11. Notes on the Endoparasites

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INTRODUCTION

There do not appear to be any published records for the endoparasitic fauna of Pulau Tioman, with the exception of several reports dealing with human malaria (Dowling and Hughes, 1959; Warren, this *Bulletin*, p. 150). The present paper is an attempt to bring together the available unpublished data on this subject, including a few records by other workers and the preliminary results of a survey of small mammals collected on the island in April 1962.

In the list which follows, the data on protozoa have been brought together primarily from the records of others. The sources of these data will be indicated in the discussions of individual species. All records for helminths and all but one for *Porocephalus* have come from the 1962 survey of small mammals. These animals, and the crude results of the survey, are listed in Table 1. It will be seen that 53 animals of seven species were dissected, and that blood films (taken at 10 a.m.) were also examined from 53 animals. Every blood examination was negative for both haematozoa and microfilariae. Blood films were taken from forest rats, *Rattus sabanus*, and tree shrews, *Tupaia glis*, at 11 p.m. as well as at 10 a.m. to increase the chances of detecting periodic microfilariae. Dissections, moderately thorough for all animals, included examination of the subcutaneous and intermuscular tissues, body cavities, organs, and intestines. Helminths, when collected, were preserved in formalin or glycerine-alcohol.

TABLE 1

Endoparasites recovered from Tioman mammals (April, 1962).

Hosts	Number Dissected	Number with:				Blood films examined	Number free of blood parasites & helminths
		Nematodes	Cestodes	Trematodes	Pentastomids		
Tupaia glis ...	13	9	—	—	—	13	4
Callosciurus notatus ...	1	—	—	1	—	1	—
Rattus exulans ...	2	—	1	—	—	1	1
R. cremoriventer ...	1	1	1	—	—	1	—
R. surifer ...	8	6	1	1	1	6	—
R. sabanus ...	3	3	1	—	—	3	—
R. sp. *tiomanicus* ...	25	12	11	2	1	28	9
	53	31	15	4	2	53	14

CHECKLIST

The list below includes all known endoparasites of man and animals on Pulau Tioman. Numbers in brackets after the hosts of helminths and *Porocephalus* refer to the number of animals found infected in the small mammal survey. The classification of the Protozoa follows Kudo (1954) while Yamaguti (1958, 1959, 1961) is followed in the classification of the Platyhelminthes and Aschelminthes.

Phylum PROTOZOA (blood parasites only)

Class MASTIGOPHORA

Protomonadina: Trypanosomatidae

Trypanosoma sp. (probably *T. ingens*)	*Tragulus napu*

Class Sporozoa

Haemosporidia: Plasmodiidae

Plasmodium vivax (Grassi and Feletti, 1890) ...	man
Plasmodium malariae (Laveran, 1881) ...	man
Plasmodium falciparum (Welch, 1897) ...	man
Plasmodium inui Halberstadter and von Prowazek, 1907	*Macaca fascicularis*
Plasmodium knowlesi Sinton and Mulligan, 1932	*Macaca fascicularis*
Plasmodium sp.	*Cynocephalus variegatus*
Plasmodium traguli Garnham and Edeson, 1962 ...	*Tragulus napu*

Haemosporidia: Haemoproteidae

Hepatocystis sp. (presumably *H. semnopitheci*) ...	*Macaca fascicularis*
Hepatocystis sp. (probably *H. vassali*) ...	*Sundasciurus tenuis*

Phylum PLATYHELMINTHES

Class CESTODA

Cyclophyllidea

Anoplocephalidae: anoplocephalid species ...	*Rattus sabanus* (1); *Rattus* sp. *tiomanicus* (1) location: small intestine

Davaineidae

Raillietina sp.	*Rattus* sp. *tiomanicus* (7) location: intestines

Dilepididae

Species in Dipylidiinae	*Rattus cremoriventer* (1) location: small intestine

Hymenolepididae

Hymenolepis diminuta (Rud., 1819) ..	*Rattus* sp. *tiomanicus* (3) location: intestines
Rodentolepis sp.	*Rattus* sp. *tiomanicus* (3) *Rattus surifer* (1) location: intestines

Class TREMATODA

Digenea: Dicrocoeliidae

Leipertrema sp.	*Callosciurus notatus* (1) location: small intestine
Zonorchis sp.	*Rattus* sp. *tiomanicus* (2) *Rattus surifer* (1) location: small intestines

Phylum ASCHELMINTHES

Class NEMATODA

Rhabdiasidea: Strongyloididae

Strongyloides ratti Sandground, 1925 ... *Rattus surifer* (1); *Tupaia glis* (2) location: small intestine larvae in faeces

Strongylidea: Strongylidae

Globocephalus sp. ... ... *Rattus sabanus* (2) location: small intestines

Strongylidea: Ancylostomatidae

Cyclodontostomum purvisi Adams, 1933 ... *Rattus surifer* (2) location: large and small intestines

Strongylidea: Trichostrongylidae

Nippostrongylus brasiliensis (Travassos, 1914) ... *Rattus sabanus* (2); *Rattus* sp. *tiomanicus* (6) location: small intestines primarily; also large intestine

trichostrongylid species ... ... *Rattus surifer* (1) location: small intestine

species (Trichostrongylinae) ... ... *Rattus surifer* (1); *Tupaia glis* (1) location: small intestine

species (Trichostrongylinae) ... ... *Rattus* sp. *tiomanicus* (4) location: small and large intestines

species (Strongylacanthinae) ... ... *Tupaia glis* (2) location: small intestines

Strongylidea: Protostrongylidae

Angiostrongylus cantonenisis (Chen, 1935) ... *Rattus* sp. *tiomanicus* (1) location: lung

Oxyuridea: Oxyuridae

Syphacia muris (Yamaguti, 1935) ... ... *Rattus* sp. *tiomanicus* (2); *Rattus surifer* (1); *Rattus cremoriventer* (1) location: intestines (primarily large)

Spiruridea: Gnathostomatidae

Gnathostoma sp. ... ... *Rattus* sp. *tiomanicus* (1); *Rattus surifer* (1) location: stomach wall

Spiruridea: Physalopteridae

Physaloptera sp. ... ... *Rattus* sp. *tiomanicus* (3) location: stomach; intestines

Filariidea

filariid species ... ... *Rattus surifer* (3); *Rattus sabanus* (1); *Tupaia glis* (7); *Rattus* sp. *tiomanicus* (3) location: subcutaneously on limbs, back, head, base of tail

microfilaria sp. ... ... *Rattus* sp. *tiomanicus*

microfilaria (*Setaria* sp.) ... ... *Tragulus napu*

microfilaria (*Dirofilaria* sp.?) ... ... *Macaca fascicularis*

microfilaria sp. ... ... *Macaca fascicularis*

Phylum ARTHROPODA

Class PENTASTOMIDA

Porocephalida: Porocephalidae

Porocephalus moniliformis (Diesing, 1834) ... *Macaca fascicularis* (1); *Rattus surifer* (1); *Rattus* sp. *tiomanicus* (1); location: (of nymphs) liver: intestinal wall

ANNOTATIONS

Trypanosoma sp. (probably *T. ingens*)

This trypanosome has been recorded recently from mouse-deer, *Tragulus javanicus*, collected in Pahang (Annual Report of the Institute for Medical Research for 1961). A member of the *lewisi* group, the trypanosome has been recorded previously from African antelope. The presence of this trypanosome in Tioman mouse-deer (*T. napu*) is reported by Dr. A.B.G. Laing (personal communication).

Plasmodium inui and **P. knowlesi**

These primate malaria parasites are common in Malayan macaque monkeys. Drs. D. E. Eyles and M. Warren have identified these plasmodia, as well as a *Hepatocystis* sp. (presumably *Hepatocystis semnopitheci*), in blood films from a number of *Macaca fascicularis laeta* collected on Tioman in September 1961 and April, 1962 (Warren, this *Bulletin*, p. 156).

Plasmodium spp.

A malaria parasite was discovered in a single blood film from a flying lemur, *C. variegatus*, collected on Tioman in September 1961 by Drs. Eyles and Laing. Subsequently we have found a *Plasmodium*, presumably the same parasite, in a flying lemur captured at Bukit Lagong near Kuala Lumpur. It has been possible to study the parasite, which belongs to a new species, in some detail; a description will be published elsewhere.

A *Plasmodium* species has also been found in blood films from Tioman mouse-deer, *T. napu* (A. A. Sandosham, personal communication). New species of both *Hepatocystis* and *Plasmodium* have recently been discovered in mouse-deer (*T. javanicus*) collected in Pahang and Selangor. These species have been described as *H. fieldi* and *P. traguli* by Garnham and Edeson (1962). It is probable that the parasite in Tioman mouse-deer is also *P. traguli*. A *Hepatocystis* sp., presumably *H. vassali*, has also been noted by Dr. M. Laird in a blood film from a squirrel, *Sundasciurus tenuis* collected on the island in April 1962 (personal communication).

Hymenolepis diminuta and **Raillietina** sp.

The former cestode, and possibly the latter as well, may be of at least potential medical importance on Pulau Tioman. *H. diminuta* is cosmopolitan in rodents and not infrequently infects man; several species of *Raillietina* normally parasitic in other mammals, including rats, have also occasionally been recorded from man.

Leipertrema sp.

This dicrocoeliid trematode of *Callosciurus notatus* closely resembles a new species of *Leipertrema* from *C. notatus* collected near Kuala Lumpur and described by Rohde (1963). It probably belongs to the same species, but preliminary comparison of measurements and characters of a series of Tioman specimens and specimens from Bukit Lanjan near Kuala Lumpur reveals certain differences: the testes of the Tioman form are generally much smaller; the maximum body diameter is usually posterior to mid-body in the Tioman form and anterior to mid-body in the other; the eggs of the Tioman form are smaller and consistently shorter; and the vitellaria are less compact in the Tioman form. There is some overlap in the measurements; it is probable that we are dealing with morphologically divergent populations of the same species (sub-species, in effect). This divergence in form—of parasites in the same host species—is of interest because of the island isolation

of one of the host populations. The morphological differences in the island trematodes suggests that their hosts have been resident on the island, and cut off from mainland *C. notatus*, for a considerable period of time, perhaps longer than some of the ground-dwelling rats.

Zonorchis sp.

At least one undescribed species of *Zonorchis* occurs in rodents of the Kuala Lumpur area (Rohde, personal communication). The Tioman form is very similar to the mainland species and may be conspecific with it.

Cyclodontostomum purvisi

This strongylid nematode does not appear to have been recorded from any host since Adams (1933) first described it from Malayan rats. The worms found in *R. surifer* do not differ in any important respects from the original description.

Species in the Family Trichostrongylidae

In addition to the well-known, cosmopolitan rodent parasite, *Nippostrongylus brasiliensis*, four other trichostrongylid species were recognised in rats and tree shrews. Two of the four, represented only by female worms, cannot be assigned to genera. A third species, found only in *R.* sp. *tiomanicus*, is well represented by male and female worms which can be assigned to the Trichostrongylinae but not to any of the known genera within this sub-family. Another species, found only in *Tupaia glis*, is referrable to the Strongylacanthinae and also appears to belong to a new genus, somewhat resembling *Molinostrongylus*.

Angiostrongylus cantonensis

This nematode has recently been shown to be of some importance to human health in that the larvae, once established in the human host, may in the course of their migrations, initiate a disease now known as eosinophilic meningitis (Horio and Alicata, 1961; Rosen et al, 1962). Cases of this disease have so far been recognized only in Hawaii and Tahiti. *A. cantonensis* is known from the mainland of Malaya as well as from Tioman. Schacher and Cheong (1960) recorded the worm from *R. r. diardi* and *R. exulans* collected in Singapore and Kuala Lumpur.

Syphacia muris

This oxyurid nematode may also be of some potential importance to human health. A closely related species, *S. obvelata* (Rud., 1802), cosmopolitan in rats and mice, has been reported several times from children in the Philippines and the United States.

Gnathostoma sp.

Adult gnathostomes were collected from the stomachs of two rats trapped above 3000 ft. on the upper slopes of Gunong Kajang and near Camp V. It is surprising that two of the six rats examined for helminths from the highest parts of the island should have carried these worms while none of the animals trapped at lower altitudes (all other surveyed animals were trapped between sea level and approximately 1100 ft.) were so infected. The worms appear to belong to an undescribed species somewhat resembling *G. doloresi*.

Representatives of the Order Filariidea

In the course of the dissections worms of only a single filariid species were found. Unfortunately no male or mature female specimens were recovered so the material cannot be assigned to genus or sub-family. Microfilariae were not detected in blood films taken from 53 Tioman rodents and tree shrews. Dr. M. Laird has,

however, noted microfilariae in a blood film from one *R.* sp. *tiomanicus* collected on the island in April 1962 (personal communication). Also, microfilariae resembling those of *Setaria* were discovered in blood films from four of six mouse-deer (*T. napu*) collected on Tioman in September 1961 by Eyles and Laing (personal communication); and Warren (personal communication) found two species of microfilariae, one apparently a *Dirofilaria*, in blood films from one of eight *Macaca fascicularis* collected in April 1962. One other record for a possible filariid was obtained by the writer in April 1962 in the course of dissections of freshly collected tabanid flies, *Chrysonzona lunulata* (Macquart). In one of 12 dissected flies a single nematode larva, about 1080 microns long and 20 microns in maximum diameter, resembling a larval filarial nematode, was found in the crushed thorax. These flies occurred abundantly in forest, and were readily attracted to man.

Porocephalus moniliformis

Nymphs of this pentastomid worm were found encysted in the liver of a long-tailed macaque dissected by D. E. Eyles during a visit to the island in September 1961. Nymphs were also removed from the liver and intestinal wall of two rats examined in the course of the small mammal survey. The adult tongue worms are commonly found in the air passages of pythons and other snakes. In view of the relatively high prevalence of infections (3 in 54 dissections) *P. moniliformis* must be a rather common parasite of the island's snakes.

DISCUSSION

The host-parasite list for Tioman emphasizes the many gaps in our knowledge of the island's endoparasites. There are, for example, no records for intestinal protozoa or helminths of humans living on the island. Nor are there any records for tissue helminths. It seems unlikely, however, that human filariasis transmission takes place on the island. Microfilariae have apparently not been noted in blood films taken from man in past surveys for malaria, and there is some doubt that common vectors of either periodic or sub-periodic *Brugia malayi* occur on the island (R. H. Wharton, personal communication). The present small mammal survey covers only a few species, and only three of these (*T. glis*, *R.* sp. *tiomanicus*, and *R. surifer*) in any number. Except for a few records of blood parasites we have no information at all for other Tioman mammals. The bird, reptile, amphibian, and fish parasites are totally unknown.

In spite of the deficiencies noted above it is possible to make a few comparisons with the situation on the Malayan mainland, although here too, except for the endoparasites of man and his domestic animals, the parasites are at present poorly known. The rodents, fortunately for our purposes, have received some attention, permitting direct comparisons with Tioman data.

Rattus rattus diardi, the ecological counterpart on the mainland to *R.* sp. *tiomanicus* in the commensal part of its range (Medway, this *Bulletin*, p. 20), was found to be a host for 9 species of nematodes in Kuala Lumpur and Singapore by Schacher and Cheong (1960). On Tioman *R.* sp. *tiomanicus* is a host for at least 7 species of nematodes. Three of these 7 (*Syphacia muris*, *Angiostrongylus cantonensis*, and *Nippostrongylus brasiliensis*) have been recorded from *R. r. diardi* elsewhere in Malaya. In addition, *R.* sp. *tiomanicus* harbours at least four species of cestodes, one trematode, and a pentastomid. Thus, in numbers of species of parasitic helminths there is certainly no major difference between the commensal *R. rattus* of the mainland and the principal commensal (and forest) rat of Tioman.

Of the 25 *R.* sp. *tiomanicus* dissected, 9 were entirely free of helminths (within the limits of the dissecting technique). At first glance an infection rate of only 64 per cent might suggest that helminths, while not "depleted" in terms of numbers of species, may be so in terms of infection rates in the Tioman rat. Comparison with the mainland data shows, however, that *R. r. diardi* and related rats of the subgenus *Rattus* are frequently entirely free of helminths (on the basis of dissections performed in the same laboratory as those under consideration here). In the helminth-host records compiled by Sandosham (1957) only 396 (65 per cent) of 605 *R. r. diardi*, and 126 (49 per cent) of 258 *R.* sp. *jalorensis* were found infected with any kind of helminth. Thus commensal and field rats of the *R. rattus* group of Kuala Lumpur had overall helminth infection rates similar to the rate for the single representative of the group on Tioman. In this connection it is interesting to note that the overall helminth infection rate for *R.* (*rattus*) *jarak* (9 of 14 animals with helminths in the Sandosham tabulation) of Jarak Island in the Straits of Malacca was 64 per cent, another figure (again based on a small sample) close to that for *R. r. diardi* of Kuala Lumpur. (For comment on the taxonomy of the *R. rattus* group in relation to Tioman, see Medway and Lim, this *Bulletin*, p. 33).

Tupaia glis from Tioman were found to be hosts for only four species of nematodes and no other helminths. *T. glis* from any one mainland locality, however, do not often serve as hosts for more than five or six species of helminths, including cestodes (unpublished data). The number of species of parasitic helminths and the overall helminth infection rates appear to be roughly the same for Tioman and mainland tree shrews.

Although only eight *R. surifer* were available for dissection, the recovery of 10 species of helminths from this small sample suggests that the helminth fauna of this host species is not particularly 'reduced' on the island.

The helminth evidence, taken by itself, suggests that the commonest ground rodents and the tree shrews were introduced from the Malayan mainland in relatively 'recent' times. The animals carry many helminths commonly found in the same or closely related species on the mainland, with apparently comparable infection rates. Although there are some new helminth forms in this small sample, their presence cannot be taken as evidence for prolonged isolation of their hosts because we do not know whether or not these same new species may occur on the mainland. It seems more likely that they will eventually be found in mainland hosts than that they will not.

Although similarities in the helminth fauna of mainland and Tioman rats and tree shrews predominate, there are a few notable differences. First and most striking is the total absence of acanthocephalans, particularly from the local representative of the *R. rattus* group. Sandosham (1957) records 108 *R. r. diardi* infected with Acanthocephala in a total of 605 dissections. Another notable deficiency in the Tioman helminth fauna is in the rat and tree shrew spirurid nematodes. *Gongylonema*, *Rictularia*, and *Protospirura* species, common in mainland commensal rats, were not found; nor were species of *Spirura* and '*Subulura*' which are seen in mainland *Tupaia*. Finally, members of the Trichuridea were also missing from the Tioman animals.

In contrast to the missing forms which one might have expected to find, the trichostrongylid nematodes were conspicuously abundant, both in numbers of species and numbers of individuals per infected host. While Schacher and Cheong (1960) recorded only one intestinal trichostrongylid from three species of rats collected in Singapore and around Kuala Lumpur, five species were recorded from three rat species and the tree shrew on Tioman. Clearly the trichostrongylids have

been able to thrive in their Tioman hosts. The prevalence of *Nippostrongylus brasiliensis* infection was very low in the survey of Schacher and Cheong (who referred to this species by its former name, *N. muris*); on Tioman six of 25 *R.* sp. *tiomanicus* and two of three *R. sabanus* carried large numbers of the worms. Some of these observed differences may, of course, reflect differences in collecting technique.

It is worth noting lastly, that the primate, *Tupaia glis*, which has proliferated remarkably on the island, has an endoparasite pattern which largely overlaps with that of *Rattus surifer*, and to a lesser extent with the patterns of the other rats. Three of the four nematodes of *T. glis* were found in *R. surifer;* and *R. surifer* in turn has a helminth pattern which overlaps to a considerable extent with that of *R.* sp. *tiomanicus*. *T. glis*, although a primitive primate and far-removed phylogenetically from the rats, shares with them the physiologic 'ability' to support certain helminths. These helminths, in turn, indicate (serving as "ecological labels'—Audy, 1947) that *T. glis* must to some extent compete for the same foods in the same habitats with *R. surifer* and the other ground rats; this is confirmed by other evidence (Medway, this *Bulletin*, p. 14).

SUMMARY

1. A list of the known endoparasites of man and animals on Pulau Tioman is presented and supplemented by annotations. The protozoa are represented by one species of *Trypanosoma*, six or seven species of *Plasmodium*, and two or three species of *Hepatocystis*. Five cestodes, two trematodes, and 16 nematodes comprise the helminths recorded to date from the island. A single endoparasitic arthropod, *Porocephalus*, completes the list.

2. A series of dissections of small mammals provided most of the helminth records presented herein. Seven of the 23 helminths were identified to species, eight more to genus, and the reminder, for various reasons, only to family or sub-family. At least two new species of trichostrongylid nematodes and one new gnathostome were collected. Some of the other helminths identified only to genus at this time may prove, with further study, to be undescribed forms.

3. The following helminths and endoparasitic arthropods of potential or possible importance to human health were recorded from animals on the island: *Hymenolepis diminuta, Raillietina* sp., *Angiostrongylus cantonensis, Syphacia muris, Gnathostoma* sp., and *Porocephalus moniliformis*.

4. In a concluding section the patterns of helminthic infection of mainland and island rodents and tree shrews are compared and contrasted. It is concluded that the helminth fauna of the ground rodents and tree shrews is not particularly depleted on the island. Overall parasite infection rates, and numbers of parasitic species per host species are roughly comparable for mainland and island *Tupaia glis, Rattus surifer*, and rats of the *R. rattus* group. A few striking differences do, however, occur in the patterns of helminthic infection of the mainland and island rodents and tupaias. Trichostrongylid nematodes are conspicuously abundant on the island, both in numbers of species and numbers of individuals; certain spirurid and trichurid nematodes commonly found in the mainland hosts are apparently absent from their island counterparts. Acanthocephala, common in *R. r. diardi* on the mainland, do not seem to be present in island rodents. A simple example, involving *T. glis* and ground rodents, is presented of the use of helminths as 'ecological labels'.

ADDENDUM

Since completion of this paper word has been received of the detection of *Wuchereria bancrofti* microfilariae in two island residents in the course of a malaria survey by the Pahang Health Department in August 1962 (Warren, personal communication). Whether these infections were imported from the mainland or acquired locally is unknown at this time.

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