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Short communication

Field Verification of the Prediction Model on Desert Locust Adult Phase Status From Density and Vegetation

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Abstract

Previous studies investigated the effect of vegetation on density thresholds of adult Desert Locust gregarization from historical data in Mauritania. We examine here the prediction of locust phase based on adult density and vegetation conditions using the statistical model from Cisse et al. compared with actual behavior of Desert Locust adults observed in the field in Mauritania. From the 130 sites where adult locusts were found, the model predicted the phase of Desert Locust adults with a relatively small error of prediction of 6.1%. Preventive locust control should be rational, based on a risk assessment. The staff involved in implementation of the preventive control strategy needs specific indicators for when or where chemical treatment should be done. In this respect, we show here that the statistical model of Cisse et al. may be appropriate.

Key words: acrididea, field sampling, Mauritania, Orthoptera, phase polyphenism

The Desert Locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae), preventive control strategy relies on early warning and early reaction to decrease the frequency of upsurges and plagues by monitoring and controlling infestations in seasonal breeding areas (Lecoq 2005). Until recently, preventive control teams did not have precise information on the density thresholds justifying chemical treatment. To help field workers in decision making to intervene or not, previous studies investigated the effect of vegetation on density thresholds of adult Desert Locust gregarization from historical (from 2003 to 2011) data in Mauritania (Cisse et al. 2013). The results provided the minimum adult densities that should be controlled according to vegetation status and cover to reduce the risk of gregarization and hence invasions. This could help to avoid overuse of pesticides and reduce their impact on the environment and health of humans and livestock. In a subsequent study, we collected field data on Desert Locust hoppers in Mauritania to estimate the probabilities of observing gregarious individuals (Cisse et al. 2015).

In this investigation, we examine the prediction of locust phase based on adult density and vegetation conditions using the statistical model from the study of Cisse et al. (2013) compared with actual behavior of Desert Locust adults observed in the field in Mauritania. This was a supplementary exercise conducted during field sampling of Desert Locust hoppers.

Materials and Methods

Study Area

The study took place in Mauritania, one of the key countries for the implementation of preventive control and hosting Desert Locust permanent habitats (Popov et al. 1991). The country is also historically an important locust migration route between the Sahel and the Maghreb in Africa (Ceccato et al. 2007). The study was conducted during and shortly after two successive annual rainy seasons (between July and December), in 2012 and in 2013. The studied areas are annually monitored by the survey teams of the national Anti-Locust Center of Mauritania and correspond to the traditional Desert Locust breeding and gregarization areas (Popov et al. 1991). Field sampling was oriented by locust presence in these areas (see Fig. 1 and Cisse et al. 2015 for details on sampling sites and conditions).

Desert Locust Adult Densities and Vegetation Sampling

The sampling methodology used to estimate the Desert Locust adult densities was consistent with the FAO guidelines (Cressman 2001). At least ten samples were taken at an individual site (survey stop) where green vegetation was present. Each sample consisted of counting the number of individuals in a foot transects of 100 m in length and 1 m in width. Parallel transects were separated by at least 50 m.

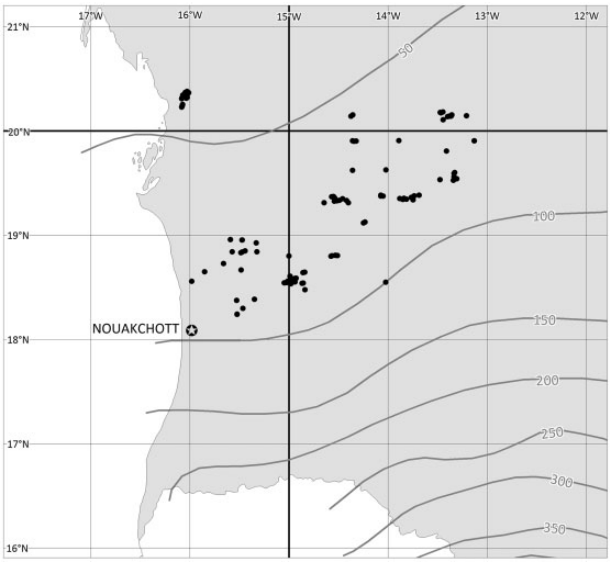

Fig. 1. Sampling sites in Mauritania where desert locust adults were found ($n = 130$). The gray lines show the isohyetes of mean annual rainfall in mm (data from AGRYMET/RIM).

Table 1. Logistic regression model from Cisse et al. (2013) of the form: logit[P(gregarious)] − Adult density + Vegetation status + Adult density: Vegetation cover.

Coefficient	Estimate	SE	z value	Pr(>|z|)
Intercept	−1.8997168	0.0397103	−47.839	<2e−16
Adult density	0.0025545	0.0001413	18.082	<2e−16
Greening vegetation	−0.0814573	0.1716030	−0.475	0.635
Shooting vegetation	−1.9947165	0.3027357	−6.589	4.43e−11
Dry vegetation	0.6888679	0.2230344	3.089	0.002
Green vegetation	−0.0892948	0.0511991	−1.744	0.081
Adult density: low cover	0.0032699	0.0003843	8.509	<2e−16
Adult density: medium cover	0.0003697	0.0001520	2.431	0.015

Vegetation cover from Cisse et al (2013).

The average number of locusts per 100 m^2 was determined from the ten samples and converted to density per hectare. Two successive survey stops were typically at 5 km from each other. Locusts characteristics were noted during the pedestrian transects. The collected data were focused on locust behavior (isolated or scattered solitarious adults; grouped transiens or gregarious adults) and body-coloration (usually brown for solitarious adults; bright pink for transiens, pink, or yellow for gregarious adults) (Symmons and Cressman 2001). Phase polyphenism confers to locust species, and desert locust in particular, considerable variation in behavioral, morphological, anatomical, and physiological characteristics, as population densities and environmental conditions of the habitat area change (Pener and Simpson 2009). The extreme gregarious adult forms are noticeably different from the extreme solitarious adult forms in various traits such as coloration, wing length, hind femur length, a bulge in the cheeks, a depression in the crest of the pronotum, a shortening of the prozona, and a constriction in the thorax (Duranton and Lecoq 1990). In the transiens adult forms (congregans or dissocians, depending on phase change direction), phase characteristics are independently and continuously induced or shifted to either direction in response to changes in the density of the population (Rao 1942, Pener and Simpson 2009). Also, the swarm migration and group oviposition are well known as typical gregarious-phase characteristics. In the field, prominence was given to behavior rather than appearance in characterizing the phase status of individuals because body color and morphological changes could occur later (Rogers et al. 2014). Also, during these 2 yr of field work, no major outbreak was in progress. As a consequence, no Desert Locust immigrant swarm arrived in Mauritania. However, small-scale gregarization of adults occurred. Phase characteristics based on behavior was consequently synthetized, as in Cisse et al. (2013), with a solitarious status or gregarious status (hence including most transiens forms). Samples were conducted in 148 sites and adult locust found in 130 sites (Fig. 1, also described in Cisse et al. 2015).

The vegetation variables of status and cover were collected for each site following the FAO Guidelines (Cressman 2001, Cisse et al. 2013). The status variable indicated 'greening' if the vegetation was found yellow but new shoots were also seen. If mixed dry and green vegetation was found with no signs of new growth, it was noted 'drying'. If the vegetation present was yellow only, it was noted 'dry'. Vegetation could also be completely 'green' or 'shooting'. The cover vegetation variable was based on the density of the vegetation compared with bare soil: it was denoted as 'low' when there was more bare soil visible, 'medium' when there was nearly as much vegetation as bare soil visible, and 'dense' when there was a lot of vegetation and bare soil was hardly visible.

Statistical Analysis

We assessed the prediction of Desert Locust adult phase with the statistical model using adult density, vegetation status and cover as established in Cisse et al. (2013). This prediction model is a multivariate logistic regression model of the form: logit[P(gregarious)] − Adult density + Vegetation status + Adult density: Vegetation cover. Table 1 presents the results of its adjustment from historical data realized in Cisse et al. (2013). By introducing the new field observations as explanatory variable in this adjusted statistical model, we could compute the probability that each sampled population of Desert Locust adult was gregarious according to its density and the status and cover of the vegetation. We then compared these predictions with the phase status observed in the field according to behavior. The probability of being gregarious from the model was compared with the characterized phase status through a simple confusion matrix. Data were analyzed with the statistical software R version 3.2.2 (R Development Core Team 2015).

Results

From the 130 sites where adult locusts were found, we observed 98 sites with solitarious adults and 32 sites with gregarious adults. Regarding vegetation status, 104 sites were green, 5 shooting, and 21 drying. Vegetation cover was low in 50 sites, medium in 51, and dense in 29 sites. Adult locust density varied from 0.002 to 50,000/ha. Comparison with the model showed eight errors of prediction for the phase status (Table 2, Fig. 2). The model predicted *solitarious* for one of the *gregarious* observations leading to a false negative rate of 3.8% (Table 2). The false positive rate was a bit higher (6.7%) with seven *solitarious* observations predicted as *gregarious*. Altogether, these tests led to a relatively small overall error of prediction of 6.1% (1—overall accuracy, Table 2).

Table 2. Confusion matrix of the model prediction from density, vegetation cover, and status (prediction threshold taken at 0.5 of probability to observe gregarious locusts) versus the observed phase status in the field

	Predicted solitarious	Predicted gregarious	Errors
Observed solitarious	97	7	False positive rate = 7/104 = 6.7%
Observed gregarious	1	25	False negative rate = 1/26 = 3.8%
Errors	False omission rate = 1/98 = 1.0%	False discovery rate = 7/32 = 21.9%	Overall accuracy = 122/130 = 93.8%

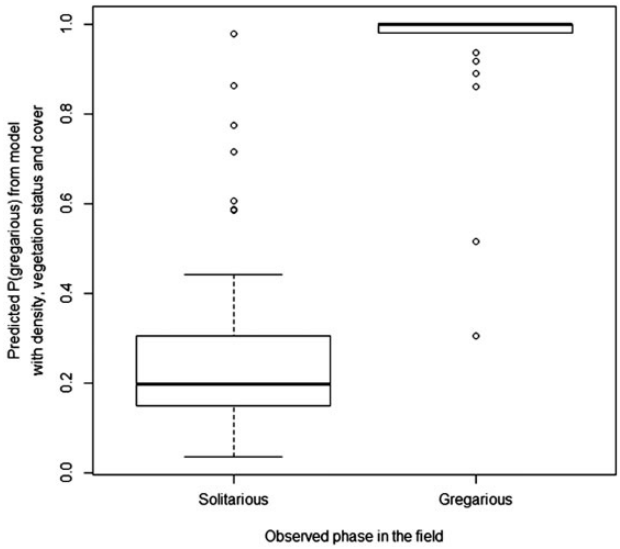

Fig. 2. Comparison of observed phase status in the field with the model prediction of the phase status from density, vegetation cover, and status (expressed as a probability of being gregarious).

Discussion

This study allowed checking the robustness of our previous findings on Desert Locust adult gregarization thresholds focusing on historical data analysis (Cisse et al. 2013). Despite the diversity of field workers who contributed to the collection of historical data in Mauritania, this study confirmed the prediction model developed from these data. The model gave a relatively low overall error rate. The false negative predictions would be the most problematic in a management context as it would indicate that *gregarious* individuals are *solitarious*. Fortunately, the model presented a low rate of false negatives with these new data. This indicates that an operational use of this model could help in determining if a given locust density and vegetation situation is at risk or not. Treatments could be decided on this base, though the locust density measure might be another source of errors.

Indeed, a certain amount of caution should be exercised when the results of foot transects are extrapolated to an entire area of green vegetation. This method may be appropriate for homogenous distribution but is not likely to account entirely for clumpiness in locust distribution within the green vegetation. Consequently, there may be an over/under estimation of density levels. This might point to the need for improving Desert Locust survey and sampling methodology.

Several studies have recognized that preventive control strategy is the only effective strategy (Duranton and Lecoq 1990, Lecoq 2004, van Huis et al. 2007, Sword et al. 2010) to prevent large invasions. Locust control should never be spontaneous; it must be rational, based on a risk assessment. This requires a cross-analysis process of locust densities and environmental factors, mainly vegetation, rainfall and time factor (beginning, middle, or end of seasonal rainy period). The staff involved in implementation of the preventive control strategy needs specific indicators for when or where chemical treatment should be done. In this respect, the statistical model of Cisse et al. (2013) may be appropriate. A simple routine that transforms locust density and vegetation status and cover into a probability to find gregarious locusts could be incorporated into the custom geographic information systems, RAMSESv4 (Reconnaissance and Management System of the Environment of Schistocerca), that is used to analyze field data for decision-making in each Desert locust affected country (Cressman and Hodson 2009).

Lastly, the statistical model could be improved further by analyzing data of all locust-affected countries according to our methodology. From this, spatial comparisons could be potentially investigated, for example between latitudes and regions.

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