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Mapping the spatiotemporal distributions of the Desert Locust in Mauritania and Morocco to improve preventive management

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Abstract

Understanding Desert Locust population dynamics is a prerequisite for the implementation of a preventive management strategy against its invasions. The present study aims to describe these dynamics through conducting probability analyses of locust presence in time and space. Historical data from field surveys conducted by management teams in Mauritania and Morocco for the period 1988–2015 were used. Temporal smoothing and spatio-temporal extrapolations were performed on a monthly basis. We established monthly probability maps of locust observation following two scenarios: recession period (mainly solitarious phase) and invasion period (mainly gregarious phase). Also, observation probability maps of hoppers or mature adults allowed the identification of seasonal breeding areas. The methodology highlights the potentially favourable areas to be monitored every year. It also highlights the lack of information in some areas of the two countries. We observed that the seasonal survey process during recession periods follow the seasonal pattern of gregarious invasions. We argue that this is the result of climatic conditions related to the oscillation of the intertropical convergence zone. However, we advise that these similar yearly cycles should not hinder surveys in recession periods to be conducted in places not receiving swarms during invasion periods. Nevertheless, we conclude that these maps should be helpful for planning the preparation of survey teams in the field. This will reduce survey operation costs and decrease invasion risks.

Keywords: *Schistocerca gregaria*; Historical data; Spatial smoothing analysis; Biotope; Phase polyphenism

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Introduction

The Desert Locust, *Schistocerca gregaria* (Forskål, 1775), is a major pest for agriculture through West Africa to western India via the Middle East. Regular invasions of this insect pose a real threat to crop production (Lecoq, 2005). Like other locust species, the Desert Locust exhibits phase polyphenism, a plastic response to population density associated with several changes in behavioural, morphological, anatomical, and physiological traits (Uvarov 1921, 1966; Pener & Simpson 2009). The isolated, harmless and hidden solitarious locusts transform into enormous hopper bands and huge devastating swarms of the gregarious form in overcrowding conditions. The transformation is progressive, necessitating several generations of intermediate forms, called transiens (Zolotarevsky 1929).

Tactile contacts between conspecifics play a major role in the induction of the behaviour change that is reversible at any time (Simpson, McCaffery, & Hägele 1999; Rogers et al. 2014). The frequencies and intensities of these inter-individual contacts depend on the population density (Uvarov 1966) and the environment (Collett, Despland, Simpson, & Krakauer 1998). Thus, densities of several hundred adults per hectare in sparse vegetation will generate the gregarious behaviour, while the same density in dense and green vegetation will not lead to gregarization (Cissé et al. 2013). Geographic areas where locusts breed at times of low densities (called recession), are also typically places where populations may increase in size to reach the critical density leading to gregarization (Despland, Collett, & Simpson 2000; Despland, Rosenberg, & Simpson 2004).

The strategy of locust preventive control focuses on proactively limiting the increase in population size at the beginning of the gregarization process (Lecoq 2004; van Huis, Cressman, & Magor 2007; Magor, Lecoq, & Hunter 2008). The countries of the western region of the Desert Locust distribution area have implemented this strategy in recent years with the support of regional and international institutions (Martini, Lecoq, Soumaré, & Chara 1998; Lecoq 2004). Preventive control is based on monitoring the outbreak areas (Lecoq 2003), followed if necessary by early intervention and thus a limited use of pesticides. This necessarily requires a good knowledge of locust ecology as well as the identification of gregarization habitats where phase change could be induced (Kennedy 1939; Bouaïchi, Simpson, & Roessingh 1996; van der Werf, Woldewahib, van Huis, Butrous, & Sykora 2005; Cissé et al. 2013; Cissé, Ghaout, Mazih, Ould Babah, & Piou 2015). The implementation of the preventive control strategy helps to maintain densities below the threshold for gregarization in order to stop an outbreak as early as possible (Duranton & Lecoq 1990; Martini et al. 1998).

In this context, all progress in improving our knowledge on the seasonal dynamics of locust populations as well as in the localization and dynamics of gregarization habitats (Popov, Duranton, Gigault 1991) is an advantage for the locust management system. This knowledge will improve the efficiency of the early reaction, allowing small scale control only when it is required, and thus reducing the costs of field monitoring operations (Babah Ebbe 2008; Doré, Barbier, Lecoq, & Ould Babah 2008). In particular, solitarious population dynamics during recession periods are keys to understand the risks of gregarization that can arise from favourable environmental conditions. Indeed, solitarious populations are considered to be at the origin of invasions (Lecoq 2001, 2005; Magor et al. 2008), although in the past, their importance were sometimes questioned (e.g. Pasquier 1942; Rainey 1963). These populations of solitarious Desert Locusts are probably much more abundant than previously believed (Chapuis et al. 2014; Chapuis, Plantamp, Streiff, Blondin, & Piou 2015). Hence, in recent years, several studies used the accumulated field data from management surveys to better understand the distribution and dynamics of solitarious Desert Locust populations (Babah Ebbe 2008; Piou et al. 2013; Lazar, Piou, Doumandji-Mitiche, & Lecoq 2016).

Desert Locust control has been facilitated by mapping population dynamics parameters (e.g. Symmons, Green, Robertson, & Wardhaugh 1974) and satellite imagery, particularly with the improvement of the resolution of vegetation index images and the decrease in temporal delay in providing such images (Cressman 2013; Latchininsky, Piou, Franc, Soti 2016). Analyses of satellite images coupled with management survey data have shown the importance of dynamics and spatial structure of vegetation in the development of solitarious populations and the gregarization process (Piou et al. 2013; Despland et al. 2004). Previous studies also proposed particular treatments of satellite images to focus on specific conditions favouring locust development (Pekel et al. 2011). However, satellite images do not replace the mapping of potential habitats of locusts from actual encounters of the insects. Pedgley (1981), Popov et al. (1991) and Popov (1997) had produced useful works by mapping Desert Locust occurrences from survey data assembled between 1939 and 1984. These could show the gregarious cycling dynamics and some potential areas where gregarization happened. In addition. Yet, these maps have a resolution of a degree square of latitude/longitude and relatively few data regarding solitarious encounters in recession periods compared to gregarious signalisation in invasion periods. Additionally, they were not updated since 1997 at the scale of several countries. National initiatives were conducted, but without a common methodology. For example, Babah Ebbe (2008) mapped the frequencies of Desert Locust observation in Mauritania with data until 2007 at the scale of quarter of degree square.

The present study aims to present a novel statistical technique to analyse the Desert Locust population dynamics from survey data. The statistical technique takes into account the fact that the survey data did not result from systematic sampling. This technique is applied to data from Mauritania and Morocco since 1988 to complete the previous mapping works. These survey data were collected by the two

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