al., 2005; Denoël and Lehmann, 2006) and also offer a diversity of shelters and microhabitats that buffer from temperature and hygrometric variations (deMaynadier and Hunter, 1995; Calhoun and Hunter, 2003). Amphibians are particularly exposed to evaporative water loss (Rothermel and Semlitsch, 2002) and this may be particular true for common frog in Southern lowland population. Such a physiological constraint may influence both movements and habitat use (Köler et al., 2011) and woodlands likely provide more suitable hygrometric and thermal conditions for this cold adapted species. The significant influence of woods on the number of clutches suggests that habitat has direct demographic consequences. Hartel et al. (2009) found that forest proximity positively influence clutch and egg mass in the agile frog (*R. dalmatina*).

The woodland dependence of the common frog reported here is particularly important to derive conservation policies since common species also needs special consideration (Gaston and Fuller, 2008). Our results suggest that mosaics of woods in patches of 50 hectares (400 m radius) are relevant to favor common frog populations. Particular attention should also be paid to the conservation of flooded pastures for reproduction. This habitat is particularly sensitive to the intensification of agricultural practices and notably drainage for crop conversion (Stoate et al., 2001). Extensive farming, which maintains mosaic of meadows, crops and woods, may therefore provide a robust conservation tool for this species.

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Appendix 1. Correlation matrix in woods covers for the different scales considered.

Radius	100 m	200 m	300 m	400 m	500 m	600 m	700 m	800 m	900 m	1000 m
100 m	1	0.93	0.83	0.76	0.72	0.67	0.63	0.59	0.56	0.54
200 m	0.93	1	0.96	0.91	0.86	0.81	0.77	0.73	0.70	0.68
300 m	0.83	0.96	1	0.98	0.94	0.90	0.86	0.82	0.78	0.76
400 m	0.76	0.91	0.98	1	0.98	0.96	0.92	0.88	0.85	0.82
500 m	0.72	0.86	0.94	0.98	1	0.99	0.96	0.93	0.90	0.87
600 m	0.67	0.81	0.90	0.96	0.99	1	0.99	0.97	0.94	0.92
700 m	0.63	0.77	0.86	0.92	0.96	0.99	1	0.99	0.98	0.96
800 m	0.59	0.73	0.82	0.88	0.93	0.97	0.99	1	0.99	0.98
900 m	0.56	0.70	0.78	0.85	0.90	0.94	0.98	0.99	1	1.00
1000 m	0.54	0.68	0.76	0.82	0.87	0.92	0.96	0.98	0.990	1

Appendix 2. Parameters estimates for the negative binomial model used to examine variation in clutches number (radius 1000 m).

Parameters	Estimate	Std. Error	z value	$\Pr(>\lvert z\rvert)$
Intercept	2.3177	0.4131	5.61	2.02E−08
covar[, i]	3.8107	0.7663	4.973	6.60E−07
Dispersion (Theta)	0.3627	0.0506		