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Author: OWEN, I. L.

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RUSA DEER *(Cervus timorensis)* AS A HOST FOR THE CATTLE TICK *(Boophilus microplus)* IN PAPUA NEW GUINEA

I. L. OWEN, Veterinary Laboratory, Department of Primary Industry, P.O. Box 6372,
Boroko, Papua New Guinea

Abstract: The rusa deer (*Cervus timorensis*) is more resistant to the cattle tick (*Boophilus microplus*) than are British breed cattle in Papua New Guinea. The average yield of replete female ticks from deer was 1.6% (0.3-3.2%) as compared to 11.2% (3.4-23.1%) from calves. Ticks from deer were more slender, lighter in weight and produced fewer eggs (mean 1,800) than did ticks from calves (mean 2,200) but the deer was shown to be an effective host. A cervid population can maintain a tick population in the absence of bovine hosts thus presenting an important factor in eradication programs. Nutritional stress appears to result in a higher seasonal prevalence of infestation amongst males and non-pregnant females.

INTRODUCTION

The rusa deer (*Cervus timorensis*) was first introduced into Papua New Guinea about 1900.[7] Today, sizeable populations occur in the Port Moresby area of the Central Province and the Trans-Fly area of the Western Province (Fig. 1). The population in the former is relatively small (estimated as 700-800 in 1972) and is hunted extensively but, owing to the difficult terrain, it appears to succeed in maintaining its numbers. The deer in the Western Province on the other hand, estimated to number up to 15,000,[17] are under little pressure from man and have unrestricted movement across the border with Irian Jaya. The two populations are separated by about 600 km of jungle and swamp.

The cattle tick, *Boophilus microplus*, probably was brought into the country on cattle from Java before World War I.[1] Eradication programs have eliminated the tick from most regions but the Port Moresby hinterland and the Trans-Fly are two of the few areas which remain tick infested. An intensive eradication program undertaken around Port Moresby between 1954 and 1958 proved unsuccessful. One reason for this, possibly, is the presence of deer within and outside grazing areas.[1] No attempt has been made to eradicate tick from the Western Province.

Early references to deer as hosts for *B. microplus* are few, although the tick was reported on rusa deer in Indonesia in 1932.[15] The ability of white-tailed deer (*Odocoileus virginianus*) to maintain a population of cattle tick sufficient to affect eradication programs was still in doubt as recently as 1963 in the United States,[18] until trials proved that the tick could undergo repeated life cycles on the deer.[14,20] Results of trials conducted in Papua New Guinea to check on the suitability of rusa deer as a host for the tick led to the belief that it was "not a favoured host".[1] A tick control program was begun in the Port Moresby area in 1959, based on the unconfirmed assumption that the deer carried ticks only when pasture infestation was high.[1] This control plan failed to prevent infestation of deer and the cattle tick remains a problem in the area.

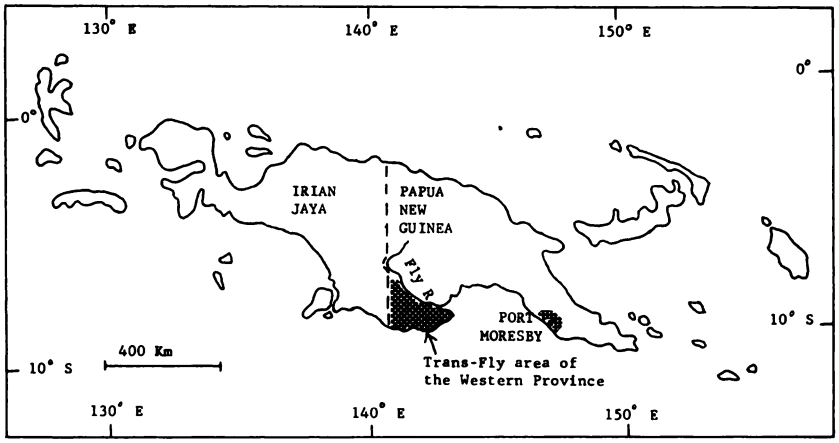

FIGURE 1. Map of the island of New Guinea showing the two areas (shaded) where rusa deer (**Cervus timorensis**) and cattle tick (**Boophilus microplus**) occur together in Papua New Guinea.

MATERIALS AND METHODS

The investigation was carried out over a number of years, partly in conjunction with other work involving cattle, deer and cattle tick. Six deer acquired originally as fawns were used for the experimental work. Three were from the Western Province and three were from Port Moresby. During field work in the Western Province between 1967 and 1971, 206 deer were killed and examined for ticks, of which 35 received closer scrutiny than the others. Some of the information has been extracted from a research report by Lindgren.[17] A total of 32 deer carcasses were inspected from the Port Moresby area during 1971 and 1972. Calves of mixed British breeds came from the tick-free Central Highlands. Ticks were obtained from the Port Moresby area and occasionally from the Western Province, and maintained on animals at the Veterinary Laboratory. Experimental animals were kept in individual, open air, moated pens with concrete floors.

Ticks were collected in sieves with 3 mm^2 apertures, counted, cleaned, dried and measured. 'Length' was taken from the 'shoulder' to the posterior tip and 'width' at the widest part of the body. Those ticks which were clearly not replete were separated from those fully engorged or replete. The rearing of tick larvae, infestation and maintenance of infested animals followed essentially the methods described by others.[2,21,22] It was assumed that, since one gram of eggs laid by ticks from a bovine host yields 20,000 larvae,[22] the same was true of eggs produced by ticks from deer. The yield of replete female ticks is expressed as a percentage of female larvae applied, assuming a 1:1 sex ratio. Tick experience of individual experimental animals is indicated in Table 1. Tests of statistical significance, using Gaussian and t-distributions as appropriate, were carried out where there were enough observations.

The climate in the vicinity of the laboratory is typical of the dry savannah grassland area around Port Moresby[19] and much of the tick infested area of the Western Province. Under these conditions the cattle tick can survive and reproduce throughout the year, but the duration of its survival on pasture varies with the locality and the time of the year.[19]

EXPERIMENTAL RESULTS

Length of Parasitic Period

Duration of the parasitic phase on deer and calves is shown on Table 1. The mean day for engorged female ticks to start dropping from both host animals was day 20; the longest time of attachment was 28 days on deer and 30 days on calves. The mean day for the largest tick-drop was day 21 from deer and day 22 from calves when, respectively, an average of 24.4% and 39.4% of the total replete ticks dropped. During days 20 to 23 of infestation, 78.8% of replete ticks dropped from deer and 86.8% from calves.

Engorged female tick drop

Table 1 also gives the numbers of engorged females which dropped from deer and calves infested with different numbers of larvae. The mean percentage of females dropping from deer not previously exposed to ticks was 1.7 and 11.8 from similarly unexposed calves. No distinct pattern emerges from the few data available following reinfestation of either host. The overall mean yield of replete female ticks from 13 calves was 11.2% and from 7 deer was 1.6%.

Table 1. Length of the parasitic phase of the cattle tick, **Boophilus microplus**, in 7 infestations on rusa deer and 13 on British breed calves, and the number of engorged female ticks which dropped from the hosts following infestation with various numbers of larvae.

Host*	No. of larvae per infestation	No. of engorged ticks dropped (% Survival)**	Dropping of engorged ticks (days after infestation)		
			First	Last	Max. drop
Deer 39546 $\boxed{1}$	10,000	74 (1.5)	20	26	20
Deer 4321 $\boxed{4}$	20,000	243 (2.4)	20	27	21
Deer 39546 $\boxed{2}$	20,000	27 (0.3)	20	22	21
Deer 39546 $\boxed{3}$	20,000	95 (1.0)	20	25	22
Deer 0221 $\boxed{1}$	20,000	324 (3.2)	20	33	22
Deer 4321 $\boxed{3}$	25,000	295 (2.4)	19	29	20
Deer 39554 $\boxed{1}$	33,000	132 (0.8)	20	32	22
Calf 0488 $\boxed{1}$	5,000	362 (14.5)	20	27	23
Calf 16261 $\boxed{1}$	10,000	308 (6.2)	21	32	22
Calf 16386 $\boxed{1}$	10,000	478 (8.0)	21	36	23
Calf 0488 $\boxed{2}$	10,000	381 (7.6)	20	25	22
Calf 39553 $\boxed{4}$	10,000	253 (5.1)	20	27	22
Calf 33460 $\boxed{1}$	20,000	884 (8.8)	20	26	22
Calf 39553 $\boxed{2}$	20,000	831 (8.3)	20	29	22
Calf 39553 $\boxed{3}$	20,000	1440 (14.4)	20	27	22
Calf 0453 $\boxed{1}$	20,000	1419 (14.2)	21	31	24
Calf 39548 $\boxed{1}$	20,000	2310 (23.1)	17	29	22
Calf 39551 $\boxed{1}$	20,000	335 (3.4)	20	28	21
Calf 39550 $\boxed{1}$	20,000	1486 (14.9)	20	29	22
Calf 39549 $\boxed{1}$	33,000	1780 (10.8)	20	34	22

* $\boxed{1}$ First, $\boxed{2}$ second, $\boxed{3}$ third, $\boxed{4}$ fourth exposure to *B. microplus* infestation.

** A 1:1 sex ratio of the larvae applied is assumed in calculating the percentage survival of engorged females.

Non-engorged female tick drop

The number of non-engorged females with a width >3 mm which dropped from deer and calves during tick-drop periods is shown in Table 2. The percentage from first and later infestations of individual deer and calves showed considerable variation. The mean yield of non-replete ticks of the total female drop from 12 calves was 4.0% and was 15.1% from 7 deer.

Size and weight of engorged female ticks

The size and weight of replete ticks dropping from the two types of hosts at first, second, third and fourth infestations are shown in Table 3. Ticks from deer were smaller in size and lighter in weight than those from calves on primary infestations, and these differences tended to become more pronounced following reinfestation. The mean size of 5411 ticks from calves was 1.04 x 0.70 cm (0.70-2.00 x 0.60-0.80) and of 795 ticks from deer 0.99 x 0.66 cm (0.70-1.20 x 0.50-0.80). The difference in mean length between ticks from calves and those from deer is not significant ($P = 0.31$) but the difference in mean width is significant ($P<0.001$). A significant difference ($P<0.001$) is apparent in the weight of ticks from the two hosts; the mean weight of ticks from calves was 0.23 g (0.08-0.27) and from deer 0.19 g (0.07-0.28).

Egg production

The percentage of replete ticks which produced eggs was similar from the two hosts; the mean for 4702 ticks from 13 calf infestations was 86% (60-97%) and the mean for 740 ticks from 9 deer was 85% (69-100%). There was a significant difference in the number of eggs (measured by weight) laid by ticks from the two hosts ($P<0.025$). Based on information from 1984 ticks obtained from calves, the mean weight of eggs produced by one tick was 0.11g and, using 115 ticks from deer, the mean per tick was 0.09g. The mean weight of eggs per tick was the same for primary and subsequent infestations; this was true for both hosts (Table 3).

Table 2. Number of non-engorged female cattle ticks (>3 mm wide) which dropped from 7 deer and 12 calves following infestations with various numbers of larvae. Percentage is given of the non-engorged ticks in relation to the total tick-drop of engorged females. ($\boxed{1}$ = first, $\boxed{2}$ = second, $\boxed{3}$ = third, $\boxed{4}$ = fourth exposure to **B. microplus** infestation.)

No. of larvae per infestation	10,000 (%)	20,000 (%)	25,000 (%)	33,000 (%)
Deer	10 (11.9) $\boxed{1}$	35 (12.6) $\boxed{4}$ 11 (29.0) $\boxed{2}$ 5 (5.0) $\boxed{3}$ 8 (2.4) $\boxed{1}$	139 (32.1) $\boxed{3}$	2 (1.5) $\boxed{1}$
Mean % yield	11.9	7.9	32.1	1.5
Calves	6 (1.9) $\boxed{1}$ 5 (1.0) $\boxed{1}$ 9 (2.3) $\boxed{2}$ 23 (8.3) $\boxed{4}$	58 (6.2) $\boxed{1}$ 53 (6.0) $\boxed{2}$ 130 (8.3) $\boxed{3}$ 20 (1.4) $\boxed{1}$ 36 (1.5) $\boxed{1}$ 2 (0.6) $\boxed{1}$ 59 (3.8) $\boxed{1}$	—	62 (3.4) $\boxed{1}$
Mean % yield	3.0	3.9	—	3.4

Table 3. Mean length, width and weight of replete female cattle ticks and the mean weight of eggs laid per tick from deer and calves infested one or more times with **Boophilus microplus** larvae. (Host number in brackets)

	Host	First Infestation	Second Infestation	Third Infestation	Fourth Infestation
Length	Deer	1.06 (39546) 1.05 (39554)	0.93 (39546)	0.99 (4321) 0.97 (39546)	0.99 (4321)
		Mean 1.05	Mean 0.93	Mean 0.98	Mean 0.99
	Calves	1.08 (0453) 1.02 (33460) 1.08 (39549) 1.09 (39550) 1.02 (39551) 1.09 (39553)	1.08 (0488) 1.02 (39553)	1.04 (39553)	0.99 (39553)
		Mean 1.06	Mean 1.05	Mean 1.04	Mean 0.99
Width	Deer	0.69 (39546) 0.70 (39554)	0.62 (39546)	0.65 (4321) 0.66 (39546)	0.67 (4321)
		Mean 0.69	Mean 0.62	Mean 0.65	Mean 0.67
	Calves	0.71 (0453) 0.69 (33460) 0.72 (39549) 0.72 (39550) 0.70 (39551) 0.73 (39553)	0.73 (0488) 0.69 (39553)	0.69 (39553)	0.68 (39553)
		Mean 0.71	Mean 0.71	Mean 0.69	Mean 0.68
Weight	Deer	0.21 (39546) 0.22 (39554)	0.16 (39546)	0.20 (4321) 0.18 (39546)	0.18 (4321)
		Mean 0.21	Mean 0.16	Mean 0.19	Mean 0.18
	Calves	0.23 (0453) 0.23 (33460) 0.23 (39549) 0.25 (39550) 0.22 (39551)	0.24 (0488) 0.22 (39553)	0.22 (39553)	0.21 (39553)
		Mean 0.23	Mean 0.23	Mean 0.22	Mean 0.21
Weight of eggs laid per tick	Deer	0.09 (39546) 0.10 (39554)	—	0.09 (4321)	0.09 (4321)
		Mean 0.09		Mean 0.09	Mean 0.09
	Calves	0.09 (0453) 0.12 (39549) 0.13 (39550) 0.10 (39551)	0.11 (0488) 0.11 (39553)	0.11 (39553)	—
		Mean 0.11	Mean 0.11	Mean 0.11	

Larval viability and infestation

On two occasions, 20,000 larval progeny of ticks from deer, and likewise from calves, were kept in ventilated tubes under conditions of high humidity and ambient temperature. Survival time (= the period between the day the parent ticks dropped from a host and 100% larval mortality) were 17 weeks on both occasions for the progeny of ticks from deer and 16 and 19 weeks for those from calves.

One calf (0488) infested with 5,000 larvae derived from ticks from deer yielded 362 replete ticks. The same calf, six months later, received 10,000 larval progeny of ticks from calves and produced 296 replete ticks.

FIELD OBSERVATIONS

Of 206 deer examined from the Western Province, 161 (78%) were found to have ticks. Deer from around Port Moresby were less commonly parasitized; 11 of 32 (34%) animals had *B. microplus* and these infestations were very light. Estimation of tick infestation under field conditions was usually subjective as circumstances did not allow specific counts to be made.

Deer from the Western Province often were heavily parasitized with larval and nymphal stages, as well as young adults in mating pairs, but few carried large numbers of replete or near-replete female ticks. The same disparity in numbers of the different stages was seen in the much lighter infested deer from the Port Moresby area. The groin, the axillae and inner sides of the limb bases were the most frequently parasitized parts, followed by the back, sides and ears. The groin and ears sometimes had high larval numbers while the remainder of the body was free.

There was no significant difference in the incidence of ticks on male as compared to female animals. Of 58 males examined from the Western Province 45 (77%) had tick, while of 148 females 116 (78%) were infested ($P = 0.09$). In the Port Moresby area, of 15 males and 17 females, 7 (46%) of the former and 5 (29%) of the latter sex carried the cattle tick ($P>0.1$).

A difference in the degree of infestation between sexes was seen amongst deer in the Western Province; of 22 males and 13 females given close scrutiny, 5 stags had heavy infestations and only one doe carried a moderately heavy tick population.

Considered on a seasonal basis, 62 of 86 deer (72%) in the Western Province carried ticks in the wet season and 99 of 120 deer (82%) in the dry season, a difference which is statistically significant ($P = 0.04$). The equivalent figures for deer in the Port Moresby area were 9 of 25 deer (36%) and 3 of 7 deer (42%) respectively, a seasonal variation which is not significant ($P>0.5$).

Table 4. Seasonal incidence of infestation with cattle tick of pregnant and non-pregnant female rusa deer in the Western Province.

	Wet Season		Dry Season		
	Number parasitized (Seasonal %)	Number non-parasitized (Seasonal %)	Number parasitized (Seasonal %)	Number non-parasitized (Seasonal %)	Totals
Pregnant deer	26 (47.2)	4 (7.2)	35 (37.6)	7 (7.5)	72
Non-pregnant deer	15 (27.2)	10 (18.1)	40 (43.0)	11 (11.8)	76
Totals	41 (74.5)	14 (25.5)	75 (80.6)	18 (19.4)	

The seasonal prevalence of parasitism in relation to the sex of the host shows that in the Western Province more deer of both sexes carried tick in the dry season; 21 of 31 (68%) males were parasitized in the wet season and 24 of 27 (89%) in the dry season. The respective figures for the females were 41 of 55 (74%) and 75 of 93 (80%). Statistically this seasonal difference in prevalence is significant with respect to the male population ($P = 0.03$) but not in relation to the female population ($P = 0.19$). When the females are divided into pregnant and non-pregnant groups (Table 4), the incidence of parasitism is shown to be significantly higher ($P = 0.046$) amongst non-pregnant deer during the dry season than during the wet season. Pregnant deer did not show a significant difference ($P = 0.35$).

Only one deer was found to carry a tick other than *B. microplus;* a male shot on the Sogeri Plateau outside Port Moresby had one non-engorged female *Haemaphysalis novaeguinae*. This tick has been recorded from "Wallaby", cattle, horse, pig and cat in Papua New Guinea.[8,26] In the Western Province another species, *H. bancrofti,* was a very common parasite of the agile wallaby (*Macropus agilis*) but, in spite of its abundance in the environment, none was found on a deer.

DISCUSSION

A bovine host is classified as susceptible by Bennett[2] when there is a return of 10% or more female ticks, as moderately resistant when yielding 2-5% and as highly resistant when there is a return of less than 1% of the female larvae applied. The average yield of engorged female ticks from experimental deer (1.3%) is within the range (1-2%) given for Zebu cattle.[27] Some workers[16,22] claim that Zebu-type cattle (*Bos indicus*) possess innate or natural resistance to *B. microplus*. Others[12,28] disagree as both Zebu-type and Shorthorn (*B. taurus*) animals were found to be equally susceptible at their first infestation but, following reinfestation, the former demonstrate an acquired resistance while the latter do not. The rusa deer may show a degree of natural resistance as the percentage of larvae applied which completed the parasitic life cycle on previously unexposed deer was consistently lower than on previously unexposed calves. (The individual deer which demonstrated least resistance (3.2% yield of the female larvae applied) had a lower susceptibility than that of the most resistant calf encountered (3.4% yield of the female larval population), neither animal having had prior tick experience). An alternative possibility is that deer may acquire resistance by the time adult ticks are developing.[11] Reinfestation work with deer indicates that reduced susceptibility follows previous tick experience (Table 1), as Wagland[28] found with Zebu-type cattle.

It is clear that with mean percentages of 11.2 recovery of replete female ticks from calves and 1.6 from deer, the vast majority of ticks fail to reach the engorged stage. Bennett[4] confirmed the findings of Roberts[23,24] and others[6,27] that the greatest loss occurs during the first 24 h. of parasitic life, especially on resistant animals. No attempt was made to assess the relative numbers of larvae and nymphs which failed to remain attached to deer but the percentage of non-replete females (15.1) collected during sieving for replete females shows that there is a considerable loss of ticks from deer within the adult instar. Bennett[4] showed that losses occur throughout the parasitic cycle on cattle and suggested that the more mature stages may be dislodged while changing their points of attachment. The fact that most of the non-engorged adults which dropped from deer were alive may confirm this. Also, self-grooming is known to be important in the elimination of ticks,[25] particularly with resistant cattle.[2] The rusa deer is a noticeably supple animal with a fairly short, bristly coat, whose hair is readily erected—all factors which may help in the removal of adult ticks during self-grooming. Distribution, at least of adult ticks, on deer may be influenced by this grooming, although Bennett[5] considered that ticks selected sites of attachment on cattle and that self-grooming had relatively little effect on tick distribution whatever the level of host resistance.

The mean size and weight as well as fecundity of (apparently) replete ticks from deer may be influenced by self-grooming, as females could be dislodged before being fully engorged but still capable of producing eggs. There is a linear relationship, up to an optimum level, between the weight of replete female *B. microplus* and egg production.[3,9] Bennett[3] claims that replete ticks from resistant cattle are consistently smaller than those from susceptible cattle but others[11,13] maintain that, as resistance develops, the reverse is the case. The results from deer are equivocal. The average weight of ticks from first infestations of deer is usually, but not always, lower than of ticks from primary infestations of calves. Ticks from reinfestations, however, were significantly lighter in weight from deer than from calves, a result which supports Bennett's[3] conclusions. It is calculated that a tick from deer produces an average of 1,800 larvae and from a calf 2,200 larvae. Although there is this difference in reproductive output between ticks from deer and calves, the average weight of ticks from deer (0.19g) is within the optimum size range (0.18-0.22g) for efficiency of egg production given by Bennett.[3]

There is some evidence to show that the type of host, calf or deer, on which a parent tick generation lives does not affect viability of, or the degree of infestation of a host by, the larval progeny.

Tissue reaction in deer is often marked, particularly under conditions of continuous infestation in the field. The skin immediately adjacent to the tick is inflamed and swollen and sometimes raised to such an extent that the larva is enclosed as if in a crater. This reaction is most noticeable on the inside of thighs, and probably approaches the hypersensitive condition noted in some cattle[22,27] and which can be ascribed to a developing resistance.[12,13]

Several authors[6,10,16] have stated that the nutritional status of an animal affects its resistance to ticks. During the dry season in the Western Province, when food becomes progressively more scarce and water is confined to restricted localities, there are reports in most years of deer carcasses being seen. The deaths are due, apparently, to starvation. It is not surprising, therefore, to find an increase in prevalence of infestation amongst Western Province deer during the dry season, which can be attributed to a lowered resistance accompanying nutritional stress. Amongst the female population, pregnant, in contrast to non-pregnant, deer did not show a significant seasonal variation in infestation. Wharton *et al.*,[29] however, found no evidence to suggest that pregnancy affected the mean susceptibility of experimental cattle or that lactational stress had a specific effect as distinct from a concomitant nutritional stress.

The much smaller population of deer in the Port Moresby area has access to extensive swamps during the dry season so that shortage of food is not encountered and this is reflected in the year-round good condition of the animals and in the low prevalence of ticks as well as the low level of infestation at all times of the year.

The prevalence (78%) of deer infested with tick in a part of the Western Province, where a distance of about 80 km separates them from the nearest cattle, shows that a permanent population of ticks can be maintained in the absence of the more favourable bovine host, at least, when host density is high. It is not known if the maintenance of tick infestation amongst the low density population of deer near Port Moresby is influenced by contact with cattle. Experimental results suggest that deer can maintain a population of ticks even when infestation numbers are relatively low, which makes the deer an effective host, although not as effective a host as are British breed cattle.

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