Journal of Stored Products and Postharvest Research Vol. 2(4), pp. 72 – 78, April 2011
Available online http://www.academicjournals.org/JSPPR
ISSI 2141-6567 ©2011 Academic Journals

Full Length Research Paper

Modelling the occurrence of *Prostephanus truncatus* (Coleoptera: Bostrichidae) in Southern Malawi

Trust Kasambala[1]* and Peter Chinwada[2]

[1]University of Malawi, Bunda College of Agriculture, Crop Sciences Department, P. O. Box 219, Lilongwe, Malawi.
[2]Tobacco Research Board, Kutsaga Research Station, Crop Protection Division, Airport Ring Road, P. O. Box 1909, Harare, Zimbabwe.

Accepted15 February, 2011

Relative humidity and temperature, and *Prostephanus truncatus* trap catch data for Chikhwawa District in Southern Malawi and for the period 1996, 1997, 1999, 2002 and 2008, was fitted into a model of predicting *P. truncatus* abundance. Results showed that none of the climatic factors studied had a significant effect on *P. truncatus* abundance. In predicting the abundance of *P. truncatus*, the model underestimated the actual trap catches. However, the observed difference were not significant (X^2 test, asymptote significance = 1, P = 0.05). With serial *P. truncatus* trap catch data, the model has potential to predict the abundance of *P. truncatus*. There is the need to validate the model by using current climate data and *P. truncatus* trap catches from different agroecosytems.

Key words: *Prostephanus truncatus,* Bostrichidae, abundance.

INTRODUCTION

Maize*, Zea mays* Linnaeus, is an important food crop and contributes significantly to food security for the people of Malawi (Pingali, 2001). However, recurrent adverse weather conditions coupled with field pests and diseases contribute negatively to yields (Mugo et al., 2002). Storage pests further reduce the amount of crop that ultimately becomes available for consumption. These losses significantly affect the availability of the staple food to people if control measures are not applied. Technologies have been developed to reduce the impact of field pests and diseases (Langyintuo, 2004), but storage pests remain a problem. The storage insect pest, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) is the most destructive insect pest on stored maize in many parts of Africa (Farrell et al., 1996).

Before *P. truncatus* introduction in Malawi in 1991, post-harvest maize losses due to insect pests were estimated at an average of 6 to 14% after about 10 months in storage (Schulten, 2002). However, after *P. truncatus* introduction, post-harvest maize grain losses of up to 80% have been reported on shelled maize after six months of storage (Singano et al., 2007). It has been reported that *P. truncatus* destroyed up to 30% of cob stored maize within a period of 3-6 months (Helbig, 1995; Singano and Nkhata, 2004). In very intense cases of infestation, the stored maize can practically be completely destroyed; resulting in total loss of the staple food (Singano and Nkhata, 2004). Available literature on the control of *P. truncatus* in maize stores indicates that major emphasis has been on the use of insecticides. The increasing incidence of insecticide resistance (Perez-Mendoza, 1999) and environmental concerns about the use of chemical insecticides calls for the adoption of alternative sustainable pest management strategies.

However, the decision to employ a particular pest management measure lies solely with the farmer depending on circumstances and aspirations he has for his grain stock in a particular season (Hodges et al., unpublished data). However, before the farmer makes the decision, risks associated with production, marketing, legal and other aspects need to be taken into consideration. Production risk is considered to be the main source of risk that farmers face (Sivakumar, 2006). Hence knowledge of and use of climate data of a particular

*Corresponding author. E-mail: trustkasambala@yahoo.co.uk

geographical area is the most important risk management strategy.

This strategy includes the development of monitoring systems and response mechanisms to current weather. In this way, uncertainties about crop productivity can be reduced since farmers have the information about the environment within which they operate and know the likely outcome of alternative pest management measures. Computer simulations and models can provide such information which is particularly useful in quantitatively comparing alternative management options in areas where seasonal climate variability is high.

Studies done by Borgemeister et al. (1997) and Nansen and Meikle (2002) indicated that the numbers of *P. truncatus* flying around looking for food is strongly affected by climatic factors such as temperature and humidity. Fadamiro and Wyatt (1995) found that the frequency of flight take-off increased with temperature over the range 20 to 30˚C but decreased sharply at 35˚C. In addition, research has also shown that the number of *P. truncatus* trapped in pheromone-baited traps varies considerably between and within years (Rees, 1991; Giles et al., 1995; Borgemeister et al., 1997). Based on these findings, models have been developed to predict the occurrence and abundance of *P. truncatus* in different agro-climatic zones (Shires, 1979; Haubruge and Gaspar, 1990; Tigar et al., 1994; Giles et al., 1995; Hodges et al., 2003).

Shires (1979), and Haubruge and Gaspar (1990) produced maps of predicted *P. truncatus* distribution in Africa based on laboratory studies. Shires (1979) showed that optimal *P. truncatus* growth occurred at 32°C and 80% relative humidity while Haubruge and Gaspar (1990) showed that *P. truncatus* survived best at temperatures around 30°C, with relative humidities of above 60%. Tigar et al. (1994) presented a model for predicting *P. truncatus* abundance in East Africa but which was based on trap catches and climatic factors from Mexico. In their model, they found that the abundance of *P. truncatus* varied with the mean annual percentage relative humidity and temperature and the total annual rainfall. Based on this model, *P. truncatus* abundance could only be estimated on a yearly basis. This model predicted higher *P. truncatus* numbers in less hot, but drier areas, such as are found at higher altitudes. Giles et al. (1995) produced a model, also based on climatic factors (from data collected at Kiboko in Kenya). Unlike the Tigar et al. (1994) estimated monthly fluctuations in *P. truncatus* numbers.

The model developed by Hodges et al. (2003) first establishes the relationship between climatic variables and pheromone trap catches. The model makes use of bimonthly relative humidity, temperature and *P. truncatus* trap data. Using a mix of biological and empirical rules that operate on temperature and humidity data a rule based model was developed. The first part of the model estimates the numbers of beetles with potential for dispersal. The second part predicts the proportion likely to disperse. This is based on the apparent effect that those *P. truncatus* developing under low temperature conditions (about 24°C) have a lowered propensity for flight, a response previously observed in a related species. To analyse data generated by the model, cumulative sum of the mean (CUSUM) analysis was used. The model was previously validated using climate data and trap catches from a woodland–savannah zone and a short grass steppe zone in Ghana and Tanzania.

Hence, the study set out to test whether the model developed by Hodges et al. (2003) could be used to predict the occurrence of *P. truncatus* in Chikhwawa District in Southern Malawi.

MATERIALS AND METHODS

Study area

Chikhwawa district is found in the Southern Region of Malawi (16.02°S 34.50°E). It is part of what is referred to as the Lower Shire Valley in which altitude ranges from about 120 m in the north to 40 m in the south. The area lies in the rain shadows of Mulanje and Phalombe mountains and the watershed of the Shire and Zambezi rivers. Temperature averages 30°C while rainfall averages 740 mm in a year. In addition, the area is subjected to annual flooding and these waters are used for dry season crop cultivation. A little secondary vegetation cover exists in Chikhwawa (Msiska et al., 1994).

Source of climatic factors data and *P. truncatus* data

The model used in this study was developed by Hodges et al. (2003). In order to fit the model, climate data records for Chikhwawa (November 1996 to November 2002) (MET, 2008) and *P. truncatus* trap catch data from Bvumbwe Agriculture Research Station (1996, 1997, 1999, 2002 and 2008) were used. Climate data records for Chikhwawa district were obtained from the Department of Meteorology Headquarters in Blantyre.

Data analysis

Data analysis procedures described by Hodges et al. (2003) were adopted in the present study. In exploring the relationship between *P. truncatus* trap catch and climatic variables, linear regression, Chi-square and cumulative sum of means (CUSUM) analysis were used. CUSUM charts were constructed by calculating and plotting a cumulative sum based on the data. By letting X1, X2… Xn represent *n* data points, the cumulative sums S0, S1… Sn were calculated. Notice that n data points leads to n+1 (0 through n) sums. The cumulative sums were calculated as follows:

1. First the average was calculated using the formulae below:

$$\overline{X} = \frac{X_1 + X_2 + \ldots + X_n}{n}$$

2. Then the cumulative sum was set at zero by setting S0 = 0.
3. The cumulative sums were calculated by adding the difference between current value and the average to the previous sum, that is,

$$S_i = S_{i-1} + \left(X_i - \overline{X}\right)$$

For i =1,2,…n

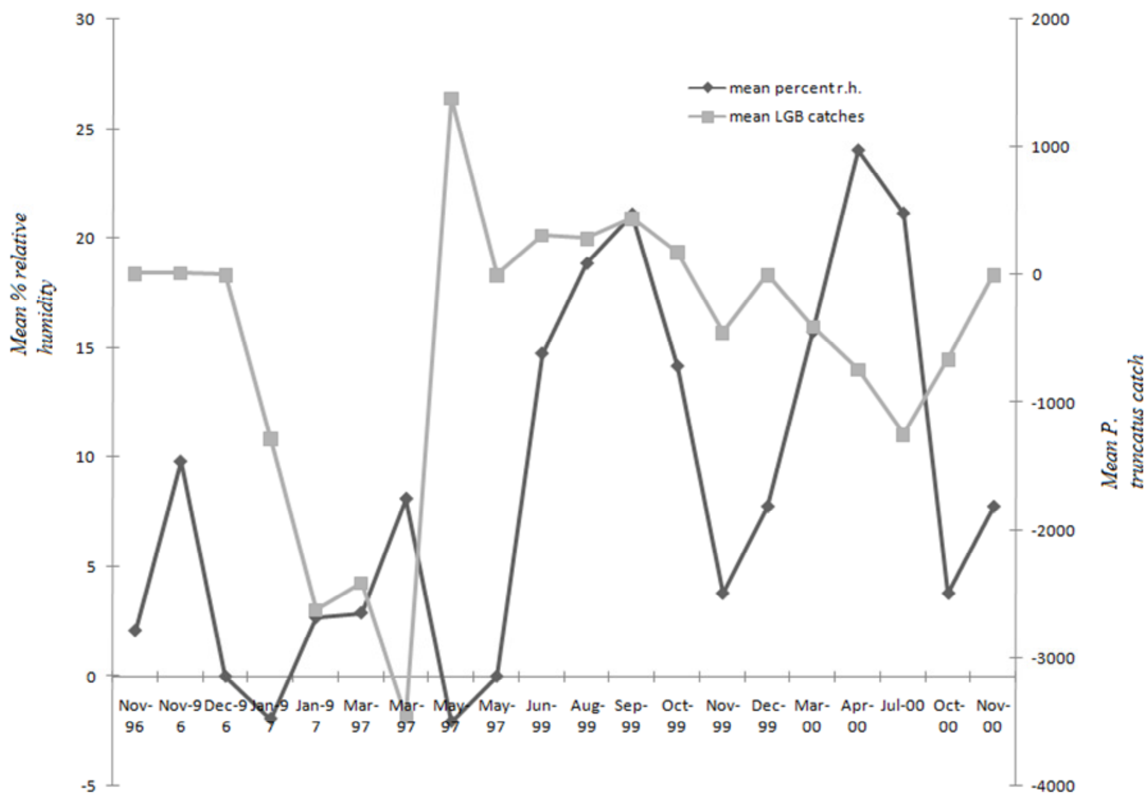

Figure 1. CUSUM plot for mean percentage relative humidity and *P. truncatus* trap catches for Chikwawa (1996, 1997, 1999 and 2000).

The cumulative sum is not the cumulative sum of the values. Instead it is the cumulative sum of differences between the values and the average. Because the average is subtracted from each value, the cumulative sum also ends at zero (Sn = 0).

When looking at CUSUM plots, the absolute values are not important; the slope of lines conveys the meaningful information (Hodges et al., 2003). A segment of the CUSUM chart with an upward slope indicates a period where the values tend to be above average and vice versa. Hence, CUSUM analysis enabled easy comparison between years and gave clues on relationships between some variables. Where bimonthly *P. truncatus* trap catch data were available, mean bimonthly temperatures were used. However, where only monthly *P. truncatus* trap catch data were available, the monthly mean temperature was used. This procedure was also followed for relative humidity.

RESULTS

Influence of climatic factors on *P. truncates*

In 1996 and 1999 (Figure 1), a decrease in *P. truncatus* catches was associated with a decrease in relative humidity. There was no clear relationship between *P. truncatus* catches and relative humidity in 1997 and 2000.

In the case of temperature, there was no consistent pattern between variation in temperature and change in *P. truncatus* catch during the study period (Figure 2).

For instance, an increase in mean temperature was associated with a decrease in *P. truncatus* caught in 1997 and October 1999/March 2000 while for the latter part of 2000, an increase in temperature was associated with an increase in *P. truncatus* caught.

As with temperature, there was also no consistent pattern between change in mean rainfall and *P. truncatus* catch (Figure 3).

In order to determine which of the climatic factors was significant in explaining the observed *P. truncatus* catches, linear regression was carried out. Analyses of climatic data (mean rainfall, mean windrun, mean temperature and mean percentage relative humidity) indicated that none of the climatic variables could be used directly in predicting *P. truncatus* trap catches (Table 1)

Predictions given by the Hodges [et al. (2003)] model

Generally, model underestimated the actual catches as Table 2 shows. However, the observed difference were not significant (X^2 test, asymptote significance = 1, P = 0.05). The graphs of predicted versus potential dispersing population were compared with the graph of actual catches (Figure 4).

Analysis of yearly *P. truncatus* and *Teretriosoma nigrescens* trap catch (Table 3) showed that the population of the natural enemy of *P. truncatus* remained substantially low as compared to *P. truncatus* population.

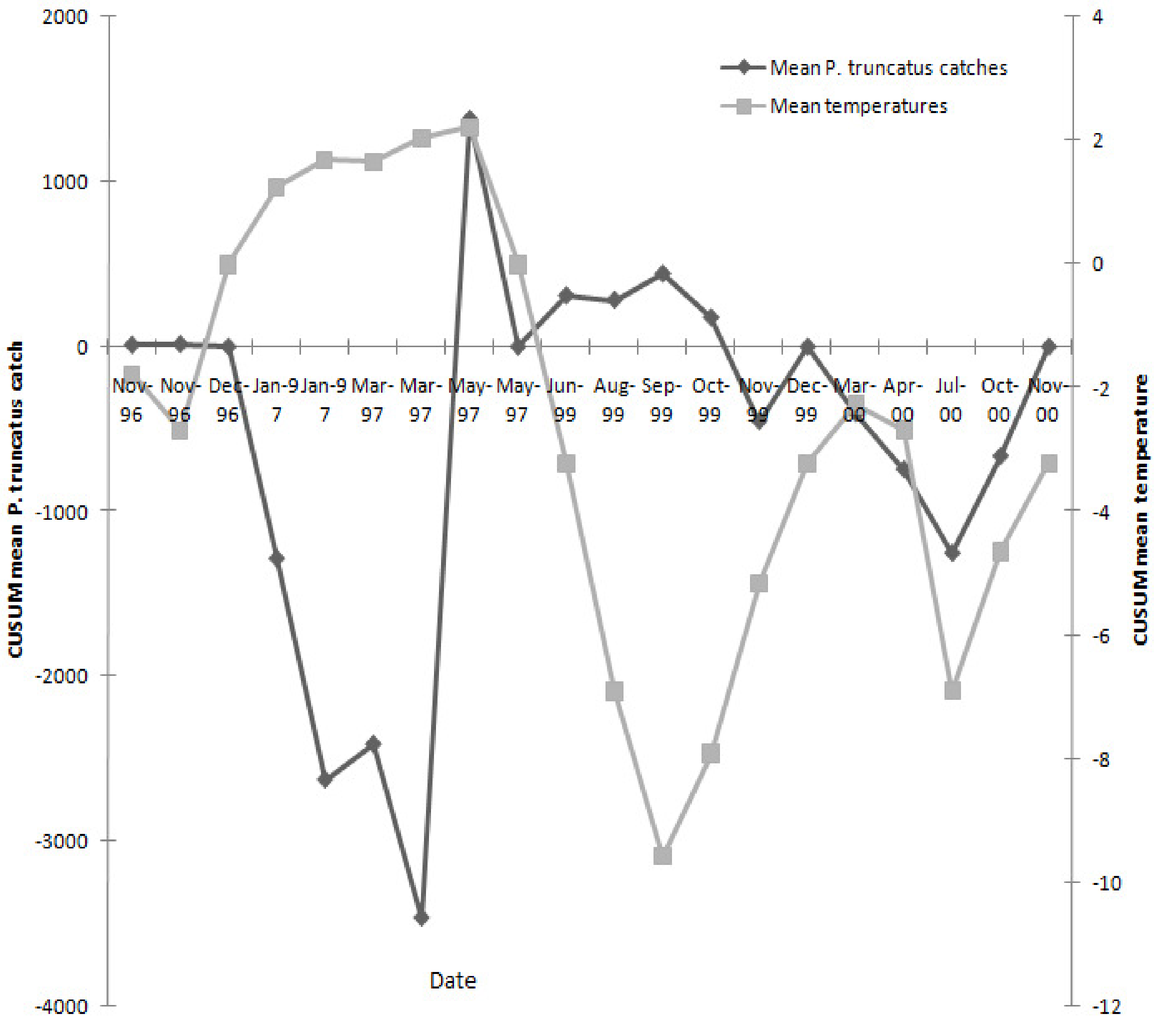

Figure 2. CUSUM mean temperature and *P. truncatus* trap catches for Chikwawa (1996, 1997, 1999 and 2000).

DISCUSSION

P. truncatus abundance was not significantly affected by any of the climatic factors studied. In contrast, studies done elsewhere indicated that *P. truncatus* abundance is influenced by climatic factors such as temperature and relative humidity (Shires, 1979; Haubruge and Gaspar, 1990; Tigar et al., 1994; Giles et al., 1995; Borgemeister et al., 1997; Hodges et al., 2003; Nansen et al., 2001). Tigar et al. (1994), in Mexico, found that a *P. truncatus* abundance varied with mean annual percentage relative humidity, temperature and total annual rainfall. Hence, according to this observation, higher *P. truncatus* numbers are expected in less hot, but drier areas, such as are found at higher altitudes. Chikhwawa District does not experience pronounced variation in temperatures. Monthly temperature averages 30℃ for the greater part of the year (Msiska et al., 1994; MET, 2008). In addition, Chikhwawa is at low altitude, 100 m above sea level; and is very hot and dry even during the coolest months in Malawi (Masangwi et al., 2010). Therefore, the impact of temperature and relative humidity on *P. truncatus* growth and development and consequently abundance could not be expected to be very significant.

The other contributing reason to the discrepancy observed could be attributed to the starting *P. truncatus* population (known as scaling factor for the environment in question) used in the model. Since *P. truncatus* trap catch data used in this study was not detailed, the scaling factor was adopted from that of Hodges et al. (2003). This may have affected the efficiency of the model because as Hodges et al. (2003) pointed out that habitat suitability for a pest is more complex than just measures of temperature and relative humidity.

On the other hand, the model was accurate in its predictions for the period November 1996 to July 1997, because the shape of the curves closely matched (Figure 2). The model was also accurate in predicting that there would be a peak between the months of May and July 1997 and that *P. truncatus* catches in the following years

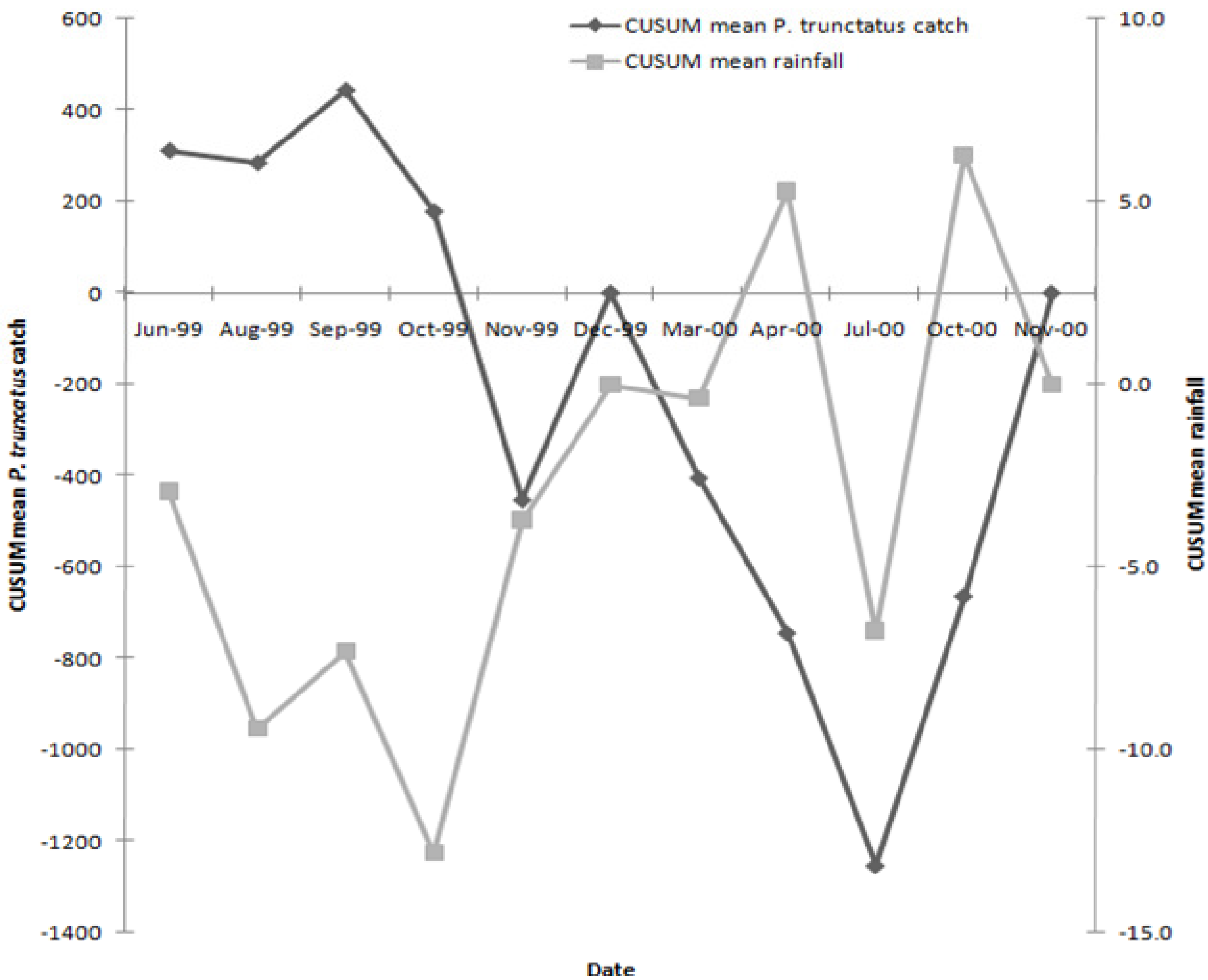

Figure 3. CUSUM of mean rainfall and *P. truncatus* catch for Chikwawa (1999/2000).

Table 1. Linear regression of climatic factors on *P. truncatus* trap catch for Chikwawa for the period November 1996 to November 2000.

Variable	b*	F	P
Mean % relative humidity	0.099	0.159	0.696
Mean temperature	0.122	0.114	0.893
Mean windspeed	-0.099	0.09	0.771
Mean rainfall	0.342	1.196	0.303

b* Standardized regression coefficient (*P* = 0.05).

would be below this peak. This observation was similar to what Hodges et al. (2003) found in Ghana.

Conclusion

Mean monthly temperatures, total annual rainfall, mean monthly percentage relative humidity and windspeed could not be used to explain the occurrence of

Table 2. *P. truncatus* numbers in Chikwawa (1996-2000) based on the Hodges [et al. (2003)] model and actual trap catches.

Month	Model	Actual
Nov-96	240	114
Dec-96	240	86
Jan-97	496	195
Mar-97	1207	1983
May-97	1415	6285
Jun-99	253	980
Aug-99	12	642
Sep-99	12	828
Oct-99	15	403
Nov-99	36	39
Dec-99	297	1121
Mar-00	433	209
Apr-00	14	275
Jul-00	178	105
Oct-00	46	1202
Nov-00	178	1276

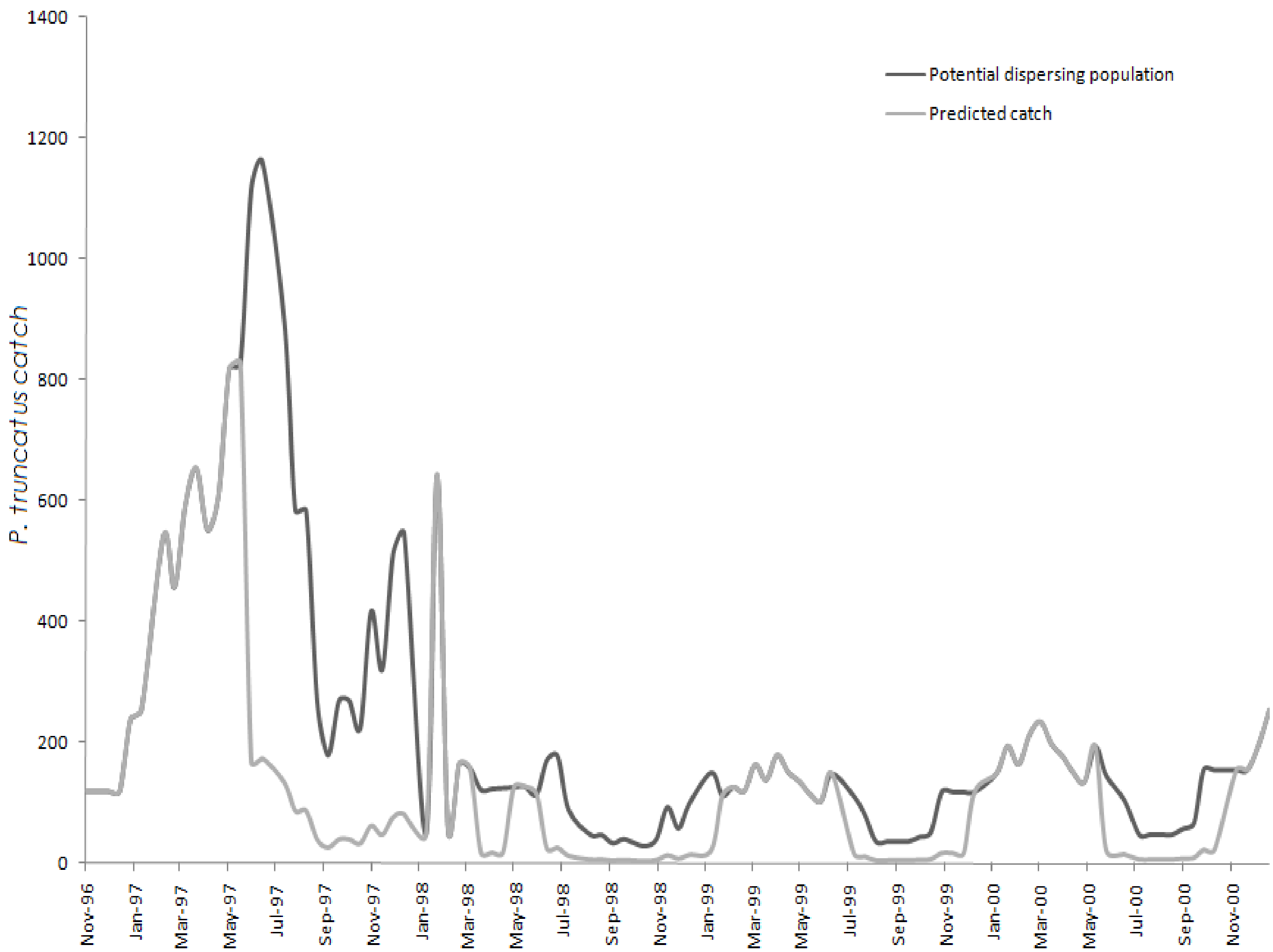

Figure 4. Potential dispersing and predicted numbers of flying *P. truncatus* for Chikwawa.

Table 3. *P. truncatus* and *Teretriosoma. nigrescens* trap catches in Chikwawa (1996-2002).

Year	*P. truncatus*	T. *nigrescens*
1996	7952	No data
1997	73048	No data
1998	139772	0
1999	119367	389
2000	13795	248
2001	29969	402
2002	4562	361

P. truncatus in Chikhwawa District. With consistent *P. truncatus* trap catch data, and relative humidity and temperature data, the model developed by Hodges et al. (2003) has the potential to predict accurately the occurrence of *P. truncatus*. There is the need to validate the model with current *P. truncatus* trap catch and climate data.

ACKNOWLEDGEMENTS

I am indebted to the International Centre for Insect Physiology and Ecology (ICIPE) for funding my coursework and the entire research process. I also thank Dr Peter Chinwada and Dr Brighton Mvumi for excellent supervisory work. I also thank Dr Rick Hodges for allowing me to use the model. I acknowledge the support of Mr Dylo Pemba and entire staff of Biology Department, Chancellor College, University of Malawi; and Mr Matsika and all staff of the Biological Sciences Department, the University of Zimbabwe.

REFERENCES

Borgemeister C, Meikle WG, Scholz D, Adda C, Degbey P, Markham RH (1997). Seasonal and weather factors influencing the annual flight cycle of *Prostephanus truncatus* (Coleoptera: Bostrichidae) and its predator *Teretriosoma nigrescens* (Coleoptera: Histeridae) in Benin. Bull. Entomological Res., 87: 239-246.

Fadamiro HY, Wyatt TD (1995). Flight initiation by *Prostephanus truncates* (Coleoptera: Bostrichidae) in relation to time of day, temperature, relative humidity and starvation. Entomologia Experimentalis et Applicata, 75: 273–277.

Farrell G, Hill MG, Nang'ayo FLO, Stabrawa A (1996). A review of investigations to improve pest management of stored maize in smallholder farms in Kenya. Integrated Pest Manage. Rev., 1: 251-263.

Giles PH, Hill G, Nang'ayo F, Farrell G, Stabrawa A, Wekesa P (1995) Entomological socio-economic investigations for the development of Integrated Pest Management strategies against *Prostephanus truncatus*. UK/Kenya Larger Grain Borer Research Project Report, 273 pp. Natural Resources Institute, Chatham, U.K

Haubruge E, Gaspar C (1990). Détermination en laboratoire des zones favorables au dévelopement des populations du grand capucin du grain, *Prostephanus truncatus* (Horn), en Afrique. L'Agronomie Tropicale, 45: 251-258.

Helbig J (1995). The ecology of *Prostephanus truncatus* in Togo with particular emphasis on interaction with the predator Teretriosoma nigrescens. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn.

Hodges RJ, Addo S, Birkinshaw L (2003). Can observation of climatic variables be used to predict the flight dispersal rates of *Prostephanus truncatus*? Agric. For. Entomol., 5: 123–135.

Langyintuo A (2004). The impact of maize breeding research project. Proceeding of a Malawi maize sector stakeholders workshop, 17 March 2004, Lilongwe, Malawi. 40 pp.

Masangwi SJ, Ferguson NS, Grimason AM, Kazembe LN, Morse TD (2010). Care seeking behaviour and implications for malaria control in Southern Malawi. South Afr. J. Epidemiol Infection. 25(4): 22-26.

Meteorological Department (MET) (2008). Agrometeorology data. Chichiri, Blantyre, Malawi. pp. 4

Msiska HDC, Munthali JT, Dzowela BH (1994). The epidemiology, distribution and control of Helminth parasites of ruminants in Malawi. FAO Corporate document repository. www.fao.org.

Mugo S, Songa J, DeGroote H, Hoisington D (2002). Insect resistant maize for Africa (IRMA) project: an overview. Proceeding of a Symposium on "Perspectives on the Evolving Role of Private/Public Collaborations in Agricultural Research." Syngenta Foundation for Sustainable Agriculture, Washington, D.C., USA, 25 June 2002, the Syngenta Staff in Greensboro, NC, USA, June 26 2002, and to the Syngenta staff in Basel, Switzerland, 27 June 2002.

Nansen C, Korie S, Meikle WG, Holst N (2001). Sensitivity of *Prostephanus truncatus* (Horn) (Bostrichidae: Coleoptera) flight activity to environmental variables in Benin, West Africa. Environ. Entomol. 30: 1135-1143.

Nansen C, Meikle WG (2002). The biology of *Prostephanus truncatus*. J. Integrated Pest Manage. Rev., 7: 91-104.

Perez-Mendoza J (1999). Survey of insecticide resistance in Mexican populations of maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). J. Stored Prod. Res., 34: 107–115.

Pingali PL (ed.). (2001). CIMMYT 1999-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector: CIMMYT, Mexico: D.F

Rees DP (1991). The effect of *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae) on three species of storage Bostrichidae infesting shelled maize. J. Stored Products Res., 27: 83–86.

Schulten GGM (2002). Post-harvest losses in tropical Africa and their prevention. http://www.unu.edu/Unupress/food/8F042e/8F042E02.htm.

Singano CD, Nkhata BT (2004). Data on larger grain borer insect collected from three districts in the southern region of Malawi using pheromone traps. Bvumbwe Agricultural Research Station, Thyolo, Malawi. 7 pp.

Singano, C.D., Nkhata, B.T., Magombo, H. and Tembo, M.O. (2007). Larger grain borer monitoring and *Teretrius nigrescens* rearing and release for the southern region of Malawi. Bvumbwe Agricultural Research Station, Thyolo, Malawi. 8 pp.

Sivakumar MVK (2006). Introductory note to the international workshop on agrometeorological risk management: Challenges and Opportunities. CAgM/MMG-2/Doc. 10.1, ANNEX I, New Delhi, India. p. 2.

Shires SW (1979). Influence of temperature and humidity on survival development period and adult sex ratio in *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). J. Stored Prod. Res. 15: 5-10.

Tigar BJ, Osborne PE, Key GE, Flores SME, Vazquez AM (1994). Distribution and abundance of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) and its predator *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae). Bull. Entomological Res., 84: 555-565.