Can ‘bad’ years for damage by *Prostephanus truncatus* be predicted?

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Abstract

*Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) is a sporadic, but serious pest of maize and cassava in the tropics. Farmers report that some years are far worse for damage than others and it is also known that the numbers of insects dispersing, as measured in pheromone traps, varies between years. Using purpose-built mini-stores it was shown that flight-trap catches of *P. truncatus* were a significant predictor of the risk of stores becoming infested in Ghana but not Tanzania. The estimated relationship between these two variables was, however, similar in both countries, and also matched data subsequently obtained from observations of farmers’ stores in Ghana. These findings are an important step towards the development of a warning system to decrease the uncertainty of *P. truncatus* threat to stored maize and cassava. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Food-security; Risk-assessment; *Prostephanus truncatus*

1. Introduction

Methods to predict the risk of serious pest attack in agriculture (Nieminen et al., 2000) and forestry (Ravlin, 1991) are gradually being developed. As more is known of pest behaviour and population dynamics, control measures can become increasingly targeted and effective. The goal of research into risk assessment is most commonly to establish the potential range and damage that could be caused by an invading pest, and to predict how the threat might change with time. For example, a decision support system has been developed to enable stakeholders to assess the risk posed to areas of forest from the gypsy moth, an exotic pest. This not only warns of those areas under current threat, but can also be used to predict the likely gypsy moth risk arising from various management options (Potter et al., 2000). In our study, the potential for using changes in the numbers of the beetle *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) captured in pheromone traps is assessed as a means of predicting seasons of high damage.

*Prostephanus truncatus* is a particularly destructive pest of stored maize and cassava (Hodges, 1986, 1994; Markham et al., 1991). Its range is expanding in Africa and most recently this pest has been reported in South Africa and Namibia (Roux, 1999; Larsen, 1998). *P. truncatus* poses the greatest threat to small-scale farming communities rather than large-scale stores, where fumigation is a cost-effective control option. Subsistence farmers in sub-Saharan Africa have changed their storage practices in response to the threat of this pest. Farmers have increased their use of insecticides and more have been shelling their maize, even though cobs are the traditional form of storage for many farmers (Golob et al., 1999). *P. truncatus* differs from other common beetle pests in maize storage in the tropics such as *Sitophilus* spp. in that the level of damage is very unevenly distributed between stores (Hodges, 1986), and those farmers who are affected can suffer such extreme losses that a season’s harvest can be effectively lost. This uncertainty makes it difficult for farmers to plan their action against this pest. They currently have two options. Either take action every season and perhaps...
use pesticides and other resources unnecessarily, or incur the risk of high food losses.

We suggest that there are two main contributors to this unpredictability of store infestation. First, in any one village at any one time, some stores will be highly infested while others remain undiscovered by the pest. This is because *P. truncatus* does not locate maize or cassava in store by responding to volatiles from the commodity itself; the initial colonisers arrive by chance (Hodges, 1994; Fadamiro et al., 1998; Scholz et al., 1997a). Once even a single male has arrived and releases an aggregation pheromone signal, dispersing adults detect this, and the commodity in store is placed under increased threat (Scholz et al., 1997b; Birkinshaw and Smith, 2000).

Second, farmers from several countries report that there is substantial year to year variation in the number of stores that are damaged. We start with the hypothesis that, for a given length of storage period, year to year variation in damage across a community is determined by annual variation in the numbers of dispersing adults. Since the initial colonisers arrive by chance, then we predict that there should be a good positive correlation between flight activity and the frequency of store colonisation. Obviously the length of a storage season will also be an important determinant of food damage. If, for example, the harvest is poor and stores only contain food for 2–3 months, then the percentage of damage will be much lower than for food stored for 6 months and over (see Holst et al. (2000), for a model of how damage increases with time).

It is possible to sample the dispersing population of *P. truncatus* using flight traps baited with synthetic aggregation-pheromone (Dendy et al., 1989; Richter and Biliwa, 1991; Fandohan et al., 1992; Hodges and Pike, 1995). Samples taken using pheromone-baited traps are not likely to be random samples of the dispersing population, however they are the best practical measure currently available. Four years of trapping data from Ghana showed that the mean trap catches over a year could vary by over threefold. Perhaps more importantly, the peaks of catches that can occur near the beginning of a storage season varied by almost tenfold between years (see data in Birkinshaw and Hodges, 2000). Females caught in traps are mostly inseminated and able to reproduce as soon as they locate a plant host (Scholz et al., 1998; Hodges and Birkinshaw, 1999), although further mating will increase their rate of offspring production (Li, 1988). No large differences in the reproductive potential of insects caught in different seasons were found in a range of habitats (Scholz et al., 1998; Hodges and Birkinshaw, 1999).

To investigate whether the trap catches of *P. truncatus* are a good predictor of store colonisation rates, the current study measured prevailing *P. truncatus* trap catches, and the incidence of colonisation of purpose-built mini-stores. These estimates of how changes in trap catches relate to the risk of stores being colonised were then compared to observations of real farmers’ stores at the end of a storage season. This on-farm validation of the risk assessment model used stored dried cassava (*kokonte*) in the Kete Krachi district of the Volta region. Cassava is the main staple crop grown in this area, some is used for family food and some is sold to a trading company for cash. There is one main season for kokonte production normally falling between December and April. The kokonte is then often stored for up to a year until the next harvest.

2. Materials and methods

2.1. ‘Mini-stores’

Experiments were done in villages in Ghana and Tanzania as shown in Table 1. Two contrasting areas in the Volta Region of Ghana were chosen. First the forest-savannah transition zone of Hohoe/Jasikan district, and second the semi-arid zone of the Nkwanta district. A semi-arid area with high reliance on maize was chosen in Tanzania.

In each village, nine mini-stores were constructed and pheromone traps hung from suitably sited trees in a regular arrangement shown in Fig. 1. Mini-stores were about 150 m apart and traps about 100 m apart depending on the suitability of the terrain. Typically,

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Summary of the locations, dates and commodities used in mini-store experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Dates</td>
</tr>
<tr>
<td>5 villages in Hohoe/Jasikan district</td>
<td>5 villages in Nkwanta district</td>
</tr>
<tr>
<td>B. Ghana</td>
<td>29/3/1999–30/9/1999</td>
</tr>
<tr>
<td>9 cassava&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9</td>
</tr>
<tr>
<td>5 villages in Hohoe/Jasikan district</td>
<td>5 villages in Nkwanta district</td>
</tr>
<tr>
<td>5 villages in Kilosa district</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Each village had a total of nine mini-stores so that each district had a total of 45 stores.

<sup>b</sup>Data from mixed commodity stores has been excluded from all analyses.

<sup>c</sup>In this experiment traps were only present for half the time.
vegetation and houses stood between traps and mini-stores.

Each mini-store consisted of a chicken wire cage supported by a wooden frame, and protected from the rain by a thatch roof. The design of the stores was slightly different in Ghana and Tanzania, but both held a volume of ~81 of commodity (60–65 cobs) 1.2–1.5 m above the ground. Local varieties of maize cobs with their sheathing leaves intact were used, and the cassava roots were dried chips about 10–15 cm long and 3–7 cm in diameter. None of the commodity showed any signs of previous infestation by *P. truncatus* and all was fumigated with phosphine for at least 7 days and then maintained in insect-proof plastic bins prior to use. In Ghana, commodity was placed in a cylindrical mesh cage with a diameter of ~60 cm and supported on a single wooden post running up the centre. In Tanzania, the mesh cage was square of sides 60 cm and supported by four legs, one at each corner. In all stores a layer of black polypropylene was fixed directly underneath the mesh cage to allow easy detection of the characteristic dust produced by *P. truncatus* boring activity.

The pheromone-baited traps used to sample the dispersing population of *P. truncatus* were Japanese beetle type supplied by Trécé Inc., Salinas, CA, USA. They consist of a yellow plastic funnel (diameter 15 cm, height 11 cm) with four vertical canes in the form of a cross, extending 10 cm up from the funnel to form a baffle. Incoming beetles hit the baffle and then tumble into the funnel to be collected by a plastic jar attached to its base, containing a Whatman’s No. 1 filter paper impregnated with a lethal dose of diluted Actellic Super EC insecticide. Each trap was baited with a standard *P. truncatus* aggregation pheromone lure consisting of a polyethylene capsule impregnated with 1 mg each of Trunc-call 1 and 2. In each village, four traps were hung 1.5–2 m above the ground on any conveniently located vegetation, often a mango tree branch. The arrangement of traps and stores in the villages is shown in Fig. 1.

Villages were visited every two weeks to collect and count the numbers of *P. truncatus* captured in the traps, to replace the existing pheromone capsule with a fresh one and to examine the mini-stores for signs of infestation. Once infested, the stores were cleared of produce and were refilled with fumigated material after a fallow period of at least two weeks (sometimes longer when commodity was scarce). Store structures were inspected for any signs of infestation and changed if any were found, however such inspection is difficult and may not always have been successful.

During the course of this experiment, the possible influence of the presence of the baited traps in the villages on the colonisation of the mini-stores was tested. This was done by leaving traps unbaited for every other trapping period, i.e. 2 weeks on, 2 weeks off.

Binary logistic regression (Genstat 4.1) was used to determine which out of a number of possible variables significantly contributed to the risk of stores becoming infested. Whether or not a mini-store had been previously colonised was termed, ‘hit before’. This variable was included to check whether our disinfection of stores before re-loading had been successful. The length of time a stored commodity had been exposed to field conditions was termed ‘store age’. This was included in the model to determine if other factors that change with time during storage such as moisture content, or the increasing infestation from other pests might influence store colonisation by *P. truncatus*. The logistic regression equation generated by this analysis was used to predict the cumulative number of *P. truncatus* that are associated with a range of probabilities of stores becoming infested. This relationship was estimated using models including only *P. truncatus* trap catch as an explanatory variable. The cumulative trap catch is the number of insects that need to be caught, whilst using any numbers of two-weekly trapping periods, to give a specific probability of stores becoming infested by *P. truncatus*.

For convenience, studies on the infestation of mini-stores in Ghana, in which pheromone-baited traps were present throughout, are referred to as ‘Experiment A’ and as ‘Experiment B’ when the traps were left unbaited in alternate two-week periods. The tests in Tanzania are labelled ‘Experiment C’.

2.2. Farmers’ stores

Krachi district, next to Lake Volta was chosen for the study. The villages in this district are relatively widely spaced and five were selected, spaced ~10 km apart and roughly in a line. Eighty farmers, from the five villages were chosen to participate in the research: Borae (13), Peposu (14), Ankase (21), Ehiamankyene (21),
Adomang (11). Borae was the biggest, and is the local administrative capital where there is a lot of trading in agricultural produce. All the other villages were fairly small farming communities and although they all contained several ethnic groups, the Kokomba were predominant. Kokombas mostly store their kokonte in traditional structures called katchalla. These were roughly cylindrical in shape and of mean height 130 cm, diameter 215 cm and 40 cm off the ground. Only farmers storing their kokonte (dried cassava chips) in katchalla stores were chosen for the study and none treated their kokonte with any protectant against insects. Cassava was usually unloaded from stores gradually in small amounts, initially mostly for sale, then for family food towards the end of the season.

Samples of the stored cassava were collected towards the end of storage period when ~one-tenth of the original quantity of commodity remained. Locally recruited and trained staff were given plastic boxes and asked to collect samples with farmers. Ten cassava pieces were picked at random and later checked by project staff for the presence or absence of *P. truncatus*. The pest initially tends to migrate to the bottom of a store (Hodges and Birkinshaw, 1999) so sampling at this point late in the season maximises the chance of an infestation being detected from such a relatively quick sampling protocol. For each store, the following information was recorded:

- date the store was loaded;
- the dimensions of the store;
- whether the wooden construction of the store was old or new this season;
- date the cassava was sampled;
- whether or not *P. truncatus* was found in the cassava sample.

The cumulative mean number of *P. truncatus* caught per trap in the village where the store was located, between the date the store was loaded, and the date the store was sampled. Since traps were emptied only every two weeks, the nearest trap catch to the dates of sampling were used.

We were not able to collect information on the presence or absence of any residual *P. truncatus* infestation in wooden component of the katchalla since the nature of their construction made inspection difficult. However, such infestation is likely in older stores.

3. Results

3.1. Mini-stores

There was considerable variation in trap catch between different sites and over time (Figs. 2–4). Trap catches were mostly under 1000 beetles per trap per two weeks, but some peaks were in excess of 3000 beetles per trap per two weeks. The mini-stores associated with the traps were colonised by *P. truncatus* or ‘hit’ to varying degrees (Table 1). The trap catches were found to be a significant determinant of these hits in experiments in Ghana, but not in Tanzania (see Tables 2, 3 and 5). However the estimates of the relationship between trap catch and risk of store colonisation were similar across all sites (Fig. 6). The estimates predict that in a two-week trapping regime (using standard traps and lures), 50% of mini-stores will be infested by the time the cumulative trap catch reaches ~2000–4000 insects.

The commodity type (maize compared to cassava) filling the store was found to influence store colonisation (see Table 2). The regression equations suggest that cassava is more likely than maize to become infested at low beetle density. In general the results suggest that cassava is less sensitive to changes in beetle numbers i.e. increases in beetle density do not result in as much increase in risk as observed in maize-filled stores.

![Fig. 2. Mean number of *P. truncatus* caught per flight trap per two-week trapping period in the Hohoe/Jasikan village cluster.](image-url)
There is no overall consistent influence of the presence of traps on the store hit-rate. The stores in Korantang village however, were hit over five times more frequently in the presence of traps than when they were absent (see Table 4).

### Table 2
<table>
<thead>
<tr>
<th>Estimate</th>
<th>SE</th>
<th>T</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.69</td>
<td>0.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Maize vs. Cassava</td>
<td>1.29</td>
<td>0.29</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hit before?</td>
<td>-0.213</td>
<td>0.257</td>
<td>-0.83</td>
</tr>
<tr>
<td>Store age</td>
<td>-0.0243</td>
<td>0.0133</td>
<td>-1.82</td>
</tr>
<tr>
<td>P. truncatus trap catch</td>
<td>0.000532</td>
<td>0.000132</td>
<td>4.04</td>
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</table>

*Overall mean deviance = 10.8, p<0.001, d.f. = 4.

### Table 3
<table>
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<th>Estimate</th>
<th>SE</th>
<th>T</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.83</td>
<td>0.29</td>
<td>-9.94 &lt;0.001</td>
</tr>
<tr>
<td>Presence of traps</td>
<td>0.308</td>
<td>0.172</td>
<td>1.79 0.073</td>
</tr>
<tr>
<td>Hit before?</td>
<td>0.533</td>
<td>0.190</td>
<td>2.81 0.005</td>
</tr>
<tr>
<td>Store age</td>
<td>0.0357</td>
<td>0.0148</td>
<td>2.41 0.016</td>
</tr>
<tr>
<td>P. truncatus trap catch</td>
<td>0.000351</td>
<td>0.000106</td>
<td>3.31 &lt;0.001</td>
</tr>
</tbody>
</table>

*Overall mean deviance = 4.8, p<0.001, d.f. = 4.

3.2. Farmers’ stores

Again there was variation in the trap catches between villages (Fig. 5). In four of the five villages, predictions
The colonisation rate of stores given their exposure to flying *P. truncatus* were good. However, Borae village was an outlier, where, although trap catches were high, the proportion of stores infested was relatively low (Fig. 6).

Regression analysis on the entire data set indicates that the age of wood used in the construction of the store, was a significant factor in store colonisation. Only about a quarter of stores with new wood (7 of 27) became infested compared to two-third of those with old wood (35 of 53). Thus age of the wood proved to be a significant factor in determining the likelihood of infestation (Table 6). In contrast, store size did not appear to be a significant factor, although there was little variation in the sizes of stores used in the

<table>
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<tr>
<th>Village</th>
<th>Traps absent</th>
<th>Traps present</th>
<th>χ²</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nkwanta</td>
<td>8</td>
<td>12</td>
<td>0.40</td>
<td>N.S.</td>
</tr>
<tr>
<td>Gekrong</td>
<td>5</td>
<td>9</td>
<td>0.57</td>
<td>N.S.</td>
</tr>
<tr>
<td>Chala Odomi</td>
<td>12</td>
<td>13</td>
<td>0.02</td>
<td>N.S.</td>
</tr>
<tr>
<td>Korantang</td>
<td>4</td>
<td>22</td>
<td>6.23</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>Keri</td>
<td>4</td>
<td>3</td>
<td>0.07</td>
<td>N.S.</td>
</tr>
<tr>
<td>Bowiri Ayaniase</td>
<td>2</td>
<td>5</td>
<td>0.64</td>
<td>N.S.</td>
</tr>
<tr>
<td>Bowiri amanfrom</td>
<td>4</td>
<td>7</td>
<td>0.41</td>
<td>N.S.</td>
</tr>
<tr>
<td>Bowiri Kyriahin</td>
<td>10</td>
<td>6</td>
<td>0.50</td>
<td>N.S.</td>
</tr>
<tr>
<td>Akpafu Odomi</td>
<td>12</td>
<td>4</td>
<td>2.00</td>
<td>N.S.</td>
</tr>
<tr>
<td>Akpafu Mempeasem</td>
<td>11</td>
<td>10</td>
<td>0.02</td>
<td>N.S.</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>91</td>
<td>1.11</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Table 4  
Frequency of mini-store colonisation by *P. truncatus* occurring when traps were left unbaited with pheromone in alternating two-week periods (Experiment B)

![Fig. 5](image1.png)  
Fig. 5. Mean number of *P. truncatus* caught per flight trap per two-week trapping period in the Kete Krachi village cluster.

![Fig. 6](image2.png)  
Fig. 6. Estimates of the relationship between cumulative trap catches of *P. truncatus* and probability of store colonisation generated during Experiments A, B and C, and actual data points from observation of farmers’ cassava stores in Kete Krachi in Ghana.
experiment. The length of time between loading and sampling for *P. truncatus* was a significant determinant of store colonisation by the pest. Obviously time exposed co-varies with the cumulative trap catch of *P. truncatus*.

### 4. Discussion

Dispersal activity, as measured using flight traps was a significant predictor of mini-store colonisation in most datasets. A cumulative trap catch of about 4000 insects is predicted to be associated with a 50% chance of store colonisation.

Mini-stores loaded with cassava were more likely to become colonised than those loaded with maize cobs at lower beetle dispersal activities. We suggest that this may be a consequence of the relative ease with which *P. truncatus* can bore into cassava compared with the sheath-covered cobs so that the beetle may be more likely to resume flight if landing on cobs than cassava. In the mini-store data there was some evidence that the length of the time the commodity had been in store influenced the chance of *P. truncatus* colonisation during any two-week period. Likewise, the length of time farmers’ own stores has been loaded with cassava was also approaching significance as a factor. This suggests that the action of other storage factors such as changes in moisture content or the action of other insects may also make stores increasingly open to *P. truncatus* invasion.

When these predictions were tested on much larger stores used by farmers, the results closely matched the predictions for four out of five villages. There did not appear to be a large increase in the risk of store colonisation from the increase in size of the stores. Such an increase may have been offset by cases where colonisations were not detected with the sampling protocol used. The size and inaccessibility of much of the cassava in the *kachalla* stores precluded any kind of comprehensive sampling plan. Alternatively it may be that *P. truncatus* start to orientate directly to stores over short distances in response to short-range cues. Direct orientation towards stores over short distances (say a few metres) may reduce the significance of store size compared to completely random location. Although long-range attraction has been ruled out, short-range attraction may be possible, especially in the case of cassava (Hodges, 1994; Scholz et al., 1997a).

Farmers’ stores have structural timbers the previous use of which had a clear influence on store colonisation. This confirms the importance of earlier observations that *P. truncatus* may survive between storage seasons in wooden storage structures (Kossou, 1992). Farmers, particularly around Ho, reported an increase in their replacement of store wood in response to this threat (Addo, unpublished data).

There is some anecdotal evidence to support our hypothesis that year to year variation in risk of infestation is determined by annual variation in the numbers of dispersing *P. truncatus*. In Tanzania, trap catches were relatively high in Morogoro/Kilosa districts in 1998 and farmers reported this year as being particularly bad for *P. truncatus* damage (Riwa, unpublished data). Likewise, particularly high levels of *P. truncatus* damage were experienced in northern Ghana in 2000/2001, where it was estimated that there was a tenfold increase in reports to the local ministry of agriculture (Andan, personal communication). Although long-term trapping data is not available for this region, traps in place in Tamale were catching over a 1000 beetles per two weeks from September to November 2000 (Andan, unpublished data).

A survey of farmers’ experiences since the arrival of *P. truncatus* into the Volta Region of Ghana did not, however, reveal a close link between trap catch data and farmers’ experiences of damage (Addo, unpublished data). However, those years with high levels of insect dispersal activity were also years of poor harvest so that the storage seasons were much reduced and with it the opportunity for populations of *P. truncatus* to grow large enough for significant losses to be sustained.

Higher dispersal activity will not only increase the rate at which stores become colonised, it is also likely to influence the immigration rate of insects responding to aggregation-pheromone signals from male colonisers. We do not yet know the significance of higher flight
activity on the speed at which stored commodity becomes damaged after its initial invasion. However, it has been suggested that this may be low compared with the rapid rate of reproduction of \( P. \) truncatus on maize or cassava (Scholz et al., 1997b).

Any warning system, based on the model proposed here, will necessarily need to be fairly general in its predictions since flight activity varies between villages that are geographically quite close and obviously flight activity is not the only influence on store infestation. Examples of other factors that our study has confirmed to be influential are the type of commodity, any \( P. \) truncatus infestation remaining in store wood and length of storage. However, when trap catches soar into the thousands, particularly if this occurs early in the storage period then we would class this as ‘high risk’. The risk system will need to be developed with stakeholders to ensure that information is provided in the most useful and appropriate form. Radio programmes and the extension services were highlighted as two important information providers in the Volta region of Ghana (Addo, unpublished data). More pest control activities are undertaken on maize than cassava, which remains largely, untreated, but this does not mean that cassava farmers could not benefit from risk warning. Farmers may invest more in inspection if a ‘bad’ year is coming and benefit from more timely selling of their commodity if their store is attacked.

The main constraints to the implementation of such a system are likely to be the sustainability of the measurement of flight activity. Previous risk assessment systems using insect trapping have sometimes faltered because the co-ordination and resources required to maintain the trapping network is too great. Separate studies have given a strong indication that climatic factors can be used to predict trap catches (Hodges, unpublished data). Africa is already well served with meteorological stations and in the future remote methods of sensing climate may prove to be an even more convenient and cost-effective source of climate data.

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References


Hodges, R.J., Pike, V., 1995. How to use pheromone traps to monitor the Larger Grain Borer (Prostephanus truncatus). Natural Resources Institute, Central Ave., Chatham Maritime, Kent ME4 4TB, UK, pp 16.

Holst, N., Meikle, W.G., Markham, R.H., 2000. Grain injury models for Prostephanus truncatus (Coleoptera: Bostrichidae) and Sitophilus zeamais (Coleoptera: Curculionidae) in rural maize stores in West Africa. J. Econ. Entomol. 93, 1338–1346.


