FORECASTING BREEDING OPPORTUNITIES FOR THE RED-BILLED QUELEA IN SOUTHERN AFRICA

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ABSTRACT

Red-billed Quelea birds (*Quelea quelea*) are major pests of small-grain crops throughout sub-Saharan Africa. These abundant birds breed colonially when conditions permit, migrating long distances, sometimes more than 2000km, to seek appropriate breeding areas or to avoid food shortage.

The birds breed in the wet season and spend the dry seasons where there are sufficient seeds of their preferred grasses available. At the start of the rains, grass seeds germinate after a threshold quantity of rain has fallen, forcing the birds to move to zones where the seeds have yet to germinate. When rain reaches the latter areas, the birds are forced to move again, usually returning in “early-rains migrations” in the direction whence they came.

By this time sufficient rain needs to have fallen to exceed another threshold within a restricted period for the new grass to have produced fresh seed. Breeding may then commence. It is the fledging birds that cause most damage to agriculture. The adult birds may then move on “breeding migrations” to nest again in the same season. Using estimates of rainfall derived from Meteosat Cold Cloud Duration (CCD) data, a spatio-temporal model has been devised. This shows at weekly intervals those areas where (a) the wet season has not yet started; (b) the early-rains migration threshold has been exceeded; (c) the threshold to permit breeding has been exceeded and (d) conditions are no longer suitable for new colonies to be established.

The model is described and results of validating it using data on breeding by southern African populations of quelea (*Q. q. lathamii*) discussed in relation to control strategies.

1. INTRODUCTION

Red-billed Quelea are so numerous in sub-Saharan Africa in some years that they can be considered to be of plague proportions when they attack crops such as millet, sorghum, rice and wheat. They have to be controlled for the benefit of subsistence farmers and also for commercial agriculture. There is some control by explosive destruction of roosting areas but most control is by aircraft or ground spraying of the organophosphate pesticide fenthion. In an average year, in South Africa alone, there are 170 separate control operations, each one on average 7 hectares, with a total kill of 50 million birds.

2. THE CASE FOR A BREEDING FORECAST SYSTEM

There is a lack of near real-time data on the development of the grasslands favoured by these birds as food. Therefore, control operations are necessarily damage report driven. Pest control offices have no information on Quelea abundance until they receive a complaint of damage from farmers. This may mean that control operations are not well timed. A whole crop can be lost while farmers wait for a control aircraft to arrive.

Much of the present control is focused on roosts of non-breeding birds as well as breeding colonies. It is fledglings from the latter that cause the most damage. but the breeding colonies, which are often in remote and inaccessible areas, may remain unreported. However, if these colonies could be controlled more efficiently, by the provision of timely information, this should ensure a greater reduction in fledgling numbers. Hence, the result of using a breeding forecast model should be less crop damage, less use of pesticide, fewer non-target kills and less environmental damage.

3. THE BREEDING FORECAST MODEL FORMAT

The format of an operational breeding forecast model should be designed to accommodate human activities and time scales. Experience gained with the forecasting of African Armyworm (*Spodoptera exempta*) outbreaks in Tanzania (Holt, J., Mushobozi, W. L., Tucker, M. R. and Venn, J. F., (2000)) indicated that a weekly, rather than a dekadal, model would be most appropriate for operational purposes.

We concentrate upon the sub-species *Quelea quelea lathamii*, which does not leave southern Africa and therefore consider only the continental area between 5°S and 35°S latitude and 11°E and 41°E longitude.

We model this region as a matrix of ½° by ½° squares. For each square, ***i*** = 1,60, ***j*** = 1,60, that is not designated as ocean, the Quelea breeding probability **(** $QB_{i,j}$ **)** is given by,

$QB_{i,j} = N_{i,j} + F_{i,j}$, where $N_{i,j}$ is nest site availability, i.e. acacia trees near grassland

and $F_{i,j}$ is food availability, i.e. grassland and cereal crop dry seeds.

$N_{i,j}$ remains true for several seasons and can be considered a constant for the seasonal model.

For the first version of the forecast system we approximate and do not directly model nest site suitability. Results from the model are interpreted in the light of knowledge of 'traditional' breeding colony sites $Qbcs$.

$Qbcs_{i,j} = \sum_{allyears} Qbco_{i,j} \geq 1$, where $Qbco$ is Quelea breeding colony observation within a square.

To aid interpretation we plot, as darkened values, all squares where Quelea have never been observed.

Now food availability, $F_{i,j}$ is a transient parameter that changes in value through the season. Quelea feed mainly on dry seed from wild grasses and cultivated cereals. This food source is available from March to September, all over southern Africa, though not in sufficient quantity to enable breeding.

Some time between October and February, if more than 60mm rain falls within a two week period then seed germination will occur. This will initiate the growing season, and with no dry seed the birds leave the area for at least two months. If a total of 300mm rain falls, within this two month or longer period, there will be sufficient plant growth for seed to be set and become available as food.

Therefore food availability for Quelea is essentially seed availability, and it is rainfall driven.

4. THE RAINFALL MODEL

We now consider all of the relevant model squares, but drop i,j , the spatial subscript.

Weekly rainfall, the addition of seven separate daily rainfall values, is represented R_t , where subscript t is the date of the last day, a Sunday, which serves as our timestep marker. Hence R_{t-6} indicates the value of weekly rainfall six weeks before timestep t. We use the superscript k to indicate the summation of a number of weeks prior to timestep t, i.e. $R_t^k \equiv \sum_{l=0,-1,-..,-k} R_t^l \equiv (R_t + R_{t-1} + ... + R_{t-k})$

Now for seed germination G_t and seed setting S_t , the food availability F_t is given by,

$F_t = G_{t-6} + S_t$, where G_{t-6} indicates that seed germination occurred at least 6 weeks prior to t

and S_t is the occurrence of seed setting which needs the 6 weeks plant growth.

Now $G_t = R_t^1 > 60\,mm$, summation of one weeks data at time t plus the previous weeks data.

and $S_t = R_t^5 > 240\,mm$, summation of one weeks data at t with the previous 5 weeks data.

For the first version of the system we choose not to model nest availability. Without this probability value, the model is now based upon simple threshold values and so probabilities reduce to 1,0, just true or false. Hence, the Quelea breeding probability now equates to Food availability and is given by

$QB \equiv F = R_{t-6}^1 > 60mm + R_t^5 > 240mm$, and weekly rainfall is the only input parameter.

Most modern rainfall estimation systems use multi-spectral data from different remote-sensing platforms. However, for an operational system we need simplicity and we therefore just use $R = 3\times(CCD_{-38})mm$, where the symbol CCD_{-38} is Cold Cloud Duration data, from the Meteosat InfraRed channel, measured at a threshold of -38°C which is combined with the GOES precipitation index of 3mm rainfall per hour of CCD.

Then, the working model is

$$QB = \sum_{k=0,-1} (CCD_{-38})_{t-6}^k > 20hours + \sum_{k=0,-5} (CCD_{-38})_t^k > 80hours$$

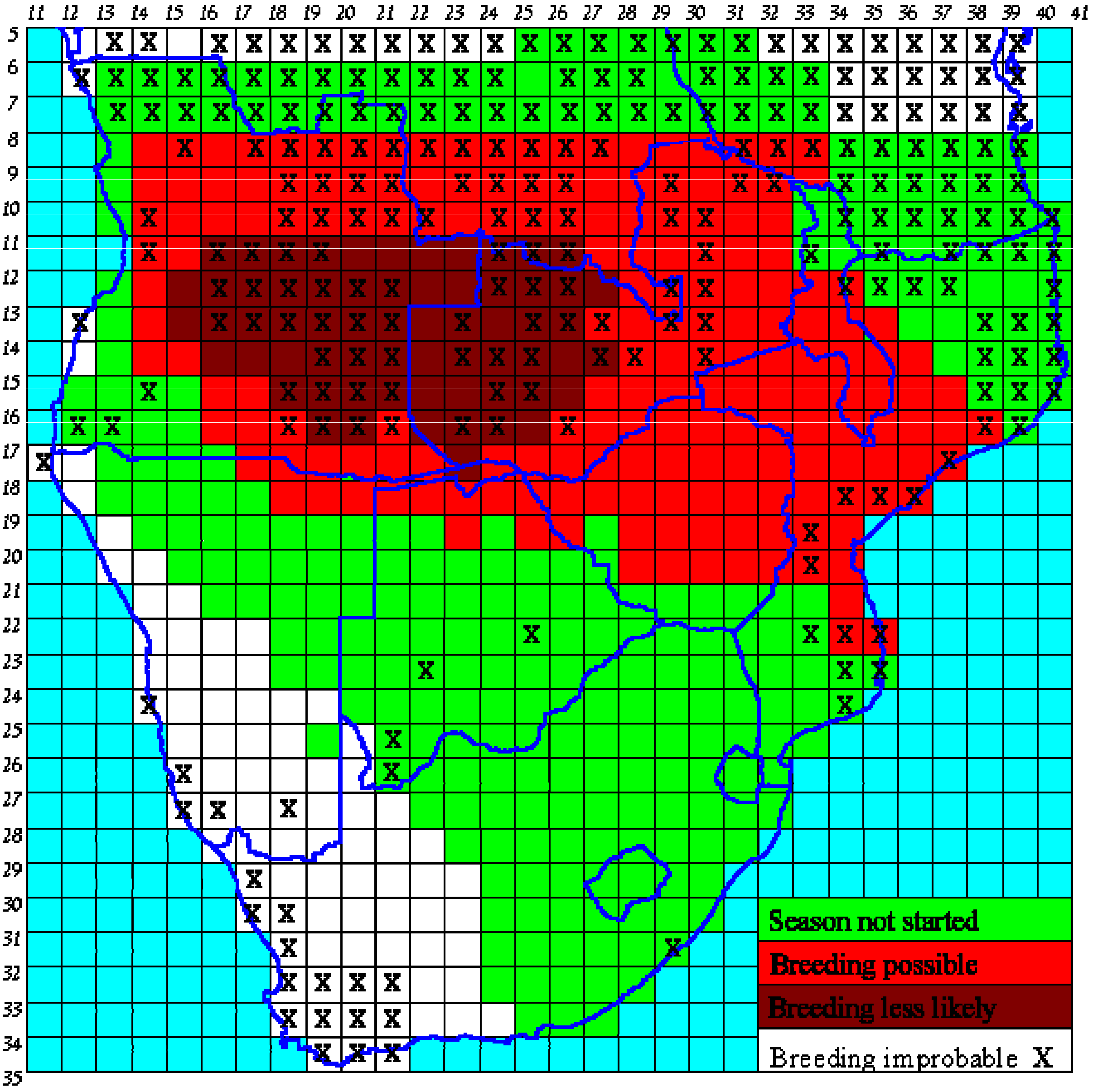
Meteosat IR data are obtained from our Bradford University Remote Sensing Ltd Primary Data User System which also runs the CCD evaluation software that was written for us by TAMSAT, University of Reading.

Initial intentions were that the model would be programmed in a Geographical Information System, Arcview. However, some organisations in Africa were already using the public domain software WinDisp to broadcast information on the internet and this approach was followed. The seven days of CCD values are archived each week and converted to IDA (Image Data Analysis) format for input to WinDisp. The data quality is first checked and then the WinDisp statistical function 'average' is used to extract values for all the pixels within the ½° by ½° squares of a grid map created in the DOS program IDA.

Now WinDisp is an image processing software package with powerful GIS functions but without the full GIS database facilities we needed some numerical back-end in which to program the model. We decided that it would enhance the clarity and transparency of the system to the end user if the model was programmed in Microsoft Excel. Past weeks' data and model values are copied to other sheets within the workbook by a weekly update macro. All of the model outputs are presented to the user through an internet browser.

This rainfall only model is run for each week of the season. The plot shown below is typical of the weekly forecast which is disseminated via the internet.

Figure 1. Output from the Quelea breeding forecast model: data for week ending Sunday 27th Jan 2002. We use this old low resolution data from our 2001/2002 season here since it gives a good greyscale image. The crosses indicate those areas where *Quelea quelea lathamii* have never been reported.

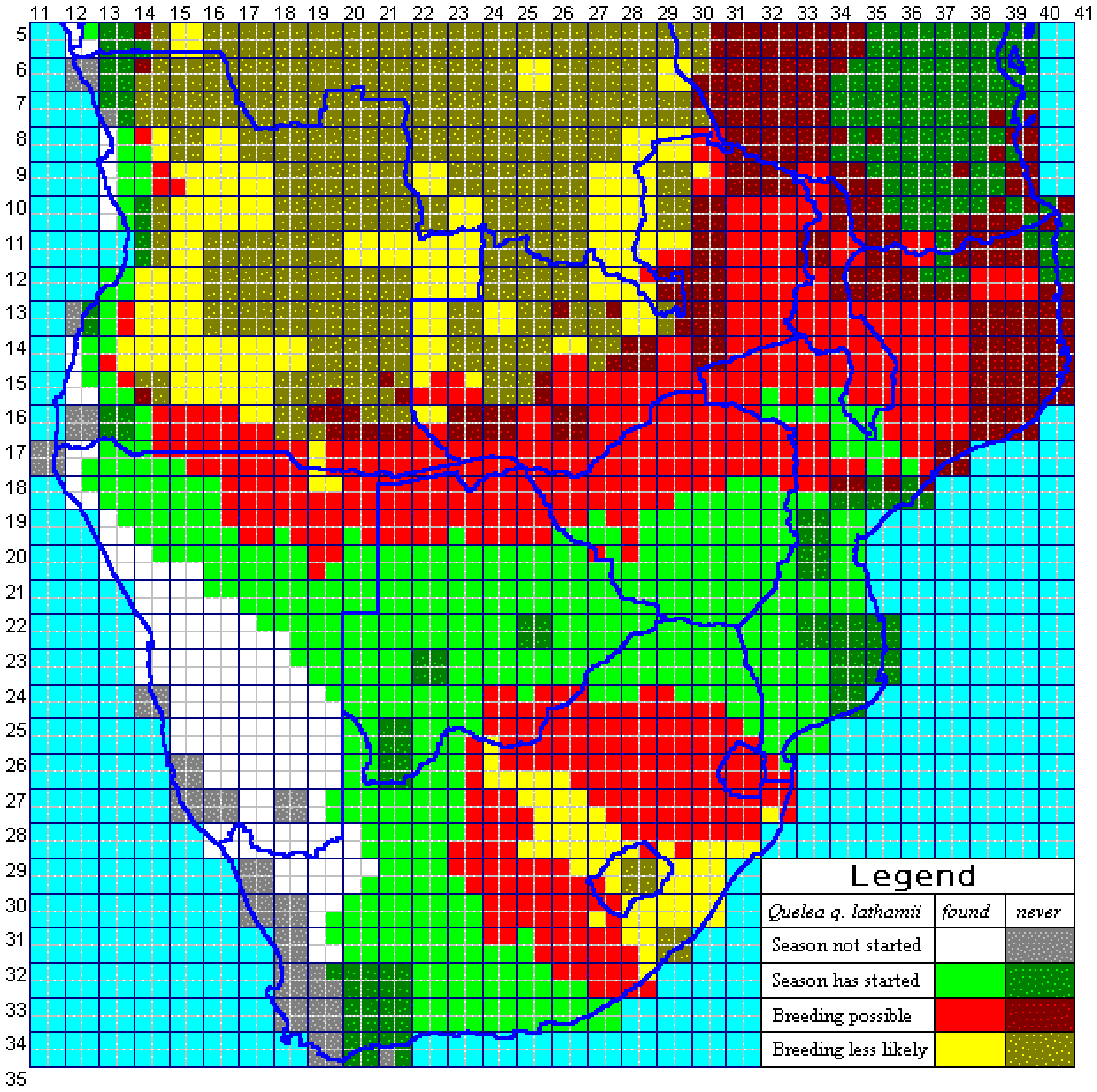


The model is quite successful. Most of the breeding colonies reported in the 2002/2003 season do occur in ‘breeding possible’ or ‘less likely’ squares. Those colonies in the ‘less likely’ squares should already have been monitored when they were flagged as being in ‘breeding possible’ squares, the non-arrival of birds noted and monitoring continued so that the colonies will be found.

There are many false positives recorded as a result of the decision not to model nest availability. For operational use we rely on the knowledge and records of the local Pest Control officer to ignore positions where nesting is not likely. There are a very few false negatives and we hope to show that these are associated with supplies of water that are not limited by local rainfall, like rivers or irrigation schemes.

We are pleased that this version of the model has been taken over by the Regional Remote Sensing Unit of SADC-FANR, Southern Africa Development Community – Food and Natural Resources Development Unit. They are still working to get the model online on the SADC website. In the meantime the model can be seen at *http://www-web.gre.ac.uk/directory/nri/quel*.

Figure 2. Output from the Quelea breeding forecast model: data for week ending Sunday 26th Jan 2003. Not a good greyscale image but it does indicate the full resolution and latest format. Darkened values instead of crosses now indicate those areas where *Quelea quelea lathamii* have never been reported.



5. MODEL DEVELOPMENT

Improvements to the Quelea breeding forecast system are planned:

1. We will work on nest site availability and this should make a full breeding probability model possible.

2. We plan to access MSG data and hope to use the extra channels for an improved rainfall estimate.

3. Exceptional generators of food availability, such as rivers or irrigation schemes, will be added to the system as separately modelled point sources.

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