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Historical agricultural changes and the expansion of a water vole population in an Alpine valley

Guillaume Halliez[a,b,c,d,*], François Renault[a], Eric Vannard[c], Gilles Farny[c], Sandra Lavorel[e], Patrick Giraudoux[d,f]

[a] Fédération Départementale des Chasseurs du Doubs—rue du Châtelard, 25360 Gonsans, France
[b] Fédération Départementale des Chasseurs du Jura—route de la Fontaine Salée, 39140 Arlay, France
[c] Parc National des Ecrins—Domaine de Charance, 05000 Gap, France
[d] Laboratoire Chrono-Environnement, Université de Franche-Comté/CNRS—16 route de, Gray, France
[e] Laboratoire d'Ecologie Alpine, Université Grenoble Alpes – BP53 2233 rue de la Piscine, 38041 Grenoble, France
[f] Institut Universitaire de France, 103 boulevard Saint-Michel, 75005 Paris, France

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ABSTRACT

Small mammal population outbreaks are one of the consequences of socio-economic and technological changes in agriculture. They can cause important economic damage and generally play a key role in food webs, as a major food resource for predators. The fossorial form of the water vole, *Arvicola terrestris*, was unknown in the Haute Romanche Valley (French Alps) before 1998. In 1998, the first colony was observed at the top of a valley and population spread was monitored during 12 years, until 2010. Spread occurred as a high population density wave. Based on farming history (1810–2003, 193 years) and spatio-temporal analysis of crop rotations, our study indicates that this water vole population outbreak has been promoted by the presence of grassland corridors that increase hayfield connectivity. These corridors appeared as a result of the conversion of cropped fields to hay meadows where water vole outbreaks have occurred. Spatial mosaic management for grasslands with decreasing spatial connectedness should be considered to prevent vole outbreak risks and promote biodiversity.

1. Introduction

Agricultural shifts generally correspond with technological and socio-economic changes (Allen, 2000). Mountainous regions are often considered to be favorable to biodiversity and more eco-friendly agricultural practices (Fjeldså et al., 1999). Currently, most areas in Europe have undergone either agricultural abandonment (and subsequent forest recolonization) or specialization (Chemini and Rizzoli, 2003). In developed countries, economic and technological changes in the 1950s led to specialized farming and geographically dissociated animal husbandry from cereal production. Thus, while vegetable and crop productions are now mostly located in the lowlands, farmers in mountainous regions have specialized in growing fodder for animal husbandry and milk production (García-Martínez et al., 2011; Cocca et al., 2012).

Today, in addition to agricultural intensification (increase of productivity in terms of quantity), specialization (production focused only on one or two crop types) is one of the greatest anthropic pressures on biodiversity and ecosystem services (Hole et al., 2005). Thus, while some species that depend on agro-ecosystems are declining (Fuller et al., 2005), others are considered to be pests because of the agricultural losses they cause (Singleton et al., 2010; Koyanagi et al., 2012; Krebs, 2013). The common vole (*Microtus arvalis*) and the water vole (*Arvicola terrestris*), are widely studied among other species, because both are potential pests to grassland (Krebs 2013).

There are many potential drivers of small mammal population outbreaks, and they are still under debate (Krebs, 2013). Small mammal populations are characterized by high intrinsic growth rates and strong inter-specific competition (Korpimäki et al., 2004). By increasing their food supply, agricultural intensification can promote the growth of small mammal populations (Morilhat et al., 2007). Additionally, agricultural specialization can modify landscape structure and composition, creating physical obstacles

* Corresponding author at: Fédération Départementale des Chasseurs du Doubs—rue du Châtelard, 25360 Gonsans, France.
E-mail addresses: doctorant@fdc25.com (G. Halliez), chargedemission@fdc25.com (F. Renault), eric.vannard@ecrins-parcnational.fr (E. Vannard), gilles.farny@ecrins-parcnational.fr (G. Farny), sandra.lavorel@ujf-grenoble.fr (S. Lavorel), patrick.giraudoux@univ-fcomte.fr (P. Giraudoux).

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to small mammal dispersal or modifying the structure and composition of vole predator guilds (Delattre et al., 1992, 1996, 1999; Giraudoux et al., 1997; Duhamel et al., 2000; Morilhat et al., 2008; Falk et al., 2011). Outbreaks may also be driven by weather conditions (White, 2011).

In temperate Europe, early studies on the agricultural damage caused by voles focused on the common vole (*M. arvalis*). Spitz (1968), for example, reported extremely high damage (87% for Alfalfa and 100% for grass and wheat) in the lowland of Vendée, France after World War II. In mountainous areas, land-use policy led to specialize into grass production and to increase parcel size during the1960s–1970s (López-i-Gelats et al., 2011). Delattre et al. (1992) reported that multi-annual fluctuations of the common vole increased with the Ratio of Permanent Grassland to Farmland (RPGF). Similarly, in Franche-Comté, France, Giraudoux et al. (1997) found a 5–6 year cycle in *A. terrestris* population abundance beginning in the early 1970s on regional scale, after the expansion of permanent grassland. For grassland voles, episodic outbreaks become chronic when a scarcity or absence of forest is combined with grassland predominance across the landscape (Delattre et al., 1992; Giraudoux et al., 1997) or when the ratio of leguminous plants increases (Spitz, 1972; Delattre et al., 1992). Earlier works have documented that landscape changes may impact the kinetics of rodent populations (Hansson, 1979; Hansson and Henttonen, 1985; Eadie, 1953; Birney et al., 1976). Lidicker (2000) conceptualized these landscape effects with the Ratio of Optimal to Marginal Patch Area (ROMPA) hypothesis. In brief, variation in rodent abundance depends on the prevalence of their optimal habitat within a landscape. In addition, water vole outbreaks in Franche-Comté (also in the Massif Central) have been characterized by a spatial spreading over several years (Giraudoux et al., 1997; Berthier et al., 2013) called a traveling wave. Such pattern has also been documented for other species, such as the bank vole (*M. glareolus*) and the field vole (*Microtus agrestis*) in Finland (Hansson and Henttonen, 1985; Ranta and Kaitala, 1997) and the field vole (*M. agrestis*) in Scotland (Lambin et al., 1998; Bierman et al., 2006). However, long-term time-series and large scales data that would permit a detailed study of such processes are rare (Ryszkowski et al., 1971; Ryszkowski, 1982; Erlinge et al., 1982, 1983).

The presence of the water vole in the Northern Alps and its sporadic damage to grasslands and orchards are well established (Morel and Meylan, 1970; Meylan et al., 1971; Airoldi, 1976). The geographical complexity of valleys and the high altitude of mountains ranges were previously believed to prevent any large-scale spreading of small mammal outbreaks. The spatio-temporal patterns of water vole outbreaks have therefore not yet been documented in this context. In the Haute-Romanche valley, neither written records (e.g. direct or indirect, from predator diet analysis) nor oral tradition evidenced population outbreaks or even the presence of the water vole before 1998, when the first water vole outbreak suddenly occurred. Due to its proximity to the Ecrins National Park (*Parc National des Ecrins*, PNE) and the risks of exposing native wildlife to pest chemical control, this outbreak has been carefully monitored and mapped by the PNE staff. A few studies provided very local data describing the presence of the water vole in the Northern Alps, but did not mention potential outbreaks in those areas (Morel and Meylan, 1970; Meylan et al., 1971; Airoldi, 1976; Habert, 1988; Lapini and Paolucci, 1992; Saucy, 1994). Thus, the initial colonization of a valley where the species was previously absent has never been studied. The Haute-Romanche valley has undergone major land use changes since the 19th century (Girel et al., 2010; López-i-Gelats et al., 2011). At that time, mixed farming, including cattle husbandry, cereal and potato production was general. The valley began to specialize in animal (cow and sheep) breeding in the 1960s (Girel et al., 2010). In the 19th century, to promote crop production (potatoes, barley,

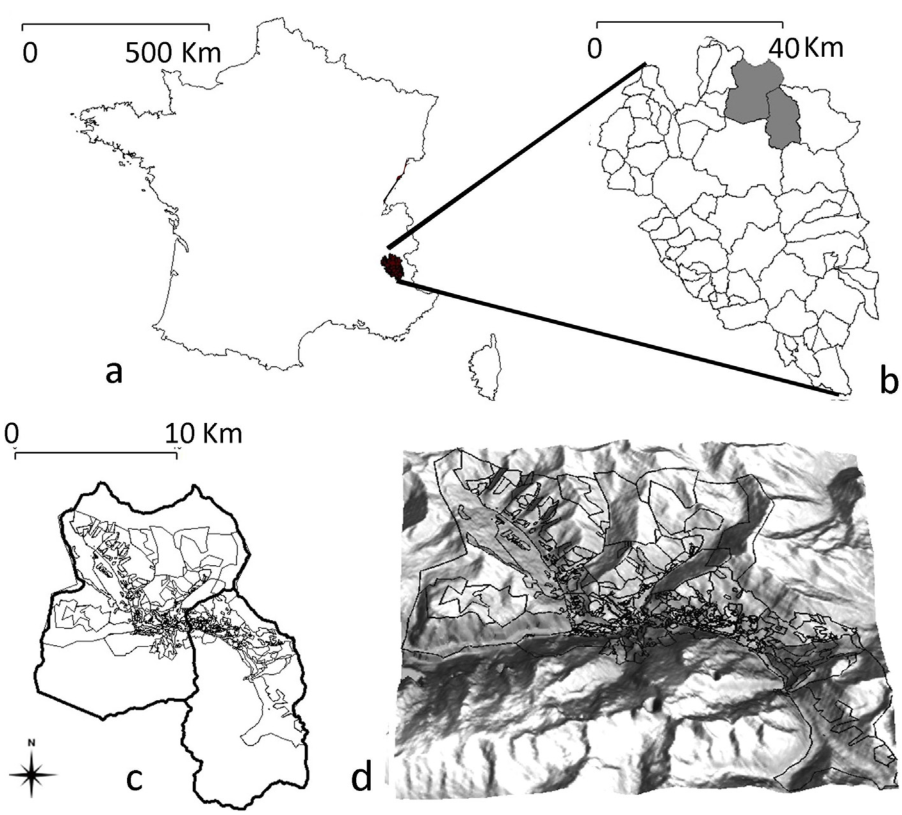

Fig. 1. (a) *Parc National des Ecrins* (PNE) (in black), (b) La Grave and Villar d'Arène communes (in grey) among the communes of the PNE(c) cadastral parcels in La Grave and Villar d'Arène (d) topography of the area (after Abrams et al., 2010).