Warning farmers when the risk of infestation by *Prostephanus truncatus* is high

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Abstract

Prostephanus truncatus (Horn) (Coleoptera: Bostrichidae) is a serious beetle pest of the maize and cassava stored by small-holder farmers. Pheromone trapping studies have shown that the abundance of flying beetles varies greatly both between and within years. In effect, both years and seasons may be good or bad for the infestation of farm stores by *P. truncatus*. This has lead to an initiative to develop a risk assessment system for the pest so that farmers can be warned in advance by extension services when they are at particular risk and so take appropriate action to minimise their losses. Experimental studies in Ghana and Tanzania and direct observations of farm stores in Ghana have shown that the incidence of infestation in stores is related to the numbers of beetles in the process of dispersal by flight. It has been possible to define curves relating the probability of infestation in stores to the cumulative catch of flying *P. truncatus* over the course of a storage season, although other factors such as previous infestation of stores can also be significant. In these experimental studies, dispersal by flight has been estimated using pheromone traps. However, the use of pheromone traps on a large-scale, to gather dispersal data is expensive and time consuming and in the long-term is unlikely to be sustainable. As a cheaper alternative, a rule-based model was developed to predict flight activity by using the relationship between beetle abundance and climatic variables. Once predictions of beetle numbers have been made and they exceed a threshold, derived from a curve predicting the probability that stores will become infestation, farmers can be warned to take action. As the model defines store infestation as the presence of a single beetle, it would be several months before serious damage would be expected, thus giving a reasonable lead-time for pest management action. The role of the risk warning system as an essential decision making tool for the integrated pest management of *P. truncatus* is discussed.

1. Introduction

Prostephanus truncatus (Horn) (Coleoptera: Bostrichidae) is a serious beetle pest of the maize and cassava stored by smallholder farmers in the tropics (Hodges, 1986; Markham *et al.,* 1991). It originated in Meso-America and spread to Africa in the late 1970s. It can now be found in at least 16 African countries south of the Sahara (Farrell, 2000). The pest is particularly damaging, actively bore from grain to grain or through dried cassava roots, so that in parts of Africa where the pest is well established, it is considered to have increased average losses of farm-stored maize from less than 5% to approximately 10% per year (Dick, 1988). Besides attacking stored food, the pest has large populations in the natural environment where its main host is believed to be dead wood (Nang'ayo *et al.*, 1993). It would appear that *P. truncatus* exists in a patchwork of meta populations largely on dead wood, such as the seasonal die back (Nang'ayo *et al.*, 1993) and twigs girdled by cerambycids (Borgemeister *et al.*, 1998), and supplemented by the starch-rich maize and cassava found in farm stores.

Monitoring the incidence of *P. truncatus* using pheromone-baited flight traps has shown that the number of beetles trapped varies considerably between both seasons and years in Mexico (Rees, 1990), Kenya (Giles *et al.*, 1995) and Benin (Borgemeister *et al.*, 1997). There are in effect 'good' and 'bad' years for this pest. Recent examples of bad years are 1998 in Tanzania (W. Riwa pers. comm.), 1999/2000 in northern Ghana (F. Andani, pers. comm), and 2001/2002 in Eastern Kenya (G. Kibata, pers. comm). For this reason we set about developing a risk assessment system so that bad years for attack by this pest could be predicted and those responsible for helping farmers could advise them accordingly.

2. What factors affect whether or not stores become infested?

Several factors may affect whether a store becomes infested by *P. truncatus*. However, of special importance is the number of *P. truncatus* flying around searching for food. Studies in Ghana, with experimental and real stores, have shown that the numbers of beetles flying around during the period of storage is directly related to the probability that the maize or cassava in any given store will become infested (Birkinshaw et al., in press).

The numbers of beetles flying was determined using a flight trap baited with *P. truncatus* pheromone. The probability of stores becoming infested is directly related to the increasing (cumulative) catch over time (Fig. 1). In the case shown in Figure 1, roughly 50% of stores would have at least one beetle in them after cumulative catch had reached 3,800 (irrespective of how long it took to reach this number). One beetle is not an infestation that is likely to be noticed by a farmer but once a male arrives at a new food source it releases a chemical scent (pheromone) that attracts other males and females and the food source may soon become heavily infested. Thus in a few months there could be significant food losses.

The relationship that has been described between cumulative trap catch and likelihood that a store will become infested is consistent with the known host selection behaviour of the pest. *P. truncatus* is not attracted to maize or cassava at long range but locates its food by making test burrow into anything soft enough to be bored (Hodges, 1994; Hodges et al., 1999). Thus the more beetles there are searching for stored food in any given storage season, the greater the chance that one will find it.

3. How to predict when there will be a bad year

The numbers of beetles flying around looking for food is strongly affected by climate (Borgemeister et al. 1997; Nansen et al., 2002). A rule-based model of the relationship between climate and the number of beetles flying has been developed so that numbers of beetles flying can be predicted (Hodges et al., in preparation). To make predictions using the model requires access to a computer with a spreadsheet program and suitable climate data from a Meteorological station. Between 1996 and 2001 in the Volta Region of Ghana there have been two bad years for *P. truncatus* (Fig. 2). The model was able to predict both of these. Further, the model was able to make an accurate prediction of flight activity levels in Tanzania and show 1998 as a very 'bad year' (Fig. 3).

To predict whether farmers might suffer significant attack by *P. truncatus* it is necessary to check the cumulative numbers of flying beetles over specific storage periods. In Ghana around Hohoe in the Volta Region, there are two maize harvests, the major and the minor, with associated storage periods from September to January and

December to July respectively. The predicted cumulative numbers of flying beetles during the storage of the major and minor harvests over three years were very similar to the actual numbers flying as determined by pheromone traps (Fig. 4).

Once predictions of beetle numbers have been made and they exceed a predetermined threshold, based on the known probabilities of store infestation, then farmers can be warned to take action. Either to market their maize and dried cassava early to avoid losses or invest in suitable pest management action. As store infestation is defined as the presence of a single beetle, it would be several months before serious damage would be expected, this gives a reasonable lead-time for pest management action. If we take a cumulative dispersal of 3,800 as the pest management action threshold, then in the case of the major season harvest in Hohoe, even in the worst year 1999/00 the cumulative beetle dispersal did not reach this level until December (Fig. 4). This was within a month of the end of the storage period, so it is unlikely that there would be serious losses unless farmers decided to store for longer than usual. However, during the minor season in both 1998/99 and 1999/00 the threshold was reached within the first two months of storage with the prospect of several months storage thereafter. The chances of serious damage in these two years was therefore high. In contrast in the 1997/98 minor season, the threshold was not reached until about May, close to the end of storage so little serious damage would be expected.

To implement the risk warning system in a particular locality will require a source of climate data, this would normally be available from the local meteorological station and access to a computer with a spreadsheet program (Excel). Initially, some trapping data for the area in question are needed to compare with model predictions to ensure that the model works well. For the system to trigger a warning, a pest management threshold has to be set. This needs to take into account local conditions since 1) some stores types offer better protection from beetle attack than others and 2) the length of time that farmers leave their crop in the field after maturity affects the extent of pre-harvest infestation and hence the proportion of stores infested at the time of loading.

4. Risk warning system in the context of integrated pest management for *P. truncatus*

The risk warning system will be of particular value in situations where farmers have a choice of pest management options based on the prediction of risk. For the type of smallholder farmer at risk from *P. truncatus* attack, the following options could include

- sell the maize stock within three months so that specific pest management measures are not needed.
- treat the whole stock with pesticide either maize cobs sprayed with, or dipped in, an emulsion or dusted with dilute dust layer by layer Shelled grain would be treated with dilute dust.
- treat only a portion of the stock with pesticide. If some of the grain is to be stored for less than three months then this may not require any pesticide treatment. The grain to be treated should be placed at the base of the store where insect infestation pressure is greater (Hodges et al., 1999), while the untreated grain is at the top and so may be easily removed for consumption or sale.
- treating the commodity with pesticides of plant origin. Farmers use a range of botanical pesticides and these vary in efficacy according to their mode of application, time of year of collection and area of collection. They may be recommended depending on the risk of attack and the circumstances of the farmer, e.g. availability of botanicals, ability to afford more effective alternatives etc.
- inert dusts to help limit pest attack. A thick layer of paddy husk ash covering the stock is effective in preventing attack. Commercial preparations of diatomaceous earths are effective in dry areas against several pest species and are currently being tested for their efficacy against *P. truncatus*.
- adopting sealed storage systems, such as mud silos or the mudding of traditionally unmudded structures. Such sealed storage can provide a very effective barrier to pest attack and can be adopted in situations where the stock is sufficiently dry that good ventilation is not required. This has been achieved with several communities in northern Ghana who do not traditionally use mudded structures (Fuseini Andan, pers.

comm.). Use of mudded structures may be combined with the use of synthetic pesticides or botanicals according to risk.

The circumstances of individual farmers and the aspirations they may have for their grain stock in any particular season will vary, as does the risk of infestation by *P. truncatus*. One means of choosing which of a range of possible pest management options to use would be to use a decision tree that takes into account the options available and the prevailing circumstances. An example of such a tree for the pest management of *P. truncatus* has been published by Farrell et al. (1996) and an example of one in which the risk warning system has been included is shown in Figure 5. Both in East and West Africa, farmers tend to leave their maize in stores for extended periods (sometimes exceeding eight months) because maize prices on rural and urban markets are lowest immediately after the harvest and highest into the 'lean' season when there is little maize available (Compton *et al.*, 1998). Field work in Tanzania, Kenya and central Benin, all in relatively hot dry areas, suggests that if maize is to be stored for less than 5 months then use of pesticide was probably not justified (Henckes, 1992; Farrell, 1996; Meikle et al., in press), whereas in southern Benin and southern Ghana (Meikle et al., in press; S. Addo pers. comm.) this period is likely to be three months. This conclusion was based on the break-even point between the value of losses and the costs of treating grain with a dilute dust insecticide. As the value of maize and cost of pesticide treatment changes from year to year then the break-even for pesticide treatment needs to be recalculated from time to time. This would be a job for the extension services that advise subsistence farmers.

Looking at the decision tree (Fig. 5) it can be seen that if the storage period was to be greater than three months then knowledge of the previous history of *P. truncatus* infestation in a store is important. If there was *P. truncatus* in the store during the previous year then the risk of infestation again in the current year is higher and the admixture of a dilute dust insecticide is recommended. However, if no *P. truncatus* were observed last year then regular inspection is required. If the pest is found subsequently, then grain shelling and insecticide treatment are required. The tree could be developed much further to include more of the options listed above to enable farmers to select options that are appropriate to their circumstances and minimise losses of grain quality and quantity. It is planned that this decision approach to pest management will be implemented as part of project activities of the UK DFID's Crop Post Harvest Programme in West Africa.

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Figure captions

Figure 1: Estimates of how cumulative *P. truncatus* trap catch corresponds to the probability that barns are infested, determined using experimental stores (lines) in Ghana and Tanzania, and actual cassava stores in five villages (symbols) in Ghana. Taken from Birkinshaw et al. (in press).

Figure 2: Mean *P. truncatus* catch of twenty pheromone traps in the Volta Region (Hohoe) of Ghana from 1996 to 2001 and the catch predicted by a rule based model (Hodges in preparation)

Figure 3: Mean *P. truncatus* catch of nine pheromone traps close to Morogoro (Tanzania 1997 to 1999 and the catch predicted by a rule based model (Hodges in preparation)

Figure 4: Mean cumulative catch of *P. truncatus* from twenty pheromone traps the Volta Region (Hohoe) of Ghana during the major and minor season maize harvests of 1997 to 2000 and the cumulative catch during the same periods predicted by a rule based model (Hodges in preparation)

Figure 5: An example of a decision tree to help extension services advise farmers on the protection of their maize against *Prostephanus truncatus*

Figure 1

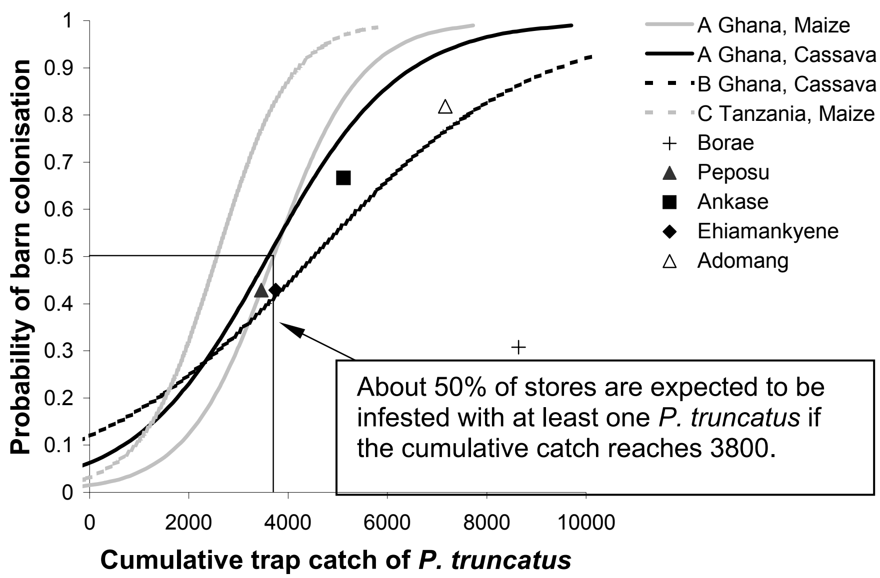
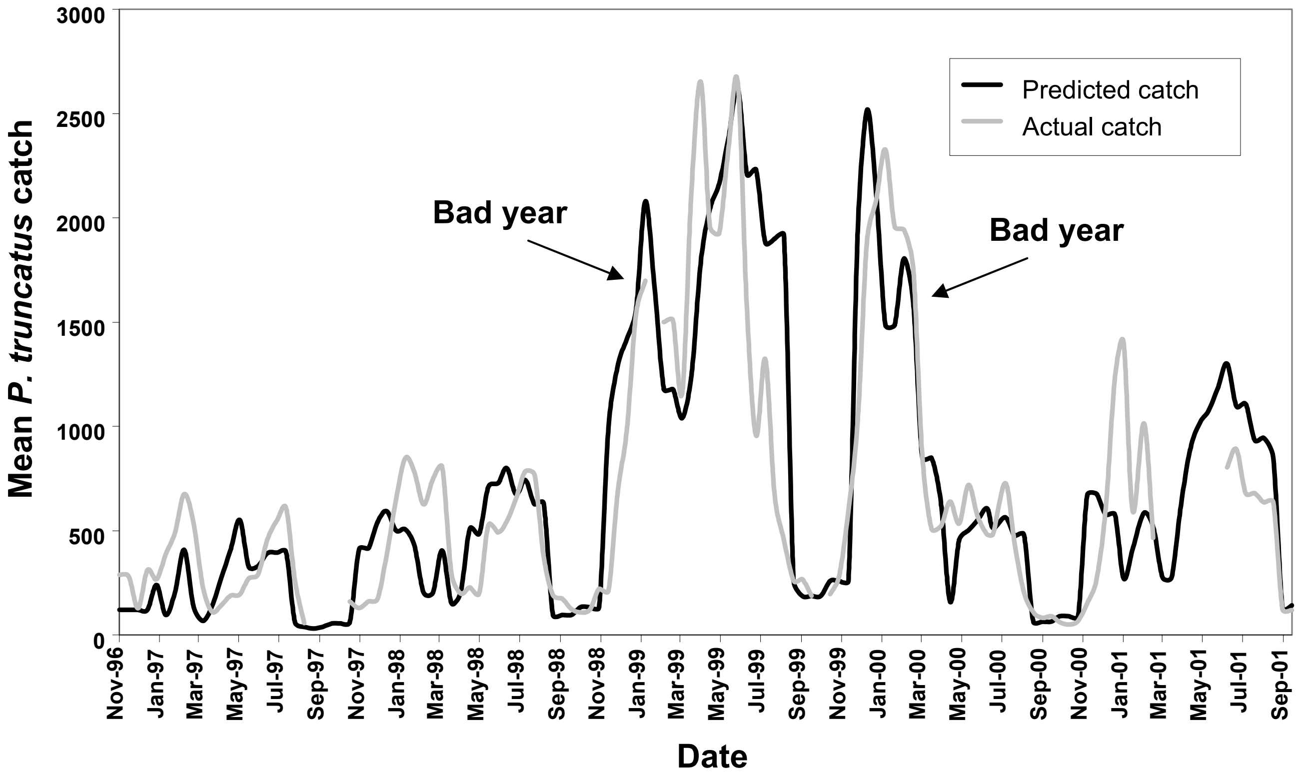
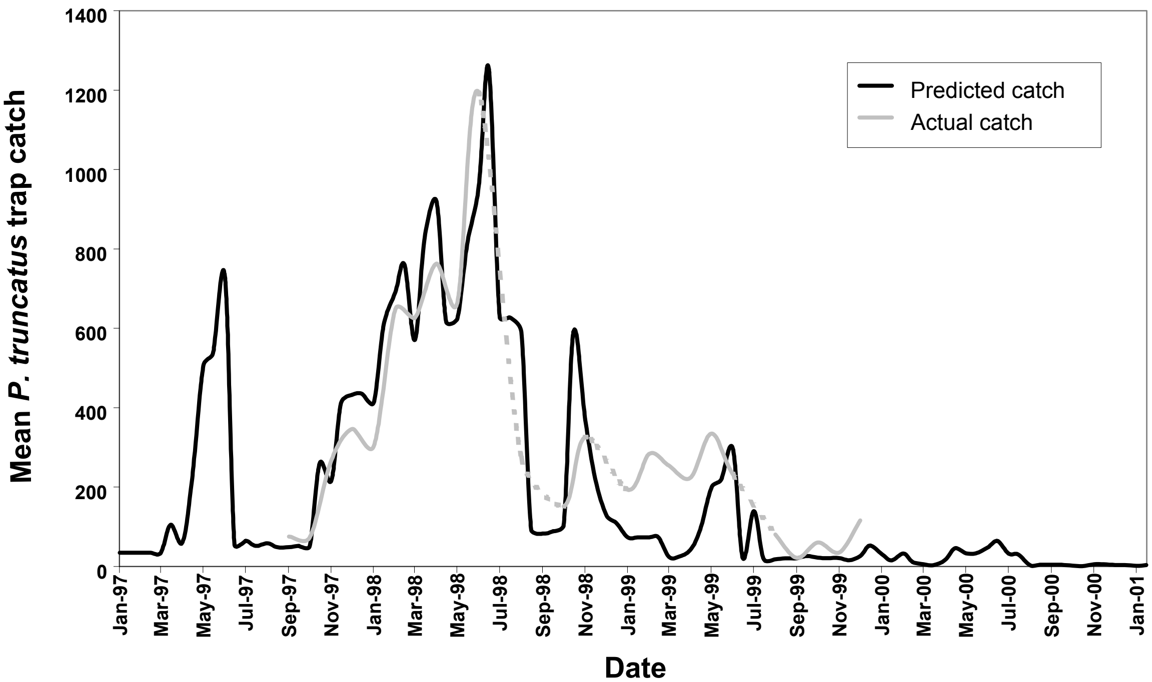

Probability of barn colonisation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2000
4000
6000
8000
10000
Cumulative trap catch of *P. truncatus*
A Ghana, Maize
A Ghana, Cassava
B Ghana, Cassava
C Tanzania, Maize
Borae
Peposu
Ankase
Ehiamankyene
Adomang
About 50% of stores are expected to be infested with at least one *P. truncatus* if the cumulative catch reaches 3800.

Figure 2



Predicted catch
Actual catch
Bad year
Bad year
Mean P. truncatus catch
Date
3000
2500
2000
1500
1000
500
0
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Nov-97
Jan-98
Mar-98
May-98
Jul-98
Sep-98
Nov-98
Jan-99
Mar-99
May-99
Jul-99
Sep-99
Nov-99
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01

Figure 3



1400
1200
1000
800
600
400
200
0
Mean *P. truncatus* trap catch
Predicted catch
Actual catch
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Nov-97
Jan-98
Mar-98
May-98
Jul-98
Sep-98
Nov-98
Jan-99
Mar-99
May-99
Jul-99
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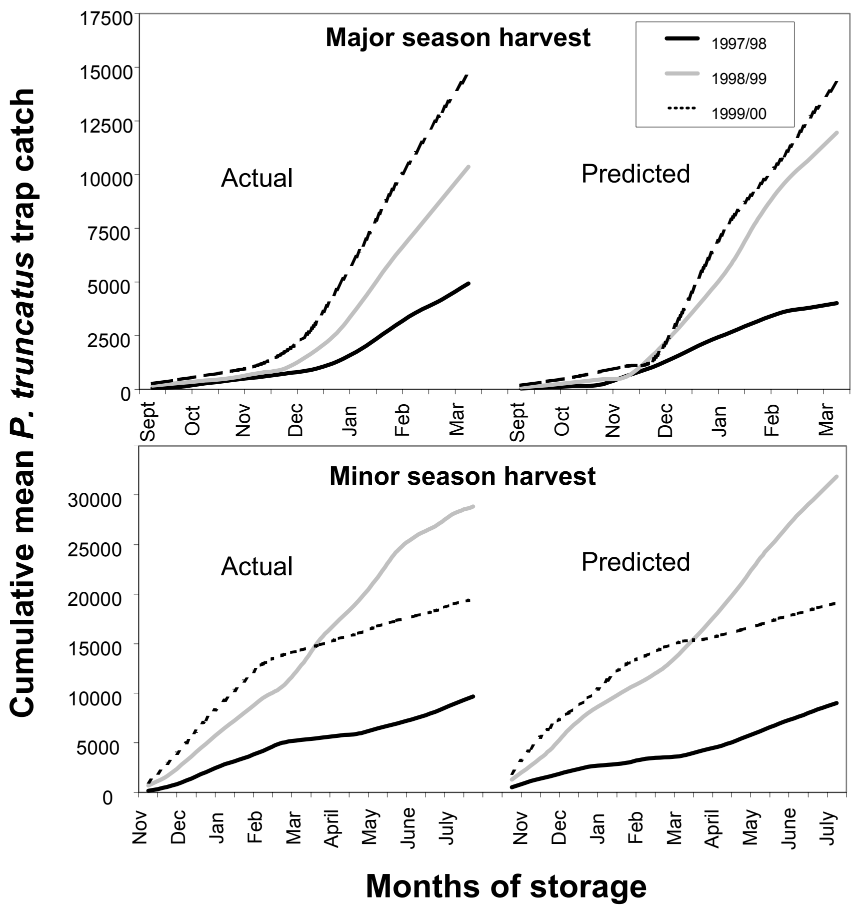
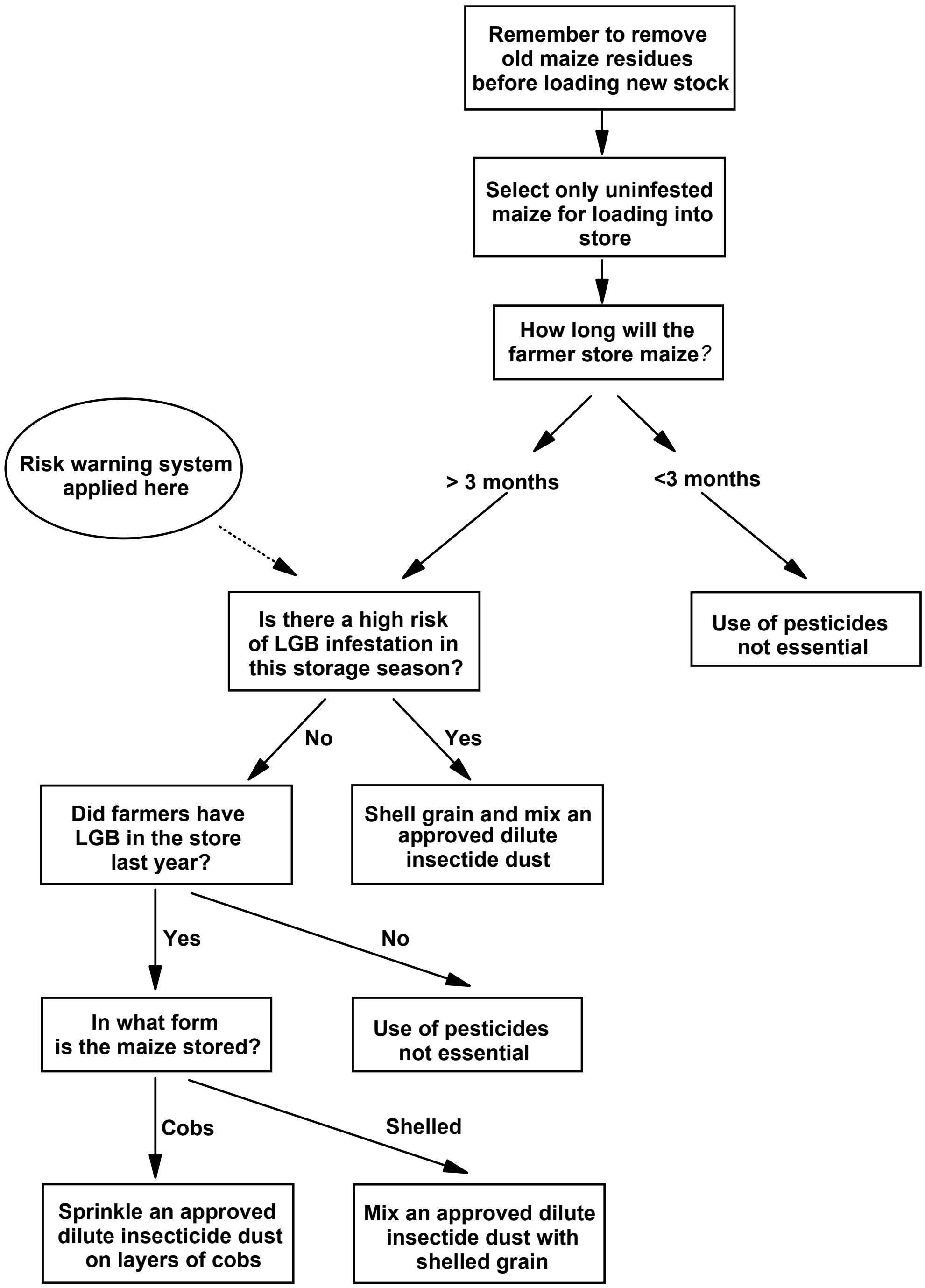
Nov-99
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Date

Figure 4



Major season harvest
1997/98
1998/99
1999/00
Actual
Predicted
17500
15000
12500
10000
7500
5000
2500
0
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Minor season harvest
30000
25000
20000
15000
10000
5000
0
Nov
Dec
Jan
Feb
Mar
April
May
June
July
Cumulative mean P. truncatus trap catch
Months of storage

Figure 5


Remember to remove old maize residues before loading new stock
Select only uninfested maize for loading into store
How long will the farmer store maize?
Risk warning system applied here
> 3 months
<3 months
Is there a high risk of LGB infestation in this storage season?
Use of pesticides not essential
No
Yes
Did farmers have LGB in the store last year?
Shell grain and mix an approved dilute insecticide dust
Yes
No
In what form is the maize stored?
Use of pesticides not essential
Cobs
Shelled
Sprinkle an approved dilute insecticide dust on layers of cobs
Mix an approved dilute insectide dust with shelled grain