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Coupling historical prospection data and a remotely-sensed vegetation index for the preventative control of Desert locusts

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Abstract

Locusts are grasshopper species that exhibit phase polyphenism resulting in the expression of gregarious behaviors that favor the development of large devastating bands and swarms. Desert locust preventative management aims to prevent crop damage by controlling populations before they can reach high densities and form mass migrating swarms. The areas of potential gregarization for Desert locust are large and need to be physically assessed by survey teams for efficient preventative management. An ongoing challenge is to be able to guide where prospection surveys should occur depending on local meteorological and vegetation conditions. In this study, we analyzed the relationship between historical prospection data of Desert locust observations from 2005 to 2009 and spatio-temporal statistics of a vegetation index gathered by remote-sensing with the help of multiple models of logistic regression. The vegetation index was a composite Normalized Difference Vegetation Index (NDVI) given every 16 days and at 250 m spatial resolution (MOD13Q1 from MODIS satellite). The statistics extracted from this index were: (1) spatial means at different scales around the prospection point, (2) relative differences of NDVI variation through time before the prospection, and (3) large-scale summary of vegetation quantity. The multi-model framework showed that vegetation development a month and a half before the survey was amongst the best predictors of locust presence. Also, the local vegetation quantity was not enough to predict locust presence. Vegetation quantity on a scale of a few kilometers was a better predictor but varied non-linearly, reflecting specific biotope types that support Desert locust development. Using one of the best logistic regression models and NDVI data, we were able to derive a predictive model of probability of finding locusts in specific areas. This methodology should help in more efficiently focusing survey efforts on specific parts of the gregarization areas based on the predicted probability of locusts being present.

Zusammenfassung

Wanderheuschrecken gehören zu den Heuschreckenarten, die einen saisonalen Polyphänismus zeigen, der sich in einem gregären Verhalten ausdrückt, das die Entwicklung von großen, verheerenden Gruppen und Schwärmen fördert. Das präventive Management von Wüstenwanderheuschrecken zielt darauf ab, Ernteschäden zu verhindern, indem die Populationen unter

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Kontrolle gehalten werden bevor sie hohe Dichten erreichen und wandernde Massenschwärme bilden können. Die Gebiete für potenzielle Aggregationen von Wüstenwanderheuschrecken sind riesig und müssen für ein effektives präventives Management durch Erfassungsteams kontrolliert werden. Die derzeitige Herausforderung besteht darin, sagen zu können, wo in Abhängigkeit von lokalen meteorologischen und Vegetationsbedingungen Erfassungen stattfinden sollten. In dieser Untersuchung analysierten wir mithilfe von verschiedenen Modellen der logistischen Regression die Beziehung zwischen historischen Erfassungsdaten von Beobachtungen der Wüstenwanderheuschrecken zwischen 2005 und 2009 und den räumlich-zeitlichen Statistiken eines Vegetationsindex, der durch Fernerkundung gewonnen wurde. Der Vegetationsindex war der zusammengesetzte, normalisierte Differenz-Vegetations-Index (NDVI), der alle 16 Tage mit einer räumlichen Auflösung von 250 m (MOD13Q1 vom MODIS-Satelliten) gegeben war. Die Statistiken, die aus diesem Index ermittelt wurden, waren: (1) räumliche Mittelwerte auf verschiedenen Skalen rund um den Kontrollpunkt, (2) relative Unterschiede in der Variation des NDVI während der Zeit vor der Kontrolle und (3) die großräumige Zusammenfassung der Vegetationsmenge. Das Bezugssystem aus mehreren Modellen zeigte, dass die Vegetationsentwicklung eineinhalb Monate vor der Erfassung zu den besten Vorhersagefaktoren für die Anwesenheit der Wanderheuschrecken zählte. Es zeigte sich auch, dass die lokale Vegetationsqualität nicht ausreichte, um die Anwesenheit von Wanderheuschrecken vorherzusagen. Die Vegetationsmenge auf einer Skala von einigen Kilometern war ein besserer Indikator, variierte jedoch nicht-linear und spiegelte damit die spezifischen Biotoptypen wider, welche die Entwicklung von Wüstenwanderheuschrecken förderten. Unter der Verwendung des besten logistischen Regressionsmodell und der NDVI-Daten konnten wir ein Vorhersagemodell für die Wahrscheinlichkeit entwickeln, mit der Wanderheuschrecken in bestimmten Gebieten gefunden werden. Diese Methodik sollte helfen, den Erfassungsaufwand aufgrund der vorhergesagten Wahrscheinlichkeit für die Anwesenheit der Wanderheuschrecken viel effektiver auf spezifische Bereiche der Aggregationsgebiete zu fokussieren.

Keywords: *Schistocerca gregaria*; Logistic regression; Mauritania; Fractal dimension; Presence absence; Consistent Akaike information criterion; Multi-model inference

Introduction

Locusts are grasshopper species capable of expressing phase polyphenism, a form of phenotypic plasticity that confers on them the capacity to change behavior, morphology, and life cycle from harmless solitarious phase individuals to gregarious phase individuals that form devastating bands and swarms through a process called gregarization (Latchininsky 2010; Pener & Simpson 2009; Simpson & Sword 2009; Simpson, Sword, & De Loof, 2005). The capacity to change phase was first identified by Uvarov (1921, 1929) and is directly linked to local increases in population density in all locust species. Increases in locust population size are generally the result of rainfall and vegetation development within favorable breeding areas. An increase in local population density, which favors inter-individual contacts and therefore gregarization, is frequently the result of the concentration of locusts into reduced areas where vegetation subsists or where reproduction is favorable. Among locusts, the infamous Desert locust, *Schistocerca gregaria* (Forskål, 1775), is one of the major threats to cultivated lands across an area of more than 31 Million km^2 spreading from western Africa to eastern India (see Sword, Lecoq, & Simpson 2010). Devastating swarms of this species have been recorded throughout history and still occur when preventative control fails to curtail the exponential explosion of population sizes (see also Lecoq 2004, 2005; e.g. report of the 2003–2005 invasion by Brader et al. 2006). A preventative control strategy for the Desert locust was defined as early as 1938 by Uvarov and implemented since the 1960s with the objective to control populations as soon as they start changing from the solitarious to gregarious phase (Lecoq 2001, 2003; Sword et al. 2010). Consequently, the countries containing areas where locust phase changes have often been observed attempt to survey or prospect these areas (known as outbreak areas) to document population status and initiate control when necessary. However, these critical areas are estimated to cover a huge area of approximately 0.25 Million km^2. In light of the need to monitor and control Desert locust populations at fine scales and as early as possible (Brader et al. 2006; Magor, Lecoq, & Hunter 2008; Sword et al. 2010), an objective of current research on the spatiotemporal ecology of this species is to provide tools to help reduce the area and times to be searched while ensuring effective monitoring of potential outbreak areas.

Long term and large-scale sampling data for Desert locust populations across its range do not exist per se. However, the data collected by survey teams are useful in summarizing the status of populations found in most countries containing Desert locust outbreak areas. These surveys are conducted with the objective of finding locust populations and documenting their density, developmental stage and phase (gregarious or solitarious). When the survey teams stop in an area, if locusts are not visible at first sight, different transect methods are applied depending on the ease of movement and type of substrate, in order to evaluate the presence of solitarious individuals. Such survey data are primarily useful to assess the local situation in order to make control decisions (Cressman 2001). These data are also centralized at international level by the FAO (Food and