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Plotting the course of an African clawed frog invasion in Western France

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Abstract—The African clawed frog, *Xenopus laevis*, is an invasive species with considerable impact in mediterranean climates, similar to its native South African Cape. A population has been established in western France since the early 1980s with a single, known, original release point. This study attempts to determine the limits of the invasion by trapping in 169 ponds in 2001 and 2002. Subsequent trapping of 192 ponds in 2003 and 2004 was undertaken in order to chart the progress of invasion, and to test the hypothesis that ponds were mostly colonised using rivers and streams as corridors. Of ponds without *X. laevis* in 2001/2002, 36% were found to have been colonised by 2003/2004. The findings clearly show that, while lotic corridors are used by this principally aquatic species, most ponds are colonised through overland migration. The consequences of this finding for invasions in France and other European countries are briefly discussed.

Keywords: amphibians; colonisation; freshwater; *Xenopus laevis*.

INTRODUCTION

Since the establishment of *Xenopus laevis* as the standard laboratory amphibian in the 1940s (Gurdon, 1996), the necessity of breeding live animals has led directly to invasive populations. Some are situated in mediterranean climates, similar to the native home of *X. laevis* in the South African Cape such as in California (McCoid and Fritts, 1995), Italy (Lillo et al., 2005) and Chile (Lobos and Measey, 2002; Lobos and Jaksic, 2005). Invasions in cooler climates are known, but are thought to have a reduced impact (Tinsley and McCoid, 1996). Impact of invasive populations includes direct predation of fish (Lafferty and Page, 1997) and amphibians (Crayon,

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in press), despite the clawed frogs' mostly invertebrate diet (Measey, 1998; Lobos and Measey, 2002).

Xenopus laevis is frequently considered to be completely aquatic, with many morphological adaptations for life within an aquatic habitat (Elepfandt et al., 2000), and appears to be clumsy and ill adept at movement on land. In its native South Africa, it is thought to use irrigation channels to move into previously unoccupied areas (Measey, 2004), and a similar explanation has been given for its rapid spread in Chile (Lobos and Measey, 2002). However, mark-recapture studies have suggested considerable overland migrations (Measey and Tinsley, 1998; Eggert and Fouquet, 2005) and there have been observations of individuals moving overland during dry periods (Lobos and Garín, 2002).

In France, a population of *X. laevis* was recorded by Fouquet (2001) in the department of Deux-Sèvres. It is thought to have originated from a single release of animals from a breeding centre in the region at the beginning of the 1980s. The region is characterised by numerous small rainwater fed ponds (*c.* 30 m^2), typically not linked by streams or irrigation channels. If *X. laevis* relies on watercourses and irrigation channels to colonise new ponds, then a clear pattern of distribution following such watercourses would be expected in the region. However, if significant numbers of individuals habitually crossed the land, a more even invasive pattern could be envisaged. Hence, this study was made to determine the invasive pattern of *X. laevis* within the Deux-Sèvres region of southwestern France.

MATERIALS AND METHODS

Ponds known to harbour populations (Fouquet, 2001) were targeted, and their nearest neighbours found with a map, or with help from local farmers. During the summers of 2001 and 2002, at least a single baited fyke trap (funnel trap in netting) was placed in each of these neighbouring ponds in the direction opposite to the release point. Traps were baited with meat and left overnight (approx. 12 trapping hours) with the presence/absence of *X. laevis* noted in the morning. All clawed frogs captured were removed and not replaced. In the case of presence, neighbouring ponds were again sought out and traps placed for the following night. In this way, a limit to the distribution of *X. laevis* within the departments of Deux-Sèvres and Maine-et-Loire was determined. In the following years (2003 and 2004), the same trapping regime was launched using the outermost positive ponds as a starting point on the southern and western part of the distribution.

RESULTS

A steady increase of distribution away from the site of release is shown in figure 1. Figure 1a shows the distribution of *X. laevis* alongside the Argenton River (in the Thouars area of the distribution), while in figure 1b many of the sites that were found

(a)

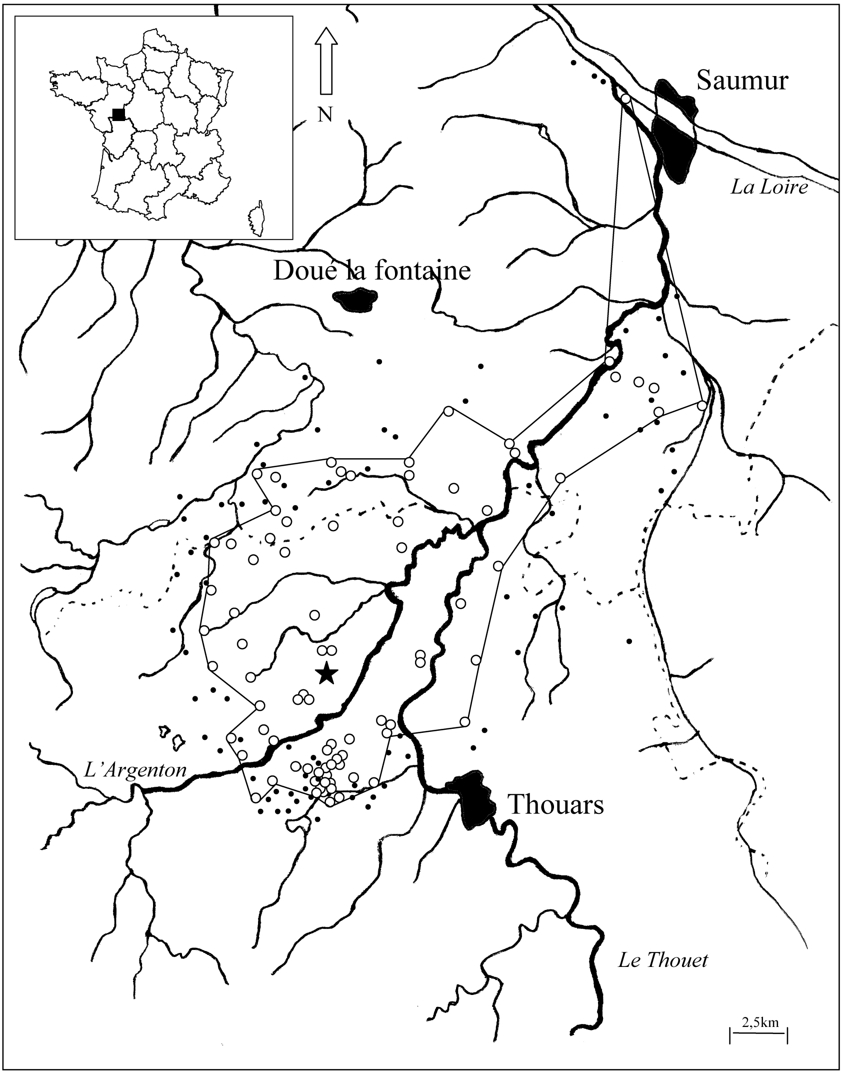

Figure 1. Distribution of trapping points. Solid circles show ponds trapped without finding *Xenopus laevis* and open circles those found to have been colonised by *X. laevis.* (a) The distribution of ponds trapped in 2001 and 2002; and (b) ponds trapped in 2003 and 2004. The solid line shows the presumed limit of the colonisation in 2002 (from trapping results). The star is the original point of release. All rivers and streams are shown, and major waterways (dark shaded) are indicated with their names. Dotted lines show the French departmental boundaries (inset).

without *Xenopus laevis* in figure 1a, were found to be positive (see also table 1). It can be seen that more ponds have been colonised along the course of streams and rivers, as has been noted in previous studies (see above). A good example is the small stream running due south of Thouars that has many negative points

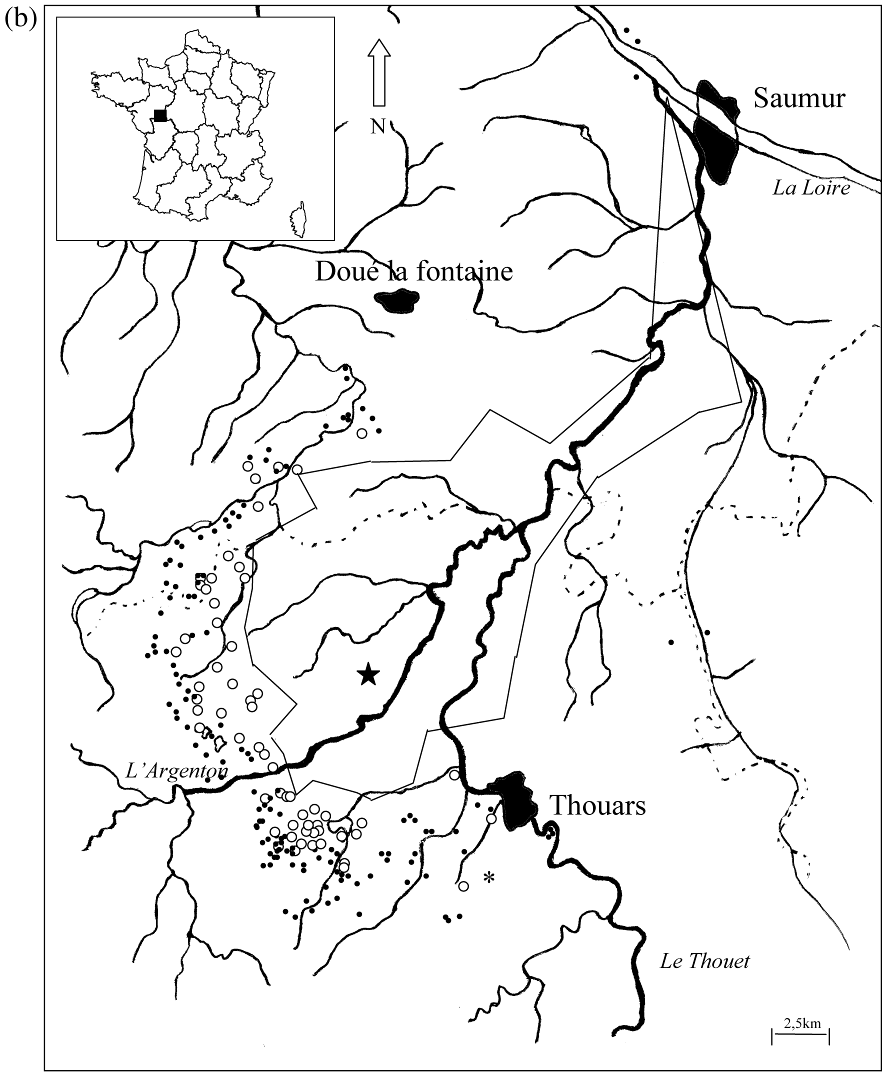

Figure 1. (Continued).

surrounding it, but positive points along its length (fig. 1b). It is possible that ponds that were further along such streams but not sampled were also colonised.

In addition to the ponds colonised through movement along streams, it can be seen that the majority of ponds are colonised through overland movements. However, during this study, only one adult female was located out of water. This individual was found dead on a road after a rainstorm. Many local residents reported that they had observed clawed frogs moving on land.

Care should be taken with the interpretation of negative trapping points, as it is possible that with very small populations, individuals may not be caught during a single nights trapping. However, the limit of the overall distribution may still

Table 1.
Numbers of water bodies with and without *Xenopus laevis* (positive and negative, respectively) in the departments of Deux-Sèvres and Maine-et-Loire of western France. Ponds identified as newly colonised were negative in 2001-2002 (in brackets are those presumed to be newly colonised given the distributions in 2001-2002; see fig. 1).

	Positive ponds	Negative ponds	Newly colonised ponds
2001-2002	84	85	–
2003-2004	62	130	31 (45)

be approximated from the numerous negative points. Inside the colonised zone every kind of water body is occupied. During a single night, numbers caught were between one and 98 (mean = 10.47 SD = 14.58) individuals, sometimes with huge densities reminiscent of situations in California and Chile where the conditions are thought to be optimal for *X. laevis* reproduction (McCoid and Fritts, 1995; Lobos and Measey, 2002). Five colonised ponds at the centre of the distribution were monitored throughout the study and none was found to have lost its populations of clawed frogs.

DISCUSSION

This is the first study that conclusively demonstrates that the principle dispersion of *Xenopus laevis* to new water bodies in the study area is by moving over ground, without reliance on aquatic corridors for dispersal. Additional areas outside the study area may also have been colonised by movement through aquatic corridors. The colonisations observed strongly suggest that individuals are not moving randomly. Instead, that they are able to detect the presence of uncolonised ponds at a distance, and orient towards them. The ability of *X. laevis* to find other water bodies whilst on land may be associated with their dual classes of olfactory receptors (Freitag et al., 1995), the terrestrial component of which may be able to detect odours given off by ponds (as has been suggested for other frogs; Savage, 1961).

Although we cannot be certain that ponds where *X. laevis* were not caught were without any individuals inside them (i.e. negative ponds, table 1), we feel that our results at least demonstrate a change in abundance. In addition, it is unlikely that all ponds were previously colonised and yet trapping efficacy gave the distributions shown in figure 1. The high number of ponds involved made more thorough trapping during the short period of this study impractical. This caveat underlines the importance for control efforts to receive appropriate funding (see below), without detracting from the gravity of the findings reported herein.

If the known release point is taken together with the date of original release, an estimate of terrestrial spread can be made to be approximately 1 km per year. It should be noted, however, that movement through streams and irrigation channels appears to be much faster than overland movement, and the status of invasion in the Loire Valley has not been thoroughly investigated. Indeed, if used, the Loire could be a major corridor for the spread of this invasive species throughout the west of France.

This area of France has an oceanic climate, rather than the mediterranean climate known to produce year round reproduction in California (McCoid and Fritts, 1995), and very large populations and densities in Chile (Lobos and Measey, 2002). However, it appears that even in this mild climate, populations of *X. laevis* quickly reach a level where management may be difficult, or at least expensive. This report also suggests that the innocuity of invasions in other areas (such as UK) should be reconsidered.

Recent interest has focused on the impact of aquatic invasions, especially in relation to declining amphibian populations (Kats and Ferrer, 2003). This case study is particularly interesting as the original release point and date is known (Fouquet, 2001), and the current range is circumscribed in a relatively small area as compared for example to Chile (Lobos and Jaksic, 2005). This region contains several protected amphibian species, including *Salamandra salamandra, Triturus cristatus, T. marmoratus*, *T. helveticus, T. vulgaris, Bombina variegata, Pelodytes punctatus, Alytes obstetricans*, *Bufo bufo, B. calamita, Rana dalmatina, R. temporaria, R. lessonae* and *Hyla arborea*. Given the results of previous studies (see above), we suggest that populations of any of these species within the area of invasion of *X. laevis* may be at risk. Studies on the impact of *X. laevis* on these species are urgently needed.

Eradication of invasive populations of *Xenopus laevis* in mediterranean climates, i.e., central Chile and California, is considered to be difficult, although to date no management or control operations are in place. In France, eradication of *X. laevis* is still possible and desirable, before this population becomes more diffuse and any management operations more expensive. However, despite the inclusion of this species in a recent synthesis of French invasions for the Ministry of the Environment (Pascal et al., 2003), no action plan has been drawn up. The lack of French governmental strategy over invasive species has been pointed and seems to be related to the belief that eradications are not desirable or possible (Pascal and Lorvelec, 2004), despite many documented examples of successful eradications of French invasive species (Lorvelec and Pascal, 2004). We follow Simberloff's (2003) most effective action on invasive species, and propose that immediate eradication of invasive *Xenopus laevis* in France is desirable, and further suggest that it will not produce undesirable results. Successful eradication of *X. laevis* populations from an area (as opposed to a single pond) is unknown, and an early implementation of the five-point global strategy (Pascal and Chapuis, 2000) would provide an important precedent both for invasions on mainland France, and other invasions of *Xenopus laevis*.

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