ECOLOGICAL DISTRIBUTION OF BLOOD PARASITES IN SOME ARBOREAL RODENTS

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Infections with *Plasmodium* and other blood parasites have been reported in several species of mammals in Malaysia (Sandosham, 1967; Dunn *et al.*, 1968). Some of these, although not human parasites, are morphologically very similar to forms parasitic to humans (Green, 1933; Sandosham *et al.*, 1962). With the second record of a human infection with *Plasmodium knowlesi* (Yap *et al.*, 1971), it is worthwhile to examine the ecological patterns of distribution of the various red cell protozoa and other blood parasites in mammals of West Malaysia. This gives us some information on the ecological requirements for the enzootic transmission of various blood parasites. The purpose of this report is to present data on various blood parasites of five species of giant squirrels. The ecological niches of these species differ as well as their specific habitats. Two of these hosts locomote like most squirrels, *Ratufa bicolor* and *R. affinis*, and three are gliders ("flying squirrels"), *Petaurista petaurista*, *P. elegans*, and *Aeromys tephromelas*. All five can be observed in the same general areas in the canopy of rainforests, although they seem to have specific ecological affinities to specific habitats depending on the degree of alteration of the forests. *Petaurista petaurista* in some areas that have sustained heavy logging have been found to be very common, but neither of the two *Ratufa* spp. are common in such areas. *Ratufa bicolor* seems to be an inhabitant of deeper forest than *R. affinis* and *Petaurista elegans* seems to occur more commonly in deep forest, or recently cut forest, than do *P. petaurista* and *Aeromys*.

Another major ecological difference between the two species of *Ratufa* and the "flying squirrels" is that both *Ratufa* are diurnal and the "flying squirrels" are nocturnal. All of these giant squirrels feed on fruit and the flying squirrels also feed on leaves. None of them usually descends to the ground and they are usually observed at least 30 feet (about 10 meters) from the ground, and often up to 150 feet (about 46 meters) or higher in the emergent trees.

Sandosham (1967) and Dunn *et al.*, (1968) reported prevalence rates for *Hepatocystis* (probably *H. vassali*) in *Ratufa affinis* and *R. bicolor*. Sandosham *et al.*, (1965) described a new species of *Plasmodium* from *Petaurista petaurista*: *Plasmodium booliati*. Another, not yet named, new species of *Plasmodium* from *Petaurista elegans* has been collected and preliminarily described by Yap *et al.*, 1970).

MATERIALS AND METHODS

A total of 380 blood specimens from giant squirrels have been examined and reported here. These were collected from 1 February 1968 through 30 March 1973. Giant squirrels are very difficult to trap, thus all but three specimens were collected by shooting. Thick and thin blood films were made on microscope glass slides and stained with Giemsa. Other samples and data were collected for related studies. Specimens were prepared as standard research reference skins and skulls.

RESULTS

The results of most of the examinations of blood samples are given in Table 1. In addition to *Plasmodium* and *Hepatocystis*, prevalence rates for microfilariae are given but it is not clear at this point what species the latter represent. Not included in Table 1 are results from examination of 42 *Petaurista petaurista* from Kuala Langat area of Selangor. These results are given in Table 2. No *Plasmodium* was found in these samples, although 24 per cent had infections with microfilariae. These squirrels from the Kuala Langat area were not collected in forest but in groves of rather isolated trees adjacent to cultivated areas, particularly oil palm. These trees were primarily cultivated durian *(Durio)* and remnants of the original forest. Neither species of *Ratufa* was observed in those highly disturbed habitats.

Another sample left out of Table 1 were eight *P. petaurista* collected from Pulau Tioman, an island off the east coast of the peninsula opposite Kuala Rompin, Pahang. Five of these "flying squirrels" had patent *Plasmodium* infections.

The rest of the samples of "flying squirrels" came from forest habitats in various parts of

Table 1

Prevalence of blood parasites in some forest canopy rodents.

Species	No. Exam.	*Plasmodium*	*Hepatocystis*	Microfilariae	*Trypanosoma*
Petaurista petaurista	61	21 (34%)	0	21 (34%)	3
Petaurista elegans	24	11 (46%)	0	2 (8%)	0
Aeromys tephromelas	22	0	0	3 (14%)	0
Ratufa affinis	68	0	49 (72%)	8 (15%)	0
Ratufa bicolor	129	0	70 (54%)	23 (18%)	0

Table 2

Prevalence of blood parasites in different types of forest.

Ratufa bicolor and *R. affinis*

Type of Forest	No. Examined	*Hepatocysis*	Microfilariae
Secondary (Selangor)	32	5 (16%)	3 (10%)
Secondary/Primary (Selangor)	113	58 (51%)	21 (19%)
Partly Timbered Primary (Trengganu)	34	32 (94%)	1 (3%)

Petaurista petaurista and *P. elegans*

Type of Forest	No. Examined	*Plasmodium*	Microfilariae
Scattered Large Trees (Selangor)	42	0	11 (26%)
Scattered Large Trees/Forest Edge (Johore)	13	2 (15%)	4 (31%)
Secondary/Primary (Selangor)	19	8 (42%)	9 (47%)
Recently Timbered (Partly) Primary/Primary (Johore)	18	9 (50%)	0

West Malaysia. The specimens of *Aeromys* came primarily from Bukit Lagong, Selangor and Tamok, Johore where many *P. petaurista* were also collected. *P. elegans* were mostly collected in the vicinity of Tamok, Johore, but not around the village, as was the case with the *Aeromys* and *P. petaurista*. Four *P. elegans* were collected in forest at elevations above 5000 feet at Cameron Highlands; none of these had *Plasmodium*, but are included in the totals in Table 1.

All of the samples of *R. bicolor* are included in Table 1. This species was usually collected in mature forests. Most of the samples (91/129) came from Bukit Lagong, where the rate of positive *Hepatocystis* samples was 50%, or about the same as that for the total of the samples.

The samples from *Ratufa affinis* collected from Subang Forest Reserve, Selangor a secondary forest, are included in Table 2 but not in Table 1. Of 26 samples examined from Subang only one was positive for *Hepatocystis*. In another series (included in Table 1) from Trengganu, collected from a partly timbered primary forest, 26 out of 28 samples were positive for *Hepatocystis*. At Bukit Lagong, a forest intermediate in the degree of disturbance, the rate of *Hepatocystis* infections in *R. affinis* was 12 out of 22 samples, or about the same rate as in *R. bicolor* collected in the same area.

DISCUSSION

Several ecological factors seem to be important regarding the distribution of blood parasites in these giant squirrels. The presence of either *Plasmodium* or *Hepatocystis* is correlated with the periodicity of activity of the hosts. *Plasmodium* infections occurred in the nocturnal species, *Hepatocystis* in the diurnal ones. However, one nocturnal species, *Aeromys* had neither. How much of this correlation is based on the susceptibility of hosts is not known. *Hepatocystis* is known to occur in nocturnal bats and mousedeer (Sandosham, 1967). Yet, nearly all of the diurnal squirrels in West Malaysia have been reported to have *Hepatocystis*, but not *Plasmodium*, infections (Sandosham, 1967; Dunn *et al.*, 1968; Muul *et al.*, 1970). On the other hand, we have found neither *Plasmodium* nor *Hepatocystis* infections among hundreds of blood specimens examined of the smaller flying squirrels, all nocturnal, which occur in West Malaysia *Hylopetes lepidus (= spadiceus)*, *H. platyurus (= lepidus)*, *Pteromyscus pulverulentus*, *Petinomys setosus*, *P. vordermanni*, *Iomys horsfieldii*). It seems that *Plasmodium* infections are fairly species specific, but so far no taxonomic distinction has been made between the *Hepatocystis* occurring in the various diurnal squirrels.

The genera *Ratufa* and *Petaurista* are not closely related systematically. It is therefore uncertain whether the periodicity of activity is the cause for the dearth of *Hepatocystis* infections in the *Petauristinae*. The absence of *Plasmodium* in *Ratufa* may be explained by the host species specificity of this parasite. There are other arboreal, nocturnal mammals in Malaysia that have *Plasmodium* infections, e.g., the colugo or flying lemur, harboring a different species (Dunn *et al.*, 1963). In Taiwan (Formosa) *Plasmodium watteni* infects *Petaurista* (Lien and Cross, 1968).

Table 2 gives the combined infection rates of *Hepatocystis* for the two species of *Ratufa* and of *Plasmodium* for the two species of *Petaurista*. Only localities from which sufficient samples were collected are included and these are arranged according to the degree to which they have sustained alteration of the original forest, with the most disturbed areas shown at the top and the least at the bottom. Although only a few habitats are available for such a comparison, it seems that the least disturbed areas favor a

higher rate of transmission of *Hepatocystis*. This was found to be the case for other species of squirrels also (Muul *et al.*, 1970).

We are dealing with two species of *Plasmodium* in the two *Petaurista* hosts, but again it seems that even within the same host species *P. petaurista*, the infection rate is higher in less disturbed areas. It was highest in *P. elegans* collected in primary and recently logged primary forests in Johore.

The infection rates with microfilariae seemed to be lowest in the less disturbed areas but variable in the others.

A possible further complication of the distribution patterns of some of these infections is temporal periodicity. This is suggested by the data on *Hepatocystis* infections in *Ratufa bicolor*. *R. bicolor* was the only species collected in sufficiently large numbers over a period of years in one locality (Bukit Lagong, Selangor) for such a comparison. A total of 91 specimens have been collected and examined from 1968 through 1972. During one six - month period, January through June 1970, 23 of 28 specimens examined were positive. During the remainder of the time the rate was less than 50%. In addition to demonstration of ecological differences between hosts of different types of blood parasites, these data indicate that surveys of parasite prevalence must take into consideration the type of habitats in which the potential hosts are collected and the possible influence of seasonal periodicity on the rate of infections.

SUMMARY AND CONCLUSIONS

The overall rates of infections of *Hepatocystis* in two species of *Ratufa* and *Plasmodium* in two species of *Petaurista* were high (54 to 72% and 34 to 46%, respectively). *Aeromys* was not found to be infected with blood protozoa. *Plasmodium* infections seemed to be host specific and correlated with (but not necessarily dependent on) nocturnal habits of the hosts. The two hosts of *Hepatocystis* reported here are diurnal. In habitats greatly altered by man the infection rates with both *Hepatocystis* and *Plasmodium* seemed to be lower than in deeper forest.

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