Oryctes rhinoceros (Coleoptera: Scarabaeidae) Larva Abundance and Mortality Factors in the Philippines

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ABSTRACT *Oryctes rhinoceros* (L.) breeding and survival in decaying coconut wood was studied in 53 plots (each 9 ha) in southern Luzon, Philippines. Compared with stumps and coconut trunks on the ground, dead standing palms were preferred for breeding and contained baculovirus-infected larvae 5- to 15-fold more frequently. The percentage of baculovirus-infected breeding sites increased with density of dead standing palms up to about five dead palms per hectare, but then decreased again. Larva mortality was higher in dead standing palms and stumps than in trunks on the ground. Rainfall was also a significant mortality factor. Palm damage due to *O. rhinoceros* increased with density of stumps and trunks on the ground but not with density of dead standing palms. It is concluded that in the Philippines dead standing palms can play an important role in spread of baculovirus and regulation of *O. rhinoceros* populations.

ALTHOUGH THE rhinoceros beetle, *Oryctes rhinoceros* (L.), is considered the most serious pest of coconut and oil palms in Southeast Asia, little quantitative information exists on larva abundance and the factors determining larva survival. Previous studies have concentrated on determining the prevalence of a baculovirus disease that effectively suppresses beetle populations (Zelazny 1973b, 1977, Young 1974, Bedford 1981, Young and Longworth 1981). Wood (1968) gave figures on large larva collections from oil palm trunks correlated to area. However, these are not suitable for ecological analysis as they were done by plantation workers who could "easily miss first-instar larvae." Bedford (1976) collected *O. rhinoceros* stages from 129 dead standing palms over a period of 2 years. He did not attempt to estimate survival rates from his results and it is clear that the samples were too small and variations too large to allow such estimates.

Our present approach has been to conduct extensive surveys over large areas with the aim of obtaining information on larva abundance per hectare as well as on mortality factors and survival rates. We hope to contribute to the knowledge of the ecology of *O. rhinoceros*, which might eventually lead to an understanding of the mechanism of beetle outbreaks and, in turn, to better control methods.

Materials and Methods

Between February 1982 and January 1984, plots (300 by 300 m) were surveyed in coconut plantations of the southern Luzon provinces Albay and Camarines Sur. A total of 53 plots was selected for evenly distributed palms (minimum 25 palms/ha) and for little undergrowth, but not for abundance of *O. rhinoceros* or decaying coconut trunks. The survey of a given plot was conducted over a series of days if necessary. All pieces of coconut trunks (unless very fresh) were counted, opened with axes, and carefully examined for *O. rhinoceros* stages. No evidence for breeding outside coconut trunks was found in the plots. Dead standing palms were felled for inspection, but 140 dead standing palms (14%) could not be cut as this would have damaged crops or houses. Trunks lying on the ground were classified as short (<2 m) or long (>2 m). Stumps, including the underground parts, were dissected if they had decayed sufficiently for *O. rhinoceros* breeding. All *O. rhinoceros* stages were removed with pieces of wood, counted, and brought to the laboratory in covered tins or bottles for a 5-week observation period. Great care was taken to avoid cross-contamination of pathogens between larvae from different sites during collection, transport, and the subsequent observation period. An individual breeding site was considered to be a piece of coconut trunk containing a batch of eggs or a group of larvae or adults in contact with each other. Occasionally, two breeding sites were found in the same trunk (e.g., on both ends) containing two well-separated groups of larvae. A site could be occupied by larvae obviously originating from different females (e.g., first and third instars) and attempts were made to estimate how many of such broods were present in each breeding site. Third instars were classified as young or old according to the amount of fat body present.

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Table 1. Comparison of *O. rhinoceros* breeding and disease incidence in four types of coconut trunks in a total of 477 ha of coconut plantation

	Stumps	Trunks lying on ground		Dead standing palms
		>2 m	<2 m	
Avg no. of coconut trunks/ha	5.4	2.2	3.1	2.1
% of trunks occupied by *O. rhinoceros* (n)	24.3a (2,553)	28.0a (1,071)	22.6a (1,495)	59.4b (838)
Estimated no. of broods per site (n)[a]	1.35a (624)	1.35a (300)	1.31a (359)	1.78b (507)
% of sites containing baculovirus (n)[a]	6.30aA (508)	2.51aA (279)	2.06aA (291)	34.82bA (425)
% of sites containing *M. anisopliae* (n)[a]	4.13aA (508)	4.30aA (279)	2.41aA (291)	5.88aB (425)
Avg no. of mature adults per site (n)	0.20a (624)	0.15a (300)	0.14a (359)	0.50b (507)
% of mature adults with baculovirus (n)	16.4a (122)	8.7a (46)	6.7a (45)	41.4b (249)

Figures followed by the same letter are not significantly different ($P < 0.02$); Wilcoxon signed-rank test, sample size 53 in rows 4, 5 and 7, or 10 in rows 2, 3 and 6. Small letters compare figures in the same row, capital letters those in the same column.

[a] A breeding site is a batch of eggs or a group of larvae or adults in contact with each other.

As judged from the fat body of mass-reared larvae, the young third instars were <1 month old. In the central hectare of each plot the palm density was determined and the palm damage due to *O. rhinoceros* was recorded on 30 palms (expressed in number of cuts on the fronds above horizontal). In the laboratory, mature and immature adults (those that had not yet left the breeding site after emergence) were separated by the condition of their cuticle or by the number of fully developed eggs in the female ovaries (Zelazny 1975). Mature adults were examined for baculovirus infection by bioassay (Zelazny 1978). Cause of death of larvae during the observation period was determined by symptoms or, if these left doubts, by bioassay. Elevation of the plots and their average rainfall per year were obtained from topographic maps and from climate data.

Survival rates were obtained from the observed numbers of the stages divided by the duration of the stages, assuming a steady overall population and random sampling of the stages. This principle is discussed by Southwood (1978).

For statistical analysis of the survey data, nonparametric methods were used, as normality or homoscedasticity could not be assumed. Both disease incidence and survival rate were estimated with greatly different accuracy in the different survey plots. For example, these variables were estimated from 5 breeding sites in one plot and from 50 sites in the next. To avoid giving such plots the same weight, either only plots with more than 20 breeding sites were used for the analysis of disease incidence or plots were combined into 10 groups with similar total numbers of breeding sites. Grouping was either done by geographical location (comparison of larva survival in different types of breeding sites), or for correlating larva survival with environmental factors by the quantitative values of these factors (e.g., for correlating rainfall with larva survival, group 1 contained those plots with the lowest rainfall records, and group 10 contained the plots with the highest rainfall; for each *O. rhinoceros* stage, amount of rainfall was then correlated with survival rates in the 10 groups).

Results

Among the four types of coconut trunks compared, dead standing palms were preferred by *O. rhinoceros* for breeding, containing on average significantly more larval broods and mature adults. They also contained a strikingly high average incidence of baculovirus infections, whereas the incidence of the fungal pathogen *Metarhizium anisopliae* (Metschnikoff) was similar in all types of trunks (Table 1). The density of dead standing palms and the incidence of baculovirus infections in all breeding sites were strongly correlated (Table 2). Closer examination of the data revealed that they fitted a second-order polynomial ($y = 4.95 + 0.48x - 0.0021x^2$) significantly better ($F = 16.3$, df $= 1{,}27$, $P < 0.01$) than a straight line. Thus, the percentage of breeding sites containing baculovirus infected larvae (y) increased with the numer of dead standing palms per hectare (x), reached a maximum (highest measured value at five dead palms/ha), and then decreased again. The baculovirus incidence also correlated significantly ($P < 0.05$) with the presence of stumps and with elevation. However, the latter correlation was apparently influenced by plots at lower elevation having on average more dead standing palms.

The number of beetle cuts per hectare on the upper fronds (representing the population of feed-

Table 2. Correlations (Spearman's correlation coefficients) between variables of *O. rhinoceros* breeding, *O. rhinoceros* damage, and some environmental variables of 9-ha plots

Variable *A*	Variable *B*		
	Beetle cuts per ha on upper fronds ($n = 53$)	Disease incidence	
		Baculovirus ($n = 30$)	*M. anisopliae* ($n = 30$)
Stumps (n)	0.62[a]	0.44[b]	0.12
Trunks on ground (n)	0.33[b]	−0.15	−0.16
Dead standing palms (n)	0.09	0.75[a]	0.06
No. of breeding sites	0.53[a]	0.35	0.09
Avg rainfall/year	−0.30[b]	−0.23	−0.08
Elevation above sea level	−0.13	−0.38[b]	0.32
Palm density	0.12	−0.04	0.16

For correlations with disease incidence, only plots where >20 breeding sites were examined for disease were used.
[a] Significant at 1% level.
[b] Significant at 5% level.

Table 3. Abundance and survival of different development stages of *O. rhinoceros* in breeding sites

Stage	Median age (days)[a]	Total recorded	No. per ha[b]	Estimated survival (%)
Egg	5	5,431	12.2	100
1st instar	18	5,441	12.1	75.1
2nd instar	34	5,634	12.6	65.1
Young 3rd instar	57	6,117	13.2	40.5
Old 3rd instar	103	5,488	12.0	18.0
Pupa	144	392	0.9	3.5
Immature adult	168	351	0.8	2.9

[a] The median age of each stage was estimated from laboratory records of five authors, as reported by Bedford (1976). Duration of the immature adult stage after Zelazny (1975).
[b] We compensated for 140 dead standing palms that were not inspected by adding equivalent numbers of stages found in other dead standing palms of the same plot.

ing adults 3–11 months before the survey) was significantly ($P < 0.05$) positively correlated with the number of breeding sites and with the density of stumps and trunks on the ground, but not with the density of dead standing palms (Table 2). On average the palm damage was 334 cuts per ha.

Table 3 gives estimates for the abundance of various *O. rhinoceros* stages per hectare and their survival rates. Larvae survived better in trunks on the ground than in stumps or dead standing palms (Fig. 1). Survival of the various stages of *O. rhinoceros* was not significantly and consistently correlated with the degree of *O. rhinoceros* damage on palms, brood density, or disease incidence. The average amount of rainfall in the plots gave negative correlations with the survival rates of all stages (that is, survival decreased with increasing rainfall), but only survival from egg to pupa gave a significant correlation coefficient ($r_s = -0.818$, df = 8).

Two types of predators were observed feeding on *O. rhinoceros* larvae during the survey, elaterid larvae (*Alaus podargus* Candèze and *Lanelater bifoveatus* Candèze). and a shrew nesting in coconut trunks and stumps. Of 608 breeding sites, 28 (4.6%) contained elaterid larvae and 5 (0.8%) shrews.

Discussion

The accuracy of survival estimates was apparently reduced by considerable variation in the ratio of the various stages of *O. rhinoceros*. Seasonal breeding patterns could have contributed to this variation. No such patterns were obvious, but repeated sampling from the same location would have been necessary to investigate this in detail.

The low survival rates of larvae in stumps and in areas of high rainfall are possibly related. The center of a coconut palm stump decays faster than the outer parts. This can cause accumulation of rain water and drowning of the larvae. The high mortality in stumps appears to contradict the strong positive correlation between number of stumps in a plot and its palm damage (Table 2). Actually, the palm damage reflects the breeding of nearly a year earlier, as the long development time of *O. rhinoceros* has to be added to the delay in the appearance of the damage on the palms. Therefore, the presence of stumps could indicate that a year earlier more breeding occurred in felled trunks that in the meantime decayed or were used for firewood. From casual observations, trunks on the ground decay faster than stumps or dead standing palms.

Although the effect of the baculovirus on *O. rhinoceros* populations has been well documented (Young 1974, Bedford 1981), the mechanisms of transmission of the virus are still not completely understood. In Samoa, the virus is thought to be transmitted most frequently from adult to adult

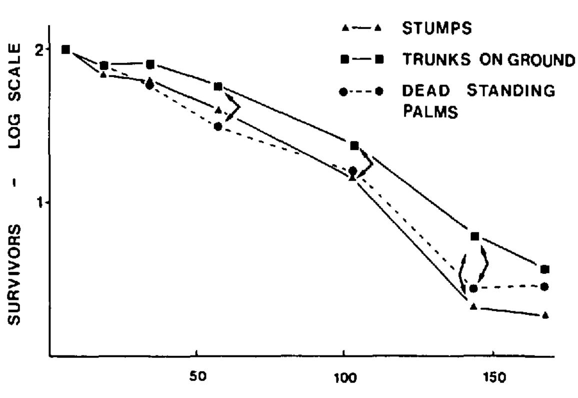

Fig. 1. Estimated percentages of survival of *O. rhinoceros* stages in three types of breeding places. Double arrows indicate significant differences ($P < 0.05$; Wilcoxon signed-rank test).

(Huger 1973, Zelazny 1976). By law, dead standing palms have to be felled, as it is recognized that they are preferred breeding places of *O. rhinoceros*. In the Philippines, dead standing palms are apparently very important for spreading the virus. Because they are frequently visited by beetles, transmission from infected adults to larvae as well as from infected larvae to visiting adults is common (Table 1).

It is encouraging from the stand point of finding better control methods for *O. rhinoceros* that the density of dead standing palms does not correlate significantly ($P = 0.39$) with the palm damage (population density). This is probably related to the observation that in dead standing palms larval survival is low and baculovirus incidence high. Although incidence of the virus was not significantly ($P > 0.05$) correlated with larva survival (possibly due to the large variation in the ratio of the stages), it also causes adult mortality and sterility in females (Zelazny 1973a). The effect of the virus on the reproduction of the beetle is probably very important for regulation of the *O. rhinoceros* population (Anderson and May 1981).

The observations suggest that transmission of the baculovirus could be optimized by controlling the number of dead standing palms per hectare. A number too large apparently will reduce the virus incidence (as the contact between adults and larvae decreases), and the highest virus levels were observed at about five dead palms per hectare.

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