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Trap catches of the coconut rhinoceros beetle *Oryctes rhinoceros* (L.) (Coleoptera, Scarabaeidae, Dynastinae) in New Britain

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Abstract

The trend in the relative populations of *Oryctes rhinoceros* (L.) in two areas of the Gazelle Peninsula, New Britain, was studied by trapping adults searching for breeding sites. In a high rainfall area with 10-year-old palms and many possible breeding sites, there was a large initial population of beetles which declined over the next three years with the gradual disappearance of the breeding sites; weekly catches were higher when the undergrowth in the trapping area was slashed, and to some extent also at new moon; catches were depressed by heavy rain. The ♂/♀ sex ratio was 0·31; all females had mated and had mature eggs in the lower ends of the oviducts. These results were compared with those from a low rainfall area with 70-year-old palms and dispersed breeding sites. Catches were generally lower; they showed no long term trend and were not related to slashing or weekly rainfall, but were inversely related to the number of rainy days per week.

Introduction

The rhinoceros beetle, *Oryctes rhinoceros* (L.), is an important pest of coconut palms, the adults boring into the crowns to feed. The larvae develop in the tops of dead standing palms, decaying coconut and other trunks and stumps on the ground, and in accumulations of compost and sawdust.

The present work describes the use of traps to study fluctuations and the long term trend in the beetle population at two localities in the Gazelle Peninsula of New Britain. The catching of beetles in traps provides relative estimates of the population, though not all the members of the population may be responsive to the traps at any one time.

Description of study areas

Raulawat Plantation

The study area contained ten-year-old coconut palms in rows. The palms were heavily damaged by *O. rhinoceros*, and many had been killed by the palm weevil *Rhynchophorus bilineatus* (Montr.) following rhinoceros beetle attack. Dead coconut stumps and trunks provided plentiful breeding sites. A heavy undergrowth of *Leucaena leucocephala* suckers and kunai grass *Imperata cylindrica* was slashed every 3–4 months, and in the latter half of the study, after 2 October 1969, the trapping area was slashed approximately monthly.

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Thermohygrograph recordings in the plantation showed little variation in the pattern of temperature and relative humidity throughout the year. Minima of 18–21°C occurred between 22.00 and 06.00 h and maxima of 30–38°C between 10.00 and 16.00 h. Relative humidity was 100% from about 22.00 to 08.00 h, and fell to 60–70% from 09.00 to 18.00 h. The average rainfall for 1968–70 was 113 in. (range 103–121 in.).

Malapau Plantation

This plantation was located in a 'rain shadow', the average annual rainfall for 1968–70 being 65 in. (range 54–74 in.). The plantation consisted of large areas of 70–80-year-old palms in rows, except for some replanted sections where the palms were about five years old. Vegetation between the palms consisted mainly of kunai grass. There were few dead standing palm trunks serving as breeding sites and, as many palms were available as feeding sites, beetle damage was light. Many tall palms seemed unhealthy and bore little fruit, possibly due to old age, sulphur deficiency or low rainfall.

Thermohygrograph recordings in the plantation showed maxima of 32–41°C between 12.00 and 14.00 h and minima of 21°C during the night. The relative humidity reached a maximum of 90% during the night, and fell to a minimum of 40–60% just after noon.

Materials and methods

Adult beetles are attracted to a trap designed by Hoyt (1963). This trap consists of a 1·8-m length of coconut trunk, 0·3 m of which is sunk upright into the ground. A 2·3-litre tin stands on the top, and on top of this a cap consisting of a 25-cm length of coconut trunk with a hole 35 mm in diameter drilled through the axis. At night beetles are attracted to the trap, presumably by the odour emitted from the decaying coconut wood of the cap and trunk. They land on the cap, crawl down the hole and fall into the tin from which they cannot escape. As the coconut wood of the caps rotted after about five months, the caps on one-fifth of the traps were renewed each month.

At Raulawat, 23 traps were distributed through an area of about 8·1 ha (Fig. 1). The traps, placed well apart yet convenient of access, were operated from 28 March 1968 to 28 January 1971. They were checked twice weekly at first but later only once

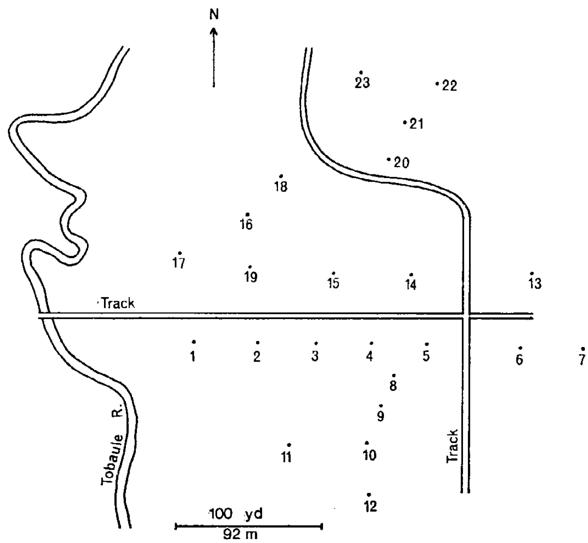

Fig. 1.—Map of trap layout at Raulawat.

TABLE I. *Regression analysis of* O. rhinoceros *catch in Raulawat traps from 28 March 1968 to 14 January 1971 (periodic cycle term of 18 weeks)*

Variable		Males: Regression coefficient	Males: t	Females: Regression coefficient	Females: t	Total: Regression coefficient	Total: t
Constant	b_0	$1{\cdot}76\times10^{0}$	—	$2{\cdot}80\times10^{0}$	—	$3{\cdot}09\times10^{0}$	—
Linear (time trend)	b_1	$3{\cdot}56\times10^{-2}$	2·66**	$4{\cdot}22\times10^{-2}$	4·50***	$4{\cdot}33\times10^{-2}$	4·57***
Quadratic ,,	b_2	$-7{\cdot}54\times10^{-4}$	3·60***	$-8{\cdot}70\times10^{-4}$	5·91***	$-8{\cdot}97\times10^{-4}$	6·04***
Cubic ,,	b_3	$3{\cdot}32\times10^{-6}$	3·56***	$3{\cdot}71\times10^{-6}$	5·68***	$3{\cdot}86\times10^{-6}$	5·84***
Cos ø (periodic cycle)	b_4	$-3{\cdot}25\times10^{-2}$	0·41^{ns}	$-1{\cdot}21\times10^{-1}$	2·19*	$-1{\cdot}12\times10^{-1}$	2·00*
Sin ø ,,	b_5	$-2{\cdot}10\times10^{-1}$	2·62**	$-2{\cdot}18\times10^{-1}$	3·89***	$-2{\cdot}22\times10^{-1}$	3·92***
Rain	b_6	$-7{\cdot}67\times10^{-4}$	2·44*	$-4{\cdot}92\times10^{-4}$	2·23*	$-6{\cdot}62\times10^{-4}$	2·96**
Variance ratio (d.f. 6, 140)			16·57***		47·26***		48·77***
100 r^2		41·5		67·0		67·6	

^{ns} = not significant; * $P\leqslant0{\cdot}05$; ** $P\leqslant0{\cdot}01$; *** $P\leqslant0{\cdot}001$.

TABLE II. *Regression analysis of* O. rhinoceros *catch in Raulawat traps from 2 October 1969 to 14 January 1971 (periodic cycle term of 18 weeks)*

Variable		Males: Regression coefficient	Males: t	Females: Regression coefficient	Females: t	Total: Regression coefficient	Total: t
Constant	b_0	$8{\cdot}24\times10^{-1}$	—	$1{\cdot}80\times10^{0}$	—	$2{\cdot}03\times10^{0}$	—
Linear (time trend)	b_1	$3{\cdot}01\times10^{-2}$	0·63^{ns}	7.85×10^{-2}	2·10*	$7{\cdot}59\times10^{-2}$	1·97^{ns}
Quadratic ,,	b_2	$-1{\cdot}01\times10^{-3}$	0·61^{ns}	$-3{\cdot}14\times10^{-3}$	2·40*	$-2{\cdot}98\times10^{-3}$	2·21*
Cubic ,,	b_3	$9{\cdot}89\times10^{-6}$	0·61^{ns}	$3{\cdot}05\times10^{-5}$	2·37*	$2{\cdot}91\times10^{-5}$	2·19*
Cos ø (periodic cycle)	b_4	$8{\cdot}17\times10^{-2}$	0·66^{ns}	$-2{\cdot}14\times10^{-2}$	0·22^{ns}	$2{\cdot}14\times10^{-2}$	0·25^{ns}
Sin ø ,,	b_5	$1{\cdot}82\times10^{-1}$	1·52^{ns}	$3{\cdot}57\times10^{-1}$	3·79***	$3{\cdot}55\times10^{-1}$	3·66***
Rain	b_6	$-9{\cdot}26\times10^{-4}$	1·97^{ns}	$-9{\cdot}84\times10^{-4}$	2·65*	$-1{\cdot}20\times10^{-3}$	3·15**
Variance ratio (d.f. 6, 59)			1·01^{ns}		4·92***		4·31**
100 r^2		9·4		33·3		30·6	

^{ns} = not significant; * $P\leqslant0{\cdot}05$; ** $P\leqslant0{\cdot}01$; *** $P\leqslant0{\cdot}001$.

per week. All beetles found in the traps were recorded and released within the trapping area. Samples of females were dissected from time to time to determine the state of development of the reproductive system. Observations on abundance of breeding sites, abundance of larvae in breeding sites, and on levels of damage to palms, were made periodically.

Thirty traps were operated at Malapau from October 1969 to December 1970. The traps were checked weekly, and all beetles were released within the trapping area.

Method of analysis

The Raulawat data showed a decline in catches over the trapping period, and a strong suggestion of a periodic effect with an interval of about 15–19 weeks. There is a rational explanation for the latter in that the whole area was periodically slashed at about this interval up to October 1969, after which the trapping area was slashed at approximately monthly intervals but the rest of the plantation continued to be slashed only periodically. Also, there is evidence from other sources that *O. rhinoceros* may be suppressed by heavy rain (Cumber, 1957).

The catches were tested on a regression model with the following components:

(i) a time trend (with linear, quadratic and cubic terms);
(ii) a period term of 15–19 weeks (to fit the slashing cycle);
(iii) effect of weekly rainfall (in.);
(iv) effect of rainfall as number of rainy days per week, as an alternative to (iii).

The initial analysis (Analysis 1) was run by computer over the entire period from 28 March 1968 to 14 January 1971, with the weekly catches of male, female and total beetles transformed to $\log_e$ values. Separate analyses were made for period intervals of 15 up to 19 weeks and the smallest residual occurred with an interval of 18 weeks. The numerical coefficients for the regression relation

$$y = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + b_4 \cos \frac{2\pi t}{18} + b_5 \sin \frac{2\pi t}{18} + b_6 r$$

where y is $\log_e$ (male catch $+1$), $\log_e$ (female catch $+1$) and $\log_e$ (total catch $+1$), t is number of weeks from start of observations, and r is weekly rainfall, are given in Table I.

Because of the change in the vegetation slashing procedure, the analysis was re-run, over the period from 2 October 1969 onwards, with the same form of regression (Analysis 2) and the coefficient with t values are shown in Table II.

To investigate any effect of moon phase, each weekly catch was classified as falling into new moon, first quarter, full moon or last quarter, according to the phase which dominated that week. The data for males, females and total were transformed to $\sqrt{(n+1)}$ and an analysis of variance was performed to compare the mean numbers of beetles caught weekly during each of the four phases (Table III).

A regression analysis was done on the weekly catches of beetles at Malapau, transformed to $\log_{10}$ $(n+1)$, and using the same regression formula as for Raulawat and a period of 18 weeks; a summary of the output is shown in Table IV.

TABLE III. *Mean number of* O. rhinoceros *beetles per weekly catch for four moon phases*

Lunar phase	No. catches	Mean no. beetles per catch: Males	Females	Total
New Moon	38	5·6	17·6	23·2
First Quarter	35	4·1	15·6	19·7
Full Moon	35	4·3	14·2	18·5
Last Quarter	35	5·0	15·4	20·4

Results

Raulawat

Time trend.—In Analysis 1, for all measures the linear and curvilinear coefficients in the time trend are significant (Table I). In Analysis 2 (Table II) the time trend coefficients for the shorter time from October 1969 onwards are identical in sign with those for the whole time (Analysis 1). The cubic curvilinear coefficients reach significance only in the females and total for the shorter time.

Periodic effect.—In Analysis 1 (Table I), there is a significant effect due to the 18-week periodic cycle terms for males, females and total (sine or cosine terms being significant); however in Analysis 2 (Table II) the effect is only significant for females and total.

Except for the cosine terms in Analysis 2 (which are not significant), the coefficients for the males have the same sign as for the females and total. However the signs for these periodic terms in Analysis 2 are reversed from those for Analysis 1 covering the whole period, suggesting that the latter part of the record, while still involving a short term periodicity, is displaced in phase from the earlier part of the record. This is explicable if there is some irregularity in the intervals between slashings in the plantation surrounding the trapping area. In the whole record the amplitude of the periodic effects is much more apparent in the earlier than in the later stages, and is evidently strong enough to counter the out-of-phase trend from the later stages.

When the vegetation grew up, it may have made the trap more difficult for the beetle to find than when it was slashed. This is a factor which should be borne in mind in such studies, though it may apply more particularly in the rapid-growing vegetation in New Guinea than elsewhere.

Weekly rainfall and days of rain.—In Analysis 1 (Table I) the rainfall term was significant. It was also significant in Analysis 2 (Table II) for females and for total, and was consistently negative, indicating that rainfall depressed the catch of beetles. Analysis 2 was repeated with number of rainy days substituted for weekly rainfall. The t values for this term were 0·38, 0·88 and 1·05 for males, females and total, respectively, and were not significant.

At Raulawat there was thus a correlation between the catch of beetles and the weekly total rainfall, indicating that there were fewer beetles moving about and hence likely to go into traps during periods of heavy rainfall. In Western Samoa, Cumber (1957) found that periods of heavy rainfall were followed by low beetle catches in traps of split coconut logs laid on the ground, and that greatest numbers of beetles were taken during periods of reduced rainfall following periods of heavy rain. He suggested that beetles were prevented from flying to breeding sites by the rainy weather, and instead remained in the palm crowns.

The logarithms of the weekly total catches of beetles resulting from Analysis 1 are plotted in Fig. 2, together with regression estimates fitting the linear, quadratic and cubic terms, 18-week periodic cycle terms, and effect of weekly rainfall. The contribution to the estimates from the trend term only, is also shown. As regards the latter, in fitting such a polynomial trend one inevitably obtains poor estimates at the extremes, and the apparent upward trend at the end of the data is not to be regarded as a real effect. The actual weekly rainfall in inches is also shown.

Lunar cycle.—The mean numbers of beetles caught weekly in the four phases of the moon are set out in Table III. From these data it appears as if the mean number of beetles per catch was greater at new moon for the males, females and total; however, the analysis of variance showed that the differences in catch between phases were not significant in all three cases (variance ratios for phase main effect on males, females and total were 0·82, 1·06 and 1·09, respectively).

The effect of moon phase could have been swamped by the time trend, slashing cycle, rainfall, or even the amount of cloud cover at night. Bowden & Church (1973) found that light-trap catches in Africa of the Pyralid *Marasmia trapezalis* (Gn.), other Pyralidae, Lampyridae, and *Dorylus* spp. (Formicidae) were increased at no moon. Nemec (1971) showed that the greatest numbers of the bollworm moth, *Heliothis zea* (Boddie), were light-trapped during last quarter, and the smallest numbers at full moon. Full moonlight suppressed bollworm moth activity, resulting in reduced oviposition at full moon; this led to a synchronisation of generation cycles with lunar phases. It might

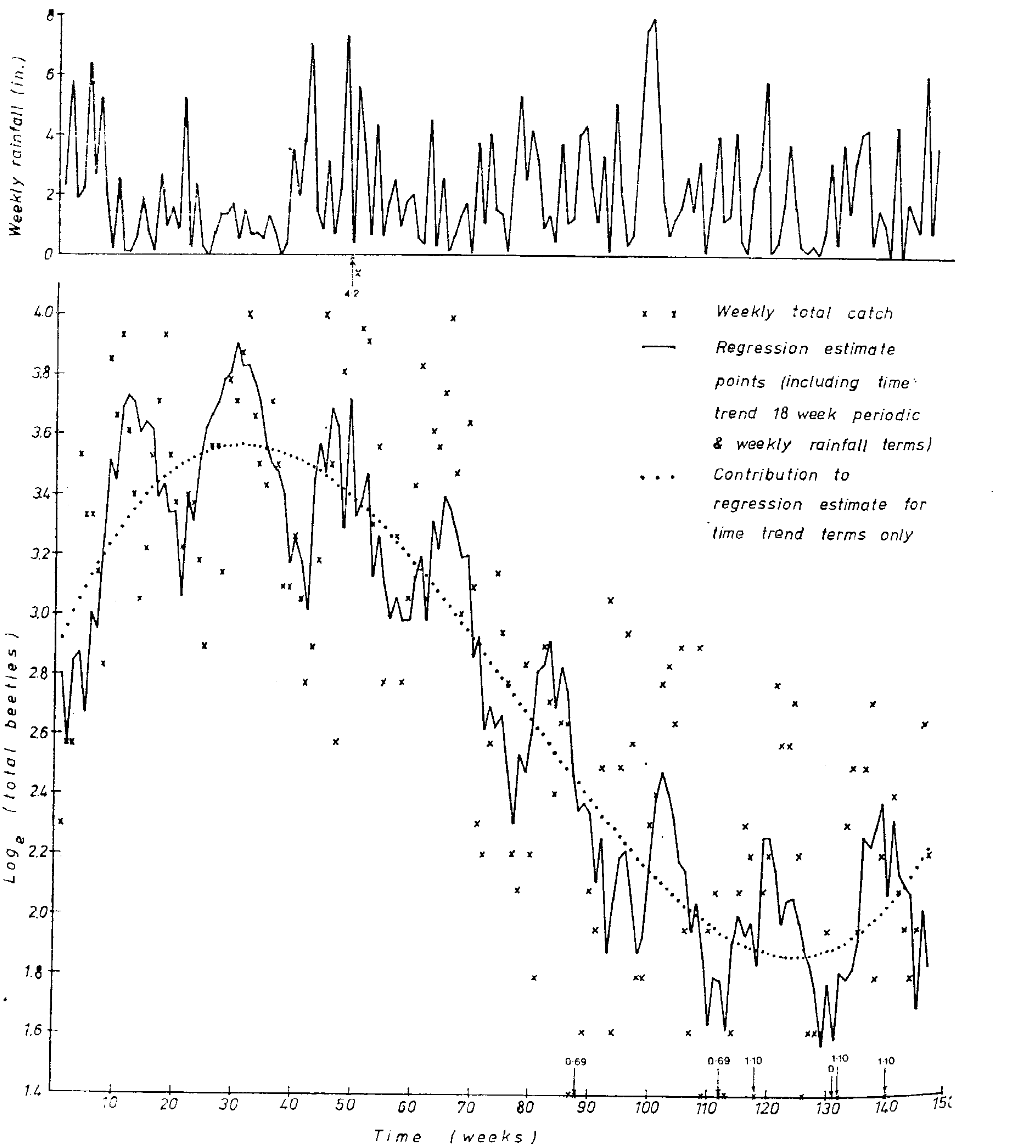

Fig. 2.—Upper curve shows weekly rainfall (in inches) at Raulawat. Lower curves show (i) $\log_e$ of weekly total *O. rhinoceros* catch at Raulawat, (ii) regression estimate points fitting the linear, quadratic and cubic time terms, periodic term for a period of 18 weeks, and a term for effect of weekly rainfall, and (iii) the contribution to these regression estimates for the time trend term only.

be that activity of *O. rhinoceros* is stimulated at low moonlight intensity, with a resultant tendency towards some degree of synchronisation of the breeding activities of the population. It would be ecologically advantageous for an insect of low population density like *O. rhinoceros*, that more members of the population be active at a given lunar phase, so that their chances of meeting and mating would be increased at that time.

Total numbers of beetles caught.—Altogether 710 males and 2323 females were caught in the traps over the study period, a ♂/♀ sex ratio of 0·31. Hinckley (1973), using similar traps in Western Samoa from October 1964 to December 1966, caught 3049 males and 1988 females, giving a sex ratio of 1·53. The reason for this difference, in sex ratio is not clear, particularly as larvae of each sex occurred in about equal proportions in both places. The New Britain results can readily be explained by assuming that females spend more time searching for breeding sites than do males, and hence tend to visit traps (which simulate breeding sites) and get caught, more often than do males. In split log traps in Western Samoa, Cumber (1957) collected approximately equal numbers of males and females over an 11-month period (5185 females, 5394 males).

Number of beetles caught by each trap.—There was considerable variation in the numbers of beetles caught by the 23 traps (mean 131/trap, range 73–205, s.d. 32) over the observation period. This was apparently because some traps were more favourably located than others; catches in some traps were consistently higher despite periodic renewals of the caps.

Reproductive condition of beetles caught in traps.—Dissection of 24 beetles caught in traps showed that 22 (92%) were mated and carried remains of spermatophores in the bursa copulatrix. The lower ends of the oviducts contained an average of 25 mature eggs per beetle (range 10–38). In Western Samoa, Hinckley (1973) found an average of 22 full-sized eggs in gravid females caught in traps.

It was not possible to obtain data on the reproductive condition of the males with the method of dissection employed.

Numbers of suitable breeding sites.—Over the period of observation the number of suitable breeding sites in the trapping area declined markedly. In July 1968 in an area of approximately four hectares there were 20 breeding sites (dead standing trunks or stumps) occupied by numerous larvae. Over the trapping period, breeding sites broke down and rotted away, or became overgrown with grass, and by the end of January 1971 only two breeding sites in the same four hectares area were found to contain *O. rhinoceros* larvae.

Palm damage.—Damage was measured as the number of beetle cuts on fronds in samples of 50–70 palms. The damage declined over the study period. In September 1968, 100% of the palms had beetle damage to the fronds (8·9 cuts per palm); in October 1970 the comparable figures were 52% (1·9 cuts) and in February 1971 39% (1·1 cuts). This decline was associated with the disappearance of breeding sites and reflected the gradual fall in the beetle population.

Malapau

The total reduction due to trend terms was not significant for males, females or total (Table IV), but the signs of the coefficients were consistent, indicating that all three terms may have been making a contribution.. The periodic effects were quite dubious, and so too was the effect due to weekly rainfall. When the programme was re-run with the number of rainy days per week substituted for total weekly rainfall, the predictive value improved, t being 3·04 ($P<0{\cdot}01$), 1·18 (n.s.) and 2·57 ($P<0{\cdot}05$) for males, females and total, respectively. This indicated that for males and total, the percentage variation explained by the regression significantly increased when number of rainy days per week was included.

TABLE IV. *Regression analysis of* O. rhinoceros *catch in Malapau traps from 2 November 1968 to 4 December 1970 (periodic cycle term of 18 weeks)*

Variable		Males: Regression coefficient	Males: t	Females: Regression coefficient	Females: t	Total: Regression coefficient	Total: t
Constant	b_0	6.03×10^{-1}	—	9.20×10^{-1}	—	1.22×10^{0}	—
Linear (time trend)	b_1	-1.17×10^{-2}	0·66^{ns}	-8.20×10^{-3}	0·43^{ns}	-1.23×10^{-2}	0·69^{ns}
Quadratic ,,	b_2	5.62×10^{-4}	1·48^{ns}	5.11×10^{-4}	1·28^{ns}	7.01×10^{-2}	1·86^{ns}
Cubic ,,	b_3	-4.08×10^{-6}	1·78^{ns}	-3.96×10^{-6}	1·64^{ns}	-5.32×10^{-6}	2·33*
Cos ø (periodic cycle)	b_4	1.19×10^{-1}	1·58^{ns}	6.66×10^{-2}	0·84^{ns}	1.07×10^{-1}	1·43^{ns}
Sin ø ,,	b_5	-2.43×10^{-1}	3·15**	3.34×10^{-2}	0·41^{ns}	-8.16×10^{-2}	1·06^{ns}
Rain	b_6	-2.52×10^{-4}	0·85^{ns}	1.17×10^{-4}	0·38^{ns}	-1.40×10^{-4}	0·47^{ns}
Variance ratio (d.f. 6, 97)			5·64***		2·91		6·27
100 r^2		25·9		15·3		28·0	

ns = not significant; * $P \leq 0.05$; ** $P \leq 0.01$ *** $P \leq 0.001$.

Totals of 173 males and 309 females were taken at Malapau, giving a ♂/♀ sex ratio of 0·56, somewhat higher than for Raulawat.

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