IMPACT ASSESSMENT OF *TERETRIUS NIGRESCENS* LEWIS (COL.: HISTERIDAE) IN WEST AFRICA, A PREDATOR OF THE LARGER GRAIN BORER, *PROSTEPHANUS TRUNCATUS* (HORN) (COL.: BOSTRICHIDAE)

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INTRODUCTION

As with most other bostrichids, the larger grain borer (*Prostephanus truncatus* [Horn]) is a wood-boring insect native to tropical forests (Chittenden, 1911) that can also attack stored commodities such as maize and cassava. From its area of origin in Mexico and Central America, where *P. truncatus* was occasionally recorded as a post-harvest pest of maize in small-scale storage facilities (Markham *et al.*, 1991), the beetle was accidentally introduced to East Africa in the late 1970s and West Africa in the early 1980s (Dunstan and Magazini, 1981; Harnisch and Krall, 1984). To date, the distribution of *P. truncatus* includes 17 countries (Hodges, 1994; Adda *et al.*, 1996; Sumani and Ngolwe 1996; Roux, 1999), covering all major maize-producing regions in sub-Saharan Africa. Losses are particularly serious in stored maize. In southern Togo, maize losses after an average storage period of six months increased from 11% before the introduction of *P. truncatus* to more than 35% afterwards (Pantenius, 1987), and in areas with high incidence of *P. truncatus* in Tanzania up to 34% maize losses have been observed after three months of on-farm storage (Hodges *et al.*, 1983). Initially, control strategies focused on fumigants and insecticides. The beetle is not very susceptible to organophosphorous insecticides (the materials commonly used as post-harvest protectants in sub-Saharan Africa), but can be efficiently controlled with synthetic pyrethroids. Hence, combinations of insecticides, consisting of a pyrethroid for control of *P. truncatus* and an organophosphate to combat pests such as the maize weevil (*Sitophilus zeamays* Motschulsky [Col.: Curculionidae]) and the Angoumois grain moth (*Sitotroga cerealella* [Olivier] [Lep.: Gelechiidae]) were successfully used for control in East Africa. However, for socio-economic reasons, this chemical control strategy was not widely adopted in West Africa (Agbaka, 1996).

As an outbreak pest causing spectacular damage and losses in Africa, but of insignificant importance in its area of origin, *P. truncatus* was considered to be a prime target for a classical biological control approach. Moreover, the identification of the male-produced aggregation pheromone of *P. truncatus* (Cork *et al.*, 1991), and its subsequent availability as a synthetic pheromone (Dendy *et al.*, 1989), greatly improved the understanding of the complex biology and ecology of the beetle.

In the late 1980s, intensive surveys for natural enemies were carried out in Mexico, Honduras, and Costa Rica. However, the natural enemy fauna associated with *P. truncatus* turned out to be rather limited. The only specialized natural enemy identified during these surveys was the histerid predator *Teretrius* (formerly *Teretriosoma*) *nigrescens* Lewis. Particularly striking was the fact that

T. nigrescens was the only insect that was also strongly attracted to the aggregation pheromone of *P. truncatus,* as shown by pheromone trap catches (Rees *et al.*, 1990) and subsequent electro-antennogram studies (Scholz *et al.*, 1998a). Both adults and larvae of *T. nigrescens* prey on larvae and eggs of *P. truncatus*, although the larvae are the more voracious predators (Rees, 1985; Pöschko, 1993).

In laboratory studies, *T. nigrescens* was able to successfully control the population growth of *P. truncatus* and prevent serious losses in maize (e.g., Rees, 1985). Since histerids are mostly polyphagous or oligophagous predators (Hinton, 1945), before the first releases of *T. nigrescens* in sub-Saharan Africa, the prey specificity of the beetle was investigated in the laboratory. Results of these studies showed that *T. nigrescens* can attack and feed on other prey than *P. truncatus*, mainly other coleopteran and lepidopteran pests commonly found in the storage environment in the tropics. But in choice experiments, it always preferred larger grain borer larvae as prey (Pöschko, 1993). These findings were later confirmed by data from an electrophoretic gut content analysis of predators sampled in Central America and West Africa, where in the great majority of samples, protein of *P. truncatus* was detected in guts of adults and larvae of *T. nigrescens* (Camara, 1996).

The predator was first released in 1991 in Togo (Biliwa *et al.*, 1992), followed by releases in Benin (Anonymous, 1992), Ghana (Compton and Ofosu, 1994), and Kenya (Giles *et al.*, 1996). To date, only limited data on impact assessment of *T. nigrescens* are available. Mutlu (1994) reported reduced *P. truncatus* infestation rates in villages in southern Togo receiving *T. nigrescens* releases; Nang'ayo (1996) observed a sharp decline in *P. truncatus* pheromone trap catches following *T. nigrescens* releases in savannah bushland areas in Kenya; and Borgemeister *et al.* (1997a) reported lower trap catches of *P. truncatus*, coupled with reduced infestation levels in rural maize stores, in south-western Benin after the introduction of the predator.

Here, we report results of a large-scale impact assessment study conducted in the Republics of Togo and Benin, involving country-wide pheromone trapping and investigations in farmers' maize stores.

MATERIALS AND METHODS

Delta sticky flight traps (Pherocon II, Trécé, Salinas, USA) baited with the two-component synthetic aggregation pheromone of *P. truncatus* (AgriSense-BCS, Pontypridd, United Kingdom) were used to collect adults of *T. nigrescens* in study areas. Between May and July of 1995, a total of 124 trapping sites were selected, 24 of which were in southern Togo and 100 in Benin. Selection of trapping sites depended on accessibility, importance of maize production and storage, presence of supposed natural forest habitats of *P. truncatus*, and reports of previous *P. truncatus* infestations in each region. The trapping sites covered all four agro-ecological zones of Benin, i.e., Forest Savannah Mosaic, Southern Guinea Savannah, Northern Guinea Savannah, and Sudan Savannah. More traps were set up in the south because of the greater importance of *P. truncatus* in this region, more intensive maize production and storage, and better infrastructure (accessibility). In the south, traps were changed every two weeks, collected and sent to the Benin station of the International Institute of Tropical Agriculture (IITA) in Abomey-Calavi. All captured insects were counted. In Atacora and Borgou, the two northern provinces of Benin, traps were changed monthly because of the low flight activity of *P. truncatus* at the beginning of the study. In every trapping site, one farmer's maize store was selected and throughout the whole storage period 10 randomly chosen cobs from the stores were sampled monthly. Data on pest infestation and losses were recorded. The study was conducted over a period of 28 months from May 1995 until October 1997. More details on the methodology are provided in Schneider (1999).

We here report results of pheromone trapping in southern Togo and the Mono and Ouémé provinces of southwestern and southeastern Benin.

RESULTS

During three years of observation in southern Togo, peak flight activity of *P. truncatus* was always recorded in April and lowest activity in October (Fig. 1). The highest trap catches occurred in the northern part of the observation area. The numbers of *P. truncatus* decreased considerably from June 1996 until the end of the observation period in May 1997. The pattern of yearly flight activity of *T. nigrescens* generally followed that of *P. truncatus*, although variation in the predator's flight activity was less pronounced than for *P. truncatus* (Fig. 1).

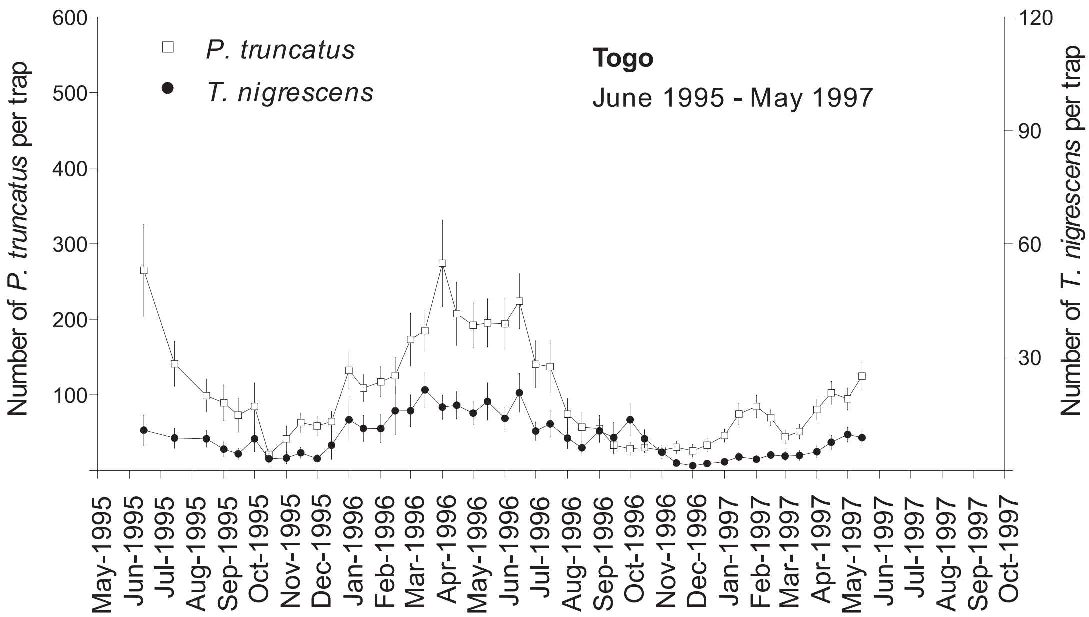

Figure 1. Flight activity of *Prostephanus truncatus* (Horn) and *Teretrius nigrescens* Lewis in southern Togo (means and SE of 24 traps, changed at 2-week intervals).

In the Mono province of southwestern Benin, the flight activity of *P. truncatus* decreased considerably in the course of the observation period (Fig. 2). The annual flight cycles of both *P. truncatus* and *T. nigrescens* in the Mono province were very similar to those observed in southern Togo. Moreover, as in neighboring Togo, the highest trap catches were always recorded in the northern part of the province.

In the Ouémé province of south-eastern Benin, peak numbers of *P. truncatus* were recorded in January 1996; trap catches of *P. truncatus* decreased considerably thereafter (Fig. 3). Highest numbers were only recorded at trapping sites in the northern part of province. In the southern part of Ouémé, trap catches were considerably lower. *Teretrius nigrescens* showed a nearly identical pattern of flight activity as its prey.

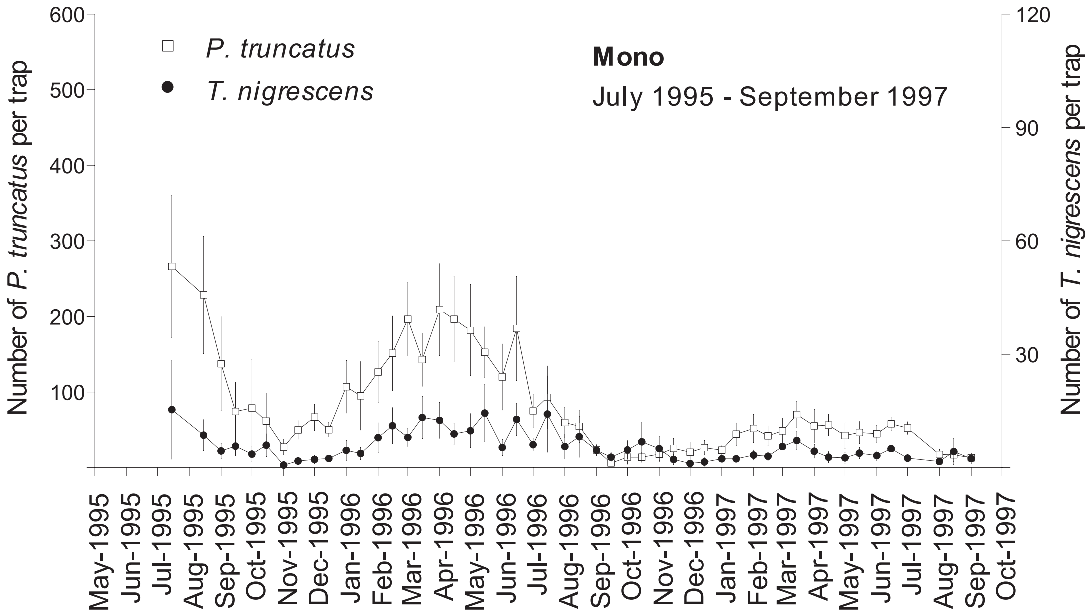

Figure 2. Flight activity of *Prostephanus truncatus* (Horn) and *Teretrius nigrescens* Lewis in the Mono Province of southwestern Benin (means and SE of 12 traps, changed at 2-week intervals).

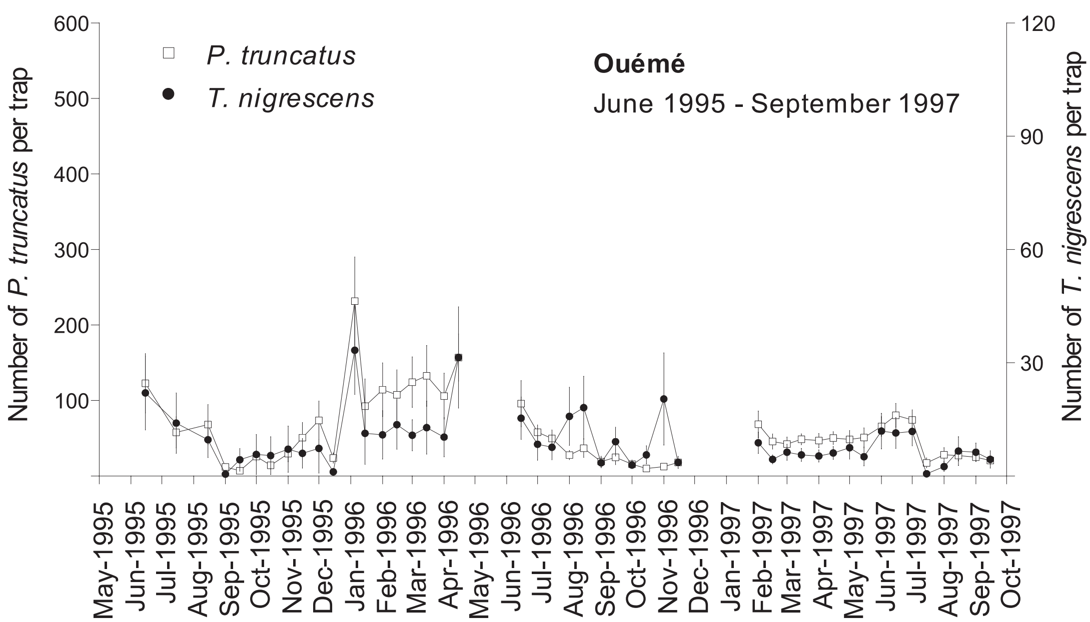

Figure 3. Flight activity of *Prostephanus truncatus* (Horn) and *Teretrius nigrescens* Lewis in the Ouémé Province of southeastern Benin (means and SE of 16 traps, changed at 2-week intervals).

DISCUSSION

Our results strongly suggest that in southern Togo and Benin, *P. truncatus* is under biological control by its natural enemy. An overall decrease in flight activity of *P. truncatus* was observed in the course of this study. The flight activity of *T. nigrescens* was closely related to that of *P. truncatus* due to the close predator-prey relationship between the two beetles.

In West Africa, *P. truncatus* was first recorded in Togo in 1984 (Harnisch and Krall, 1984). Larger grain borer was first detected in the Mono province of south-western Benin in 1986 in locations very close to the border with Togo (Anonymous, 1986). Since then the pest has spread comparatively slowly from east to west in Benin. In our study, strikingly low *P. truncatus* densities, both in traps and in rural grain stores, were observed in the Ouémé province of south-eastern Benin (see also Schneider, 1999). The west-to-east distance in southern Benin, i.e., the distance between the Mono and Ouémé provinces, is approximately 130 km. Apparently, it took *P. truncatus* more than 10 years to spread from the initial infestation areas close to the border with Togo to Ouémé province. In contrast, *T. nigrescens* dispersed very rapidly from release areas in Togo into Benin. First recorded in 1992 in the Mono province (Borgemeister *et al.*, 1997a), the predator rapidly moved eastwards and colonized the Atlantique and Ouémé provinces of southcentral and southeastern Benin. Most likely, the early arrival of *T. nigrescens* prevented outbreaks of *P. truncatus* in Ouémé.

Flight activity of *P. truncatus* showed considerable fluctuations over the study period. Highest trap catches were always recorded in April, the beginning of the major rainy season in southern Togo and Benin. Catches then fell to an all-year-low in October. During the main dry season from October to March, trap catches of *P. truncatus* again increased. Similar yearly patterns of flight activity of *P. truncatus* were also observed in southern Togo (Wright *et al.*, 1993; Helbig, 1993) and in southern Benin (Borgemeister *et al.*, 1997b). Presumably meteorological factors partly govern the flight pattern of *P. truncatus* (e.g., Tigar *et al.*, 1994; Nang'ayo, 1996; Borgemeister *et al.*, 1997b; Scholz *et al.*, 1998b). In addition, flight activity of *P. truncatus* was strongly related to the pattern of maize farming and storage. In southern Togo and Benin, peak flight activity was recorded in April, i.e., at the end of the main maize storage period. Borgemeister *et al.* (1998) conducted a gut content analysis of migrating *P. truncatus* in southern Benin and showed that peak flight activity in March and April was caused by beetles dispersing from grain stores.

Flight activity of *P. truncatus* in central and northern Benin showed greater spatial variability, with areas with both high trap catches ("hot spots") and very low trap catches (Schneider, 1999). *Teretrius nigrescens* was recorded in the majority of all pheromone trap sites in central and northern Benin, although in considerably smaller numbers than in southern Benin and Togo. Hence, in conclusion, the predator is apparently able to successfully control pest populations in the south of both countries. Possibly *T. nigrescens* is responding better to the hot and humid climate in coastal West Africa compared with the dry and hot Sahelian climate of central and northern Benin.

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REFERENCES

Adda, C., C. Borgemeister, W. G. Meikle, R. H. Markham, I. Olaleye, K. S. Abdou, and M. O. Zakari. 1996. First record of the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), in the Republic of Niger. *Bulletin of Entomological Research* 86: 83-85.

Agbaka, A. 1996. Etude biologique et possibilité de lutte intégrée contre *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) ravageur des stocks de maïs dans les milieux paysans en République du Bénin. Thèse de Doctorat de 3ième ciecle. Faculté des Sciences et Techniques de l'Université National de Côte d'Ivoire. Abidjan, Côte d'Ivoire.

Anonymous. 1986. *Rapport annuel 1986 du SPV Porto Novo, République du Bénin*. Service de Protection des Végétaux, Porto Novo, Republic of Benin.

Anonymous. 1992. *Rapport annuel 1992 du SPV Porto Novo, République du Bénin*. Service de Protection des Végétaux, Porto Novo, Republic of Benin.

Biliwa, A., J. Böye, H. U. Fischer, and J. Helbig. 1992. Stratégie de lâchers et études de suivi de *Teretriosoma nigrescens* au Togo, pp. 138-142. *In* Böye, J., M. Wright, and G.-A. Laborius (eds.). *Implementation of and further Research on Biological Control of the Larger Grain Borer*. *Proceedings of an FAO/GTZ Co-ordination Meeting*. FAO, Rome, Italy, and GTZ, Eschborn, Germany. FAO, Rome, Italy.

Borgemeister, C., F. Djossou, C. Adda, H. Schneider, B. Djomamou, K. Azoma, and R. H. Markham. 1997a. Establishment, spread and impact of *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae), an exotic predator of the larger grain borer *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), in south-western Bénin. *Environmental Entomology* 26: 1405-1415.

Borgemeister, C., W. G. Meikle, D. Scholz, C. Adda, P. Degbey, and R. H. Markham. 1997b. Seasonal and meteorological factors influencing the annual flight cycle of *Prostephanus truncatus* (Coleoptera: Bostrichidae) and its predator *Teretriosoma nigrescens* (Coleoptera: Histeridae) in Benin. *Bulletin of Entomological Research* 87: 239-246.

Borgemeister, C., A. Tchabi, and D. Scholz. 1998. Trees or stores? The origin of migrating *Prostephanus truncatus* collected in different ecological habitats in southern Benin. *Entomologia Experimentalis et Applicata* 87: 285-294.

Camara, M. 1996. Elektrophoretische Untersuchung des Beutespektrums von *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae), ein natürlicher Feind des Großen Kornbohrers *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). Ph.D. dissertation. Georg-August-University. Göttingen, Germany.

Chittenden, F. H. 1911. Papers on insects affecting stored products: the lesser grain borer; the larger grain borer. *Bulletin of the Bureau of Entomology of the U.S. Department of Agriculture* 96: 29-52.

Compton, J. A. F. and A. Ofosu. 1994. Biological control of the larger grain borer with *Teretriosoma nigrescens*, pp. 1-8. *In* Compton, J.A.F. (ed.). *Quarterly Report 4/94, Ghana Larger Grain Borer Project (Research Programme Volta Region)*. Ghana Ministry of Food and Agriculture, Accra, Ghana and United Kingdom Overseas Development Administration, London.

Cork, A., D. R. Hall, R. J. Hodges, and J. A. Pickett. 1991. Identification of major component of male-produced aggregation pheromone of Larger Grain Borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). *Journal of Chemical Ecology* 17: 789-803.

Dendy, J., P. Dobie, J. A. Saidi, J. L. Smith, and B. Uronu. 1989. Trapping the larger grain borer *Prostephanus truncatus* in maize fields using synthetic pheromones. *Entomologia Experimentalis et Applicata* 50: 241-244.

Dunstan, W. R. and I. A. Magazini. 1981. Outbreak and news records. Tanzania. The larger grain borer on stored products. *FAO Plant Protection Bulletin* 37: 80-81.

Giles, P. H., M. G. Hill, F.L.O. Nang'ayo, G. Farrell, and G. N. Kibata. 1996. Release and establishment of the predator *Teretriosoma nigrescens* Lewis for the biological control of *Prostephanus truncatus* (Horn) in Kenya. *African Crop Science Journal* 4: 325-337.

Harnisch, R. and S. Krall. 1984. Further distribution of the Larger Grain Borer in Africa. *FAO Plant Protection Bulletin* 32(3): 113-114.

Helbig, J. 1993. Untersuchungen zur Ökologie und Biologie von *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in Togo unter besonderer Berücksichtigung der Wechselbeziehungen mit dem Prädator *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae). Ph.D. dissertation. Technical University Berlin. Berlin, Germany.

Hinton, H. E. 1945. The Histeridae associated with stored products. *Bulletin of Entomological Research* 35: 309-340.

Hodges, R. J. 1994: Recent advances in the biology and control of *Prostephanus truncatus* (Coleoptera: Bostrichidae), pp. 929-934. *In* Highley, E., E. J. Wright, H. J. Banks, and B. R. Champ (eds.). *Stored Product Protection. Proceedings of the 6th International Working Conference on Stored-Product Protection*. CAB International, Wallingford, United Kingdom.

Hodges, R. J., W. R. Dunstan, I. A. Magazini, and P. Golob. 1983. An outbreak of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in East Africa. *Protection Ecology* 5: 183-194.

Markham, R. H., V. F. Wright, and R. M. Ríos Ibarra. 1991. A selective review of research on *Prostephanus truncatus* (Col.: Bostrichidae) with an annotated and updated bibliography. *Ceiba* 32(1): 1-90.

Mutlu, P. 1994. Ability of the predator *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae) to control larger grain borer *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) under rural storage conditions in the southern region of Togo, pp. 1116-1121. *In* Highley, E., E. J. Wright, H. J. Banks, and B. R. Champ (eds.). *Stored Product Protection. Proceedings of the 6th International Working Conference on Stored-Product Protection*. CAB International, Wallingford, United Kingdom.

Nang'ayo, F.L.O. 1996. Ecological studies on Larger Grain Borer in savanna woodlands of Kenya. Ph.D. dissertation. Imperial College, London.

Pantenius, C. 1987. Verlustanalyse in kleinbäuerlichen Maislagerungssystemen der Tropen, dargestellt am Beispiel von Togo. Ph.D. dissertation. Christian-Albrechts-University. Kiel, Germany.

Pöschko, M. 1993. Biologie und Wirtsspezifität von *Teretriosoma nigrescens* Lewis. Ph.D. dissertation. Technical University Berlin. Berlin, Germany.

Rees, D. P. 1985. Life history of *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae) and its ability to suppress populations of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). *Journal of Stored Products Research* 21: 115-118.

Rees, D. P., R. Rodriguez Rivera, and F. J. Herrera Rodriguez. 1990. Observations of the ecology of *Teretriosoma nigrescens* Lewis (Col.: Histeridae) and its prey *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in the Yucatan peninsula, Mexico. *Tropical Science* 30: 153-165.

Roux, P. W. J. 1999. Larger grain borer: further developments. *Plant Protection News* 55: 3-4.

Schneider, H. 1999. Impact assessment of *Teretriosoma nigrescens* Lewis (Coleoptera: Histeridae), a predator of the larger grain borer *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). Ph.D. dissertation. Hannover University. Hannover, Germany.

Scholz, D., C. Borgemeister, and H.-M. Poehling. 1998a. EAG and behavioural responses of the larger grain borer, *Prostephanus truncatus*, and its predator, *Teretriosoma nigrescens*, to the borer-produced aggregation pheromone. *Physiological Entomology* 23: 265-273.

Scholz, D., C. Borgemeister, R. H. Markham, and H.-M. Poehling. 1998b. Flight initiation and flight activity in *Prostephanus truncatus* (Coleoptera: Bostrichidae). *Bulletin of Entomological Research* 88: 545-552.

Sumani, A. J. and A.R.K. Ngolwe. 1996. Zambia: the status of the larger grain borer, pp. 177-182. *In* Farrell, G., A. H. Greathead, M. G. M. Hill, and G. N. Kibata (eds.). *Management of Farm Storage Pests in East and Central Africa. Proceedings of the East and Central African Storage Pest Management Workshop, 14-19 April 1996, Naivasha, Kenya*. CAB International, Wallingford, United Kingdom.

Tigar, B. J., P. E. Osborne, G. E. Key, M. E. Flores-S, and M. Vazquez-A. 1994. Distribution and abundance of *Prostephanus truncatus* (Coleoptera: Bostrichidae) and its predator *Teretriosoma nigrescens* (Coleoptera: Histeridae) in Mexico. *Bulletin of Entomological Research* 84: 555-565.

Wright, M.A.P., D. Akou-Edi, and A. Stabrawa. 1993. Larger grain borer project Togo. Infestation of dried cassava and maize by *Prostephanus truncatus*: Entomological and socio-economic assessments for the development of loss reduction strategies. Report R1941, Natural Resources Institute, Chatham, United Kingdom.