9. Introductory Report on the Terrestrial Arthropods

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INTRODUCTION

The accounts of the vertebrates in this series of papers have been concerned, amongst other things, with the taxonomy of the animals recorded and their affinities with forms from Malaya and elsewhere. It is quite impossible to treat the arthropods in this way since the services of a large number of specialist taxonomists would be necessary to achieve this aim. Even if this were possible, the incidence and distribution of many of the insects of the Malayan region, even of the comparatively well-studied Rhopalocera, is so imperfectly known that it is doubtful whether many valid conclusions could be drawn. I have therefore attempted to summarise by means of a commentary and tables the principal families (or super-families)[23] recorded in the different habitats on the island and to indicate their possible role in the ecology of the habitat. This approach is by no means original, both Usinger and La Rivers (1953) and Gressitt (1954) have used it in their discussion of the insects of Arno Atoll and of Micronesia respectively, and it seems to me that this approach helps to convey a general impression of the fauna.

In dealing with the soil and litter meiofauna, I have departed from this procedure because no study of these forms has been made in Malaya and very little has been done within the Indo-Malaysian sub-region. I have therefore listed the orders found in the various samples and indicated the numbers recovered, imperfect as these data probably are.

TERRESTRIAL HABITATS

Strand (Table 1)

The sandy, open beaches at Tekek and elsewhere carried little insect life. A number of Diptera were present, including various muscoids which were feeding on refuse and other debris and which were attracted in very large numbers to the corpse of a *Varanus* lizard which had died near Camp I. Various smaller Diptera were found moving over the beach at random and were presumably finding something on which to feed. Robber flies (Asilidæ) and small æshnid dragonflies were frequently seen hunting over the beach and were observed preying on the flies, whilst various ants and lycosid spiders made short excursions from the leaf litter of the beach vegetation.

Table 1

Strand communities

Open beach		
Saprophages	...	... Diptera (various).
Scavengers	...	... Amphipoda, Formicidæ.
Predators	...	... Aeshnidæ, Lycosidæ, Asilidæ, Ocypodidæ (crab).
Headland beaches		
Scavengers	...	... Gryllidæ, Acarina, Formicidæ.
Predators	...	... Lycosidæ.
By dammed stream		
Scavengers	...	... Diptera, Tridactylidæ.
Predators	...	... Cicindelidæ, Libellulidæ, Aeshnidæ.

23. Identifications were usually made with Brues, Melander and Carpenter (1954) although other authors have been consulted. For the Thysanoptera, I have followed Preisner's (1949) simpler classification.

Below the rocky headlands between bays, rather more insect activity was found; small gryllids were scavenging in the shade of rocks in the intertidal zone together with a small red acarine and lycosids. Ants were also present on the beach and in one place large numbers were found in a "head down, tail up" posture. Although the ants were watched for a considerable time, no indication of what they were seeking was obtained, nor did examination of the sand reveal any difference between this and other sand in the vicinity.

A rather fuller insect scene was encountered at one spot on the beach where dunes had entirely cut off a small stream from the sea and formed a pond from which the water percolated through the dunes to the sea. Here, large numbers of flies including dolichopodids had congregated near the edge of the water and, on being disturbed, flew on to the pond and settled on a floating algal mat. Tridactylid crickets were feeding on the moist sand and several cicindelids were hunting amongst them. Several specimens of the small æshnid were hawking over the pond as was a larger libellulid.

At night, the character of the beach changed and the only forms found were ghost crabs (*Ocypode ceratophthalma*), which were present in large numbers, many amphipods, and a few ants and lycosids.

Beach Vegetation (Table 2)

In the flat areas, coconut palms were planted right down to the strand except in areas of mangrove, but none the less a characteristic beach flora formed a narrow band of vegetation in many places and with this was associated a varied insect fauna. The substrate was very sandy and no typical soil arthropods were present although the pits of numerous myrmeleonid larvæ were found, especially in sheltered areas such as beneath the rest-house (Camp I) which was built in Malay style with a clearance of 3–6 ft. These preyed on the litter fauna, notably the numerous ants but also probably the small scavenging amphipods and Blattaria. Numerous lycosid spiders were found in the leaf litter and these made short excursions on to the strand as well as hunting among the leaves.

TABLE 2

Beach vegetation

Litter and soil layer		
Scavengers	...	Formicidæ, Blattaria, Amphipoda, Gryllidæ.
Predators	...	Lycosidæ, Myrmeleonid larvæ.
Vegetation layer		
Phytophages	...	Chrysomelidæ, Elateridæ, Coreidæ, Tingidæ, Pyrrhocoridæ, Cynipidæ, Lepidoptera larvæ, Jassoidea, Cantharidæ, Curculionidæ, Fulgoroidea, Dipterous leaf miners.
Flower visiting	...	Culicidæ, Small Diptera, Lepidoptera adults, Thysanoptera (Phlæothripidæ and Thripidæ), Otitidæ, Apoidea, Other hymenoptera, Syrphidæ, Bombylidæ.
Scavengers	...	Formicidæ, Diptera (various), Ipid borers, Blattaria, Cerambycoid borers.
Predators	...	Aranea (including Salticidæ, Argiopidæ, Thomisidæ, Zodariidæ), Asilidæ, Odonata (many types), Coccinellidæ, Myrmeleonidæ.
Parasites	...	Ichneumonidæ, Braconidæ, Chalcididæ, Tachinidæ.

The vegetation carried a complex of insect life some of which was closely associated with individual plants. In this category may be included a small dipterous leaf miner (Anthomyidæ?) which was attacking *Scævola*, fulgoroids (?Flatidæ) on *Casuarina*, and various Thysanoptera which were recorded from the flowers of *Canavalia* (Thripidæ) and from flowering grasses (Phlæothripidæ). Other forms were less host-specific and these included numerous Acrididæ, a bright green chrysomelid, a number of plant-feeding Heteroptera, and lepidopterous larvæ.

Many plants were in flower, and were visited by a large concourse of insects: the introduced *Euphorbia heterophylla* was especially attractive and was visited by many butterflies, Hymenoptera and Diptera. The predators of this complex included many Asilidæ and Odonata. Spiders were prominent, the most frequent forms being salticids and argiopids together with the flower-squatting thomisids. Parasitic hymenoptera were also seen frequently and, although often seen on flowers, were probably hunting their hosts as well as feeding.

Mangrove (Table 3)

The small areas of mangrove appeared rather lacking in fauna and only web-spinning argiopids, numerous ants, and flies were recorded whilst a small grylloid (Ereopteridæ?) was taken on the leaves. Mangrove is, however, a characteristic breeding place for Ceratopogonidæ and, since these were frequent pests at Camp I, it is probable that they were a component of the fauna.

TABLE 3

Mangrove

Mud		
——	...	... Ceratopogonid larvæ?
Vegetation		
Phytophages	...	... Grylloidea.
Scavengers	...	... Formicidæ, Diptera.
Predators	...	... Argiopidæ.

Coconut Plantations (Table 4)

The outstanding members of the plantation fauna were two large nephiline argiopids (Plate 11) which built webs stretching from palm to palm. This web frequently carried several small males and was sometimes utilised by other spiders, including a small gasteracanthine, which presumably lived on small insects which were not taken by the large spiders. No attempt was made to assess the incidence of coconut pests, although the coconut weevil (*Rhyncophorus ferrugineus*) was frequently seen in flight and was probably responsible for considerable damage, and a lymexilid was taken at light on one occasion. Other pest forms were not recorded, although damage which might be associated with both *Brontispa* and *Oryctes* was seen.

The trunks of the trees sheltered a number of bark-dwelling forms including scorpions and aradoid bugs, whilst the fallen nuts attracted small Diptera and Coleoptera as well as providing shelter for ground dwelling forms such as millipedes. Ants again were very common and were preyed on by *Draco volans* as well as by some mammals.

TABLE 4

Coconuts

Fallen nuts	
Saprophages	Diptera (including Drosophilidæ), Coleoptera (including Nitidulidæ).
Scavengers	Formicidæ, Diplopoda.
Bark stratum	
Fungivores	Aradidæ.
Scavengers	Formicidæ.
Predators	Scorpionida.
Under-storey (grass) (Also padang area)	
Phytophages	Acrididæ, Thysanoptera, Lygæidæ.
Scavengers	Isopoda, Decapoda, Formicidæ, Amphipoda.
Predators	Cicindelidæ (adult and larvæ), Mantidæ (Padang area only).

The under-storey of the plantation was either grass or, when the plantation was uncared for, woody plants, notably an introduced *Lantana* sp. The grass supported many Acrididæ and Lygæidæ and numerous small Diptera whilst the uncared-for areas had a similar fauna to that of the regeneration (see below). The numerous tracks which crossed the plantations were a favourite haunt of cicindellid beetles, whose larvæ lived beneath the tracks. A large green form with three yellow spots on each elytron (probably *Cicindela aurulenta*) was the most frequent but a smaller black form was recorded occasionally. A third species was recorded only at Tk. Nipah.

Regeneration (Table 5)

A species of *Lantana* was the dominant form on all land which had been cleared and then allowed to revert and other vegetation was usually negligible. The flowers of *Lantana* were very attractive to a wide range of flower-visiting species and numerous butterflies, bees and flies were seen on the flower heads as well as a few Coleoptera including mordellids and lycids. Phytophagous insects included curculionids and chrysomeloids among the Coleoptera, and one of these latter, a large yellow gallerucid, was a very prominent member of the community. The species flew frequently and before sunset considerable numbers were flying simultaneously; on one occasion a flight was observed at the north end of Juara bay and for over 30 minutes a continous stream of beetles was passing overhead about 20 ft. up and flying inland along the line of cliffs. No predators successfully attacked them, although large odonates flew at them repeatedly; during the Juara flight a group of about twenty libellulids made repeated attack movements without ever seizing one.

TABLE 5

Lantana Regeneration

Litter layer	
Scavengers	Blattaria, Gryllidæ, Formicidæ.
Vegetation	
Flower visitors	as for shore vegetation and also: Anthomyidæ, Lycidæ, Mordellidæ.
Phytophages	Chrysomeloidea, (including Gallerucidæ, Halticidæ), Lygæidæ, Curculionidæ, Elateridæ, Coreidæ, Tingidæ, Jassoidea.
Scavengers	Formicidæ, Drosophilidæ, Muscidæ.
Predators	Asilidæ, Reduviidæ, Aranea (including Argiopidæ and Salicidæ), Odonata (various), Cicindelidæ.

Other phytophagous insects associated with *Lantana* included flea beetles (Halticidæ), various jassoids, lygæids, coreids and tingids, together with a few phytophagous Orthoptera. The only sawfly (Tenthredinoidea) recorded was taken in regenerative growth on the headland north of Kg. Tekek. Few predators were found, apart from asilids and odonates, whilst cicindelids were common on the tracks throughout the regeneration, and a wide range of spiders, with argiopids and salticids dominant, was present.

The litter fauna was similar to that of the shore vegetation, Blattaria, various gryllids and ants being the principal forms recorded.

Padang Areas (cf. Table 4)

Although the growth of *Lantana* was typical of reverting cultivated land, in a few places open areas of long grass were found (cf. Plate 5). These carried a similar fauna to that recorded in the more cared for coconut plantations with Acrididæ the most prominent component together with many lygæids. This area was of interest in that it was the only place where a mantid was recorded on the island.

Ricefields (Ladang) (Table 6)

Apart from coconut, rice was the main crop grown and was planted on areas of cleared hill side (*ladang*) which were subsequently allowed to revert to jungle or were later planted with banana and cassava. During the period of our visit, there was only stubble on the ricefields and it was therefore not possible to discern the presence of the various lepidopterous borers which are associated with the crop in Malaya. Nevertheless, a considerable population of insects was present of which the numerically dominant group was the Thysanoptera. In addition, various homopterous bugs (Jassoidea, Fulgoroidea) were found in large numbers as were coreids and lygæids although these, together with acridids, may have been feeding on the grasses and other plants growing amongst the rice. Fungi growing on the leaves and stems of the plants were probably the reason for Psocoptera and Collembola (Poduromorpha) being found and this may also account for the presence of an oribatid mite (Oribatuloidea) in considerable numbers.

TABLE 6

	Rice (and weed grasses, etc.)
Phytophages	Phlæothripidæ, Jassoidea, Membracidæ, Acrididæ, Thripidæ, Fulgoroidea, Lygæidæ, Coreidæ.
Saprophages (and fungivores)	Diptera (various), Collembola, Oribatei, Psocoptera.
Scavengers	Formicidæ.
Parasites	Pteromalidæ, Scelionidæ, Ichneumonidæ.
Predators	Asilidæ, Aranea (various), small Coleoptera.

A wide range of predators and parasites were recorded, including ichneumonid, scelionid and pteromalid wasps in the latter category, and asilids, small predatory Coleoptera and spiders in the former. Various small Diptera were in many cases saprophytic and others were associated with litter-dwelling larvæ (see later, Soil and Litter Meiofauna).

Other Crops (Table 7)

Egg plant (*Solanum melongena*). A few egg plants were found in one spot, and these were carrying an infestation of both halticids and epilachnines.

Banana. The relatively young plantings of this crop appeared to be free of serious insect attack although a range of phytophagous insects were found, including curculionids, pentatomids and cassids. The presence of a brown lacewing (Hemerobiidæ) suggested the presence of aphids or other small plant-bugs although these were not found. The leaf sheaths were devoid of the usual arthropodan fauna possibly because of the youth of the planting.

TABLE 7

Other crops

Egg Plant		
Phytophages	...	... Halticidæ, Epilachninæ.
Banana		
Phytophages	...	... Cassidæ, Curculionidæ, Pentatomidæ.
Predators	...	... Hemerobiidæ.
Citrus		
Phytophages	...	... Eriophyidæ, Trypetidæ, Coccidæ, Other Diptera.
Durian (rotten)		
Saprophages	...	... Nitidulidæ, Staphylinidæ, Diptera (various).

Citrus. The small plantings of citrus at Tekek were uncared for but again supported little in the way of pests although the fruit suffered from rust mite and a scale was present on a few trees. The owner of the trees did not collect the fruit (limes) systematically; the chief use for the fruit appeared to be as a leech repellent! The rotting fruit on the ground was attacked by a number of Diptera including trypetids and these may have been the cause of initial fruit fall.

Durian. The chief pests of durian were mammalian. However, a number of insects fed in the empty husks including nitidulids and staphylinids as well as various flies.

Primary Forest (Table 8)

The forest which covers most of the island provides a number of different habitats, regardless of intimate host-plant relationships, and since most of the collecting was done in forest, considerably greater numbers of insects were recorded. The following account therefore summarises only the most prominent groups recorded.

Litter layer. The meiofauna of the litter layer is discussed in greater detail later, but certain of the larger forms were not collected in the Tullgren funnels. The litter layer was nowhere deep, except in hollows, and was usually less than an inch in depth. The majority of forms recorded were predatory or scavenging, although a number of millipedes were encountered including forms 15 cm. long, which were found in groups of thirty or more on several occasions. Of other forms, ants of many species were represented whilst grylloids (Oecanthidæ) and stenopelmatids were common, the density frequently being greater than one to the square foot. Cockroaches were frequent as were phalangids and reduviid bugs, and a sow-bug (Armadilliidæ) was locally abundant. "Trilobite larvæ" (Lycidæ ♀) (Plate 11 were often encountered, both in the litter and on logs and rocks. At night additional forms, including thelyphonids, many spiders, crabs, and predaceous beetle larvæ, made their appearance.

Rotten logs. Rotten logs and tree stumps are a common feature of all tropical rain forests and have a special fauna associated with them. Termites and ants were extremely common in this habitat, as were many beetle larvæ, the most frequent being scarabæiform and elateriform types, together with millipedes, isopods and dipterous larvæ. Collembola also occurred in large numbers whilst scorpions, pseudoscorpions, centipedes, and various predaceous beetles formed the predators of the community.

Fungi formed a habitat which to some extent overlapped that of the rotting logs and these carried a large number of adult beetles as well as coleopterous and dipterous larvæ. An interesting form taken on a single bracket fungus was a large tube-forming lepidopterous larva; the tube consisted of pellets held together with silk and was 3–4 cm. in length.

Logs also formed a nest site for small sweat bees (*Trigona* sp.).

A number of flies were attracted to the logs, the most prominent being a tylid (micropezid) which wandered over the logs vibrating its fore-legs vigourously. The final stages of mating of these curious long-legged flies was observed on several occasions. The male and female faced each other and the male 'pawed the ground' with one fore-leg, gradually approaching the female. Before reaching her, the male moved round behind her, and she adopted a characteristic stance, opening her wings and bringing them forward and up. The male mounted her and coupling took place immediately; the pair remained *in copula* for some time and its conclusion was not observed.

TABLE 8

Primary Forest

Litter layer	
Saprophages and Scavengers ...	Diplopoda (various) (Sphærotheriidæ, Polydesmoidea, Juliformes, etc.), Gryllotalpidæ, Formicidæ, Stenopelmatidæ (also predatory?), Armadillidiidæ, Blattaria, Grylloidea (including Oecanthidæ), Crabs.
Predators	Reduviidæ, Phalangida, Coleopterous larvæ, Thelyphonida, Ascalaphidæ (larva), Lycidæ(♀), Aranea (various), Chilopoda.
Rotten log layer	
Saprophages	Isoptera, Collembola, Passalidæ, Coleopterous larvæ (various), Diplopoda (various), Stratiomyidæ.
Scavengers	Formicidæ, Acarina, Armadalliidæ, Elateridæ.
Predators	Scorpionida, Chelonethida, Staphylinidæ, Chilopoda.
Nest sites	Apidæ (*Trigona* sp.).
Fungus (rotten and healthy wood)	
Fungivores	Erotylidæ, Cryptophagidæ, Endomychidæ, Tenebrionidæ, Scaphidiidæ other Coleoptera, Bostrychidæ, Staphylinidæ, Tube-building caterpillars, various coleopterous and dipterous larvæ.
Rocks†	
Scavengers and lichen feeders	Machilidæ, Oniscidæ Tenebrionidæ, Formicidæ*, Chrysomeloidea, Lepidoptera (larva), Grylloidea, Psocoptera.
Predators	Chelonethida*, Dermaptera (Spongiphoridæ?), Scorpionida*, Staphylinidæ, Aranea (including Clubionidæ).

* Frequently found hiding under rock flakes.

†Tree tunks similar but with Isopteran tunnels abundant.

Tree, vine and carpet layer

Phytophages	Lepidoptera (various), Phasmida, Melolonthidæ, Coccoidea Cantharidæ, Cicadidæ, Scutellaridæ, Chrysomeloidea (various including Gallerucidæ, Hispidæ, Halticidæ), Coreidæ, Tettigoniidæ, Pentatomidæ, Dascillidæ, Mordellidæ, Gryllacridæ, Tipuloidea, Jassoidea, Cicadellidæ, Flatidæ, Grylloidea, Cercopoidea, Lygæidæ, Cynipoidea (galls), Curculionidæ, Cecidomyidæ, Apoidea, Cetoniidæ.
Wood-boring	Cerambycoidea, Brenthidæ, Siricoidea, Isoptera.
Scavengers and Saprophages ...	Formicidæ, Dolichopodidæ, Calliphoridæ, Blattaria, Tenebrionidæ, Muscidæ, Bibionidæ, Celyphidæ, Otitidæ.
Predators	Cicindelidæ, Panorpidæ, Reduviidæ, Dryinidæ ♀, Asilidæ, Ichneumonidæ, Pompilidæ, Sphecoidea (Bembicidæ?), Miridæ, Dermaptera, Lampyridæ, Aranea various (Argiopidæ, Eusparassidæ, Clubionidæ, Mygalomorpha, Salticidæ, etc.).

Rock faces. The numerous boulders (Plate 12) and large rocks formed a special habitat on which lichens, mosses and a small creeper provided cover for a wide variety of insects, and this habitat was very similar to that of the bases of trees on which a similar vegetation flourished. The characteristic fauna included a large machilid, several small beetles, a cricket, lepidopterous larvæ, tetrigids, isopods and ants, and these were preyed on by various spiders, including ant-mimicing clubionids, dermapterans, staphylinid beetles, scorpions and pseudoscorpions. Rock flakes which were still associated with the matrix formed a sheltered habitat under which ants nested, and which also provided cover for scorpions, pseudoscorpions and other photo-phobic forms.

The curious stalk-eyed flies (Diopsidæ) were frequently found in large numbers in the vicinity of these rocks, and very rarely away from them, but no reason for this close association could be found. The species was not associated with any form of vegetation, contrary to the habit of many of this family which occur in short vegetation, especially grass; Curran (1945) has suggested that the stalked nature of the eyes is an adaptation to seeing round the far side of grass leaves. In this instance, the somewhat waisted abdomen and the hovering flight suggested a small wasp (e.g., Stenogasterinæ) and the stalked eyes enhanced this impression as they resembled the thickened antennæ in both shape and posture.

Tree trunks differed from the rocks in that isopteran earth passages were very frequent, and also in the presence of cicada castes. Cicadas themselves were remarkably abundant, as were several species of ants.

Vegetation. As might be expected, the insects associated with vegetation were exceedingly numerous. One of the most frequent of the insects of the carpet and herb layers was a scorpion-fly (Panorpidæ) of which large numbers were seen and a good series collected. This form does not appear to be common in mainland forests and its appearance in large numbers on Tioman suggests the absence of some controlling factor. Other prominent members of this layer were a small, bright blue, oval celyphid and an orange and black cicindelid; small Dolichopodidæ were also seen frequently. Various Chrysomeloidea were found in large numbers, often apparently linked with a few species of host plants, although a bright blue gallerucid was common everywhere. Of the other forms recorded it is not possible to pick out any for special mention, especially since many were taken in flight.

Cecidomyids were taken on several occasions on spiders' webs where they were resting in large numbers without being molested by the resident spider. This habit has been recorded in several tipulids (cf. Tams, reported in Edwards, 1934, on *Limonia seychellarum* Edw.) but usually in these instances relatively few insects

are involved and they settle in a horizontal line. As can be seen from the photograph (Plate 12), the cecidomyids rest all over the web. The significance of this practice is not known, and although Hendrickson (pers. comm.) believes that in tipulids the aggregation has sexual significance, prolonged observation of the webs failed to reveal any mating behaviour in these midges. In contrast to the tipulid aggregations, there was little activity on the webs, and it may be that the midges use the webs as a means of eluding predators.

Gunong Kajang

The investigation of the fauna of the higher land around Gunong Kajang was severely hampered by the very wet weather and the short duration of the trip. The general impression was that, within the primary forest, the fauna was much the same as at lower altitudes, although many types were far less abundant; the only noticeable absentees were the water associating forms. Only single specimens were collected of the panorpid and of the orange and black cicindelid, whilst the litter-dwelling grylloids and stenopelmatids were noticed far less frequently; the same observation is generally true of other forms. Few new forms were collected with the exception of some small diptera (including a few empids) which were found flying about over a damp, mossy rock near Camp V.

Higher up on G. Kajang, the fauna was conspicuously depleted; very few forms were recorded here, although on the summit many insects were seen in flight. At dawn of the night we spent on the summit (Camp VI) large cerambycids, curculionids, scarabæids and chrysomeloids as well as several smaller Coleoptera were seen in flight, while many small Diptera including a swarm of psychodids were also present. Insect activity at the summit must have been great at all times, as a swarm of large libellulids as well as a number of Swiftlets (*Collocalia* spp.) were very fully occupied.

Arthropods associated with *Rafflesia hasselti* (Table 9)

Rafflesia hasselti was found on several occasions on lianes. The flowers were not product at ground-level (cf. Henderson, 1951: 425–426) but emerged from the stem some six to twelve feet above the ground, the buds having the general shape of a cabbage heart and the flower having a span of 12–14 in. The buds of this plant are believed by the islanders to have medicinal value, and are collected and sold locally and on the mainland.

TABLE 9

Rafflesia (Inflorescence)

Alive (Flower visitors)	...	Sciaridæ, Muscidæ, Calliphoridæ.
Dead (Saprophages, etc.)	...	Scolopendroidea, Homopteran nymph, Acari, Dipsocoroidea, Collembola (Poduromorpha), Lathridiidæ?

The flowers of *Rafflesia* (Plate 14) are reported to be attractive to carrion infesting flies, and a specimen kept in camp certainly appeared to attract these flies, large calliphorids and muscids alighting on and near it, as did a small nematoceran fly, probably Sciaridæ. The cause of this attraction appeared to be visual stimulation since no fœtid odour was apparent, as may be found in certain diptera-pollinated asclepiads such as *Caralluma* (cf. Bullock, 1963), although Holttum (1954) reports that a strong odour is produced in some species of *Rafflesia*.

A number of dead buds were also found, and examination of one of these revealed a small arthropodan community of saprophages and predators to be well-established. These included small beetles, mites, poduromorph collembolans, dipsocoroid bugs and scolopendroid centipedes. It would be interesting to know what induced these forms to climb the twelve or more feet to reach this specialised and rather peculiar habitat.

Cave faunas (Table 10)

Of the several caves and overhangs visited on the island, only those which supported a population of Black-nest Swiftlets, *Collocalia maxima*, carried any typical cave fauna. In one such cave, Gua Sinah, the floor was littered with droppings and the rotting feathers of birds. This accumulation provided food for a number of dipterous larvæ, some small tineid moth larvæ, ants and small beetles, as well as a large number of Acarina. The walls carried a number of juliform millipedes and several large rhaphidophorine cave crickets, whilst a large striped spider (Eusparrasidæ?) was found in several crannies. The nests of the swiftlets yielded two types of Acarina, one of which was probably ectoparasitic and the second a scavenger. In addition, two liphistiid webs were found in the entrance passage; one contained a live spider, which unfortunately escaped, and the second was empty. A second cave nearby added little to the list, except for a large Amblypygi (Charontidæ), and a small crab.

TABLE 10

Cave fauna (*Collocalia maxima*)

Guanophages	Acarina, Coleoptera, Tineid larvæ, Dipterous larvæ.
Scavengers	Formicidæ, Rhaphidophorinæ, Collembola, Juliform Diplopoda, Staphylinidæ.
Predators	Liphistiidæ, other Aranea (Eusparrasidæ), Amblypygi, crab.
C. maxima nests	Acarina.

Examination of the guano from these two caves yielded numerous mites and a few other forms including tineid larvæ, dipterous larvæ, staphylinid beetles and a collembolan. This contrasts strongly with guano collected from a similar birds'-nest cave on Pulau Tulai by Lord Medway and D. R. Wells, in which there were very few mites, and numerous dipterous larvæ. The constitution of the guana appeared to be the same, with the sclerites of winged ants and a few beetle elytra forming the only identifiable food remains. It was however noted at the time that the Tulai samples were much darker in appearance than those from the main-island caves. These differences may be related to the natural moisture content of the caves.

AQUATIC HABITATS (Table 11)

A wide range of aquatic habitats was present on the island and these carried a considerable diversity of arthropodan forms. In this section I have also included those forms which are usually associated with water, e.g. Plecoptera adults, since these are more readily considered in relation to water than the ecology of the surrounding country.

The Sea and Mangrove Areas

On the open sea, only marine Gerridæ (Halobatinæ) were found but in the small bays, and especially amongst the mangrove on P. Tulai, marine Veliidæ (Haloveliinæ) were also present.

Coastal Plain

On rivers which flowed directly into the sea, such as the S. Ayer Besar at Tekek, the only insect life recorded was gerrids, the Halobatinæ overlapping to some extent with other Gerridæ. Truly aquatic insects were not taken, probably due to the river "backing-up" with the rising tide and much of the meander being subject to a certain amount of salinity. In these conditions, only amphipods, prawns and crabs existed and these forms also occurred in pools which were flooded at high-tide.

However, where fresh-water ponds had developed as a result of the river being dammed by dunes, a flourishing insect community had become established as in the pond shown in Plate 13. Here a floating algal mat harboured much of the insect life and very few animals were present on the sandy bottom. The insectan community were all juvenile and included a range of Odonata and a few Ephemeroptera, as well as numerous Chironomidæ of which some were living within the algal cells. In addition both culicines and anophelines were present in small numbers; crustacea were mainly represented by Cladocera.

The surface fauna included gerrids, veliids and hydrometrids whilst the various Diptera on the shores of the pond frequently flew onto the mat and joined these surface forms. Above the pond, predators consisted of odonates, and tetragnathine spiders had built their webs on all overhanging vegetation. Variations on this complex occurred in other stream meanders which were not subject to tidal encroachment.

Cleared Areas

The streams running through cleared hillside areas were rather depleted in their fauna, one examined at Tekek only containing bætid larvæ and possibly a naucorid. (This last escaped capture despite my efforts and, if the sight identification is correct, was the only truly aquatic hemipteran recorded.) At Mokut, a stream had a greater fauna, consisting mainly of dipteran and plecopteran larvæ, but even so comparison with a similar forest stream (see next section) reveals considerable depopulation.

Primary Forest

Above the coastal plain, the streams were usually rocky and more or less precipitous. In the more torrential parts of the streams little in the way of insect life could be found, although gerrids were present in all environments. Otherwise the only forms which could be found were larval heptagenids and libellulids whilst trichopteran adults were seen "dancing" over the rapid waters.

In the slower running parts of the river where rocks were less water-worn and some sedimentation had taken place, more forms were found, Trichoptera, Odonata, Ephemeroptera and Diptera all being represented. In the calmer backwaters a greater diversity occurred; the families differed from those in the main river and aquatic cockroaches and small beetle larvæ (probably Helodidæ) were recorded. The smaller feeder streams, which were often overgrown with vegetation and, except after rain, carried only a very small amount of water so that small pools formed, again showed some change in fauna, the larger anisopteran nymphs disappeared whilst nemourids, perlids and tipulids appeared. This habitat was also the only one from which mesoveliids were recorded.

TABLE 11

Aquatic communities

Sea and Mangrove		
Predators and Scavengers	...	Gerridæ (Halobatinæ), Veliidæ (Halovelinæ).
River meanders subject to tidal influx		
Scavengers ...	...	Amphipoda, Isopoda, Crabs, Prawns, Gerridæ.
Fresh-water Ponds (Coastal)		
Phytophages ...	...	Cladocera, Chironomidæ.
Scavengers ...	...	Bætidæ, Culicidæ.
Predatory ...	...	Gomphidæ, Aeshnidæ, Megapodagrionidæ, Libellulidæ.
Surface feeders	...	Gerridæ, Veliidæ, Hydrometridæ.
Above surface (predators)	...	Argiopidæ (Tetragnathinæ), Odonata.

Stream through regeneration

Scavengers	...	Simuliidæ, Limoniidæ, Cænidæ, Hydroptilidæ, Bætidæ, Blepharoceridæ.
Predatory	...	Naucoridæ?
Surface	...	Gerridæ, Veliidæ.

Forest stream (rocky torrential)

Scavengers	...	Heptagenidæ.
Predator	...	Libellulidæ.
Water surface	...	Gerridæ.

Forest stream (rocky, slower flowing)

Main stream

Scavengers	...	Hydropsychidæ, Heptagenidæ, Simuliidæ.
Predatory	...	Amphipterygidæ.

Back waters

Scavengers	...	Hydropsychidæ, Bætidæ, Potomonthidæ, aquatic Blattaria, Chironomidæ, Simuliidæ, Cænidæ, Helodidæ?
Predators	...	Corduliidæ, Gomphidæ.
Water surface	...	Gerridæ.

Slow flowing stream (over small, unworn stones)

Scavengers	...	Heptagenidæ, Perlidæ, Simuliidæ, Nemouridæ, Tipulidæ (or predatory?), Hydropsychidæ, Phrygænidæ, Bætidæ, Chironomidæ.
Predators	...	Epallagidæ, Amphipterygidæ.
Water surface	...	Mesoveliidæ, Gerridæ, Veliidæ.

Slow flowing stream (sedimentary bottom)

Scavengers	...	Perlidæ, Atyidæ (prawn), Heptagenidæ.
Predatory	...	Corduliidæ, Gomphidæ.
Water surface	...	Gerridæ.

Seepage Pools

Predatory	...	Corduliidæ, Libellulidæ, Cœnagrionidæ, Dytiscidæ.
Water surface	...	Veliidæ.

Rock pools (fresh-water, leaves)

Scavengers	...	Small Blattaria.
Predators	...	Dytiscidæ.

Rock Pools (on water slide)

Scavengers	...	Dixidæ, small Coleoptera, Heptagenidæ, Hydropsychidæ, Peltoperlidæ.
Predators	...	Amphipterygidæ, Epallagidæ
Water surface	...	Gerridæ, Veliidæ.

Rock Pools (rain water and sea spray)

Scavengers	...	Culicidæ, Cladocera.

Nepenthes pitchers (Kajang) and tree-holes

Scavengers	...	Culicidæ.

Although the majority of streams were rocky, in some areas on the eastern side few rocks were present and the streams flowed sluggishly over a silty bottom. Most rock-living forms disappeared and the fauna was greatly reduced, only a few Odonata, Ephemeroptera and Plecoptera being present. Rather similar conditions, although with a higher humus and mud content, existed in various seepage pools and puddles, and in these the fauna was still further restricted and only a few odonate larvæ were found, together with small predaceous beetles. Since all these

forms are predaceous, it would be expected that some prey would be present. However, only mosquito larvæ were recorded and it is possible these together with insects which fell into the water formed the entire diet. This might be supplemented by cannibalism.

Rock Pools

On the main stream of the S. Ayer Besar, the large boulders often contained small hollows in which rain-water and leaves accumulated (Plate 14). These contained large numbers of small aquatic cockroaches and beetles. The basic attraction may have been small dipterous and other larvæ which were living on the dead leaves above the level of the water.

Two other types of "rock-pools" were examined. The first of these, at Kg. Lalang, lay half-way down a steep cliff down which water was running ("water-slide"). The water accumulated on a ledge in a small, shallow pool before over-flowing and continuing down the cliff. This small pool contained a variety of forms which resembled to some extent the feeder streams, in that only zygopteran larvæ represented the odonates, whilst hydropsychids, dixids and very small beetles were also present. Even in such a small and relatively inaccessible area both veliids and gerrids were present on the water.

The second type of pool was coastal, occurring in hollows on rocks near the high-tide mark but presumably deriving most of its water from rain although the water tasted distinctly brackish. The only forms recorded, albeit in some numbers, were mosquito larvæ and Cladocera.

Pitchers and Tree Holes

One final type of aquatic habitat which deserves mention is the small accumulations of water in tree-holes, *Nepenthes* pitchers, etc., which occasionally carried mosquito larvæ. These were relatively few however and the majority of such habitats were devoid of insect life.

Water-associating Insects

A considerable number of insects were found along the streams and rivers in the forest area although not actually living in or on the waters. These were not essentially confined to the river areas but were taken in far greater numbers here than elsewhere. Chief among these were the Odonata, and especially the Zygoptera, which were present in large numbers and considerable diversity. Trichoptera were recorded several times as were a few isolated Plecoptera but throughout our stay not a single adult Ephemeroptera was seen. Numerous Diptera including dolichopodids, asilids and tabanids were caught along the streams as well as many smaller flies which were foraging on the rocks and amongst damp leaves at the edge of the rivers.

The lichen-covered boulders on the main course of the S. Ayer Besar in the forest were especially well populated with small Diptera which rested on them, and gave the impression of sporulating bodies of the lichen until disturbed. The semi-aquatic tetrigids were also present in large numbers and these extended their range down into the *ladang* areas; and a small green cicindelid was only recorded in close proximity to the water both on the boulders and on foliage over-hanging the streams. Many spiders (chiefly Tetragnathinæ) had spread their webs over the water courses and preyed on the numerous forms which used the stream as a flight-way.

In the coastal areas, little was recorded apart from odonates and spiders, although a number of insects including tabanids and ants used the stream as flight-ways. Chironomid adults were observed in considerable numbers over a fresh-water pool at Tekek at night.

ECTOPARASITES AND BITING FLIES

Ectoparasites (Table 12)

The mammals and birds which were collected were with few exceptions examined for ectoparasite infestations. The intensity of examination was, however, somewhat variable. Specimens collected near to Kg. Tekek were usually examined with a binocular microscope; those collected on G. Kajang were only examined by eye. Much of the work of collecting was performed by Mr. C. K. Ng, and by Mr. B. L. Lim during his stay on the island, although all members of the party participated from time to time. A detailed account of the Acarina collected appears later in this volume (Nadchatram et al.) whilst the Siphonaptera are listed in Appendix 1 from data supplied by Dr. R. Traub.

Of the mammals examined, only three species were "clean" and these are all arboreal forms, namely *Ratufa*, *Petaurista* and *Cynocephalus*, all of which were taken in small numbers. The two insectivores carried acarine infestations only whilst the four Chiroptera were mainly subject to ectoparasitic diptera although acarines were recorded from both *Pteropus* and *Cynopterus*. The only primate examined, *Tupaia*, carried both acarines and a few fleas, and the only ungulate, *Tragulus*, was attacked by ixodids, trombiculids and apterous hippoboscids. Amongst the rodents, the various species of *Rattus*, *Sundasciurus* and *Callosciurus* were subject to attack by many acarines and by fleas; *C. notatus*, *R.* sp. *tiomanicus* and *R. surifer* also yielded Anoplura (Hæmatopinidæ in the first two cases). In addition a small mallophagan was recorded from a single specimen of *R.* sp. *tiomanicus*. The other three rodent genera showed various gaps in the parasite pattern; *Atherurus* carried only acarines, *Lariscus* had acarines and fleas, and the small flying squirrel, *Iomys*, had fleas and dixodids only. Several specimens of *Rattus* were also found to have pseudoscorpions clinging to their fur, but these were presumably nest-dwelling forms which had either accidentally or intentionally allowed themselves to be carried out of the nest. A single rat's nest, believed to be of *R. surifer*, contained many of these arachnids as well as a phalangid (Sironidæ) and a juliform millipede.

The birds were mainly free of ectoparasites, the majority carrying only a few Mallophaga, mainly Philopteridæ. The two species of *Fregata*, however, were heavily infested with mallophages, whilst *F. andrewsi* also carried a few hippoboscids.

Biting Flies

Three families of biting flies were recorded on the island. Ceratopogonids, including *Culicoides* sp., were somewhat common along the coast, especially near mangrove although rarely, during our visit, in such numbers as to make life miserable. Tabanids were common, especially in the forest, and, as has been noticed elsewhere (see Dunn later), were readily attracted to man. Culicidæ were very common in the coastal and cleared areas, although in the primary forest man-biting forms were rare. Apart from the *Anopheles* spp. which have been summarised by Warren (see later) the most frequently noticed form was an *Aëdes* (assumed to be *A.* (*Stegomyia*) *albopictus*) which was common in the coconut plantations. Although many simuliid larvæ were common in the forest streams, no case of adults biting man was recorded.

TABLE 12

Ectoparasitic arthropods recorded from the mammals and birds.

	Acarina					Diptera			
	Trombiculidæ	Ixodidæ	Other Acari‡	Mallophaga	Anoplura	Nycteribiidæ	Streblidæ	Hippoboscidæ	Siphonaptera
MAMMALIA									
Insectivora									
Crocidura malayana	+	+							
Hylomys suillus	+	+							
Dermoptera									
Cynocephalus variegatus ..									
Chiroptera									
Pteropus hypomelanus ..			+			+			
Cynopterus brachyotis ..		+*	+			+			
Eonycteris spelæa ..						+	+		
Rhinolophus sp.							+		
Primata									
Tupaia glis	+	+	+						+
Rodentia									
Petaurista petaurista ..									
Iomys horsfieldi		+							+
Ratufa bicolor									
Callosciurus notatus ..	+	+							+
C. nigrovittatus	+†	+			+				+
Sundasciurus tenuis ..	+	+	+						+
Lariscus insignis	+†	+							+
Rattus sp. *tiomanicus* ..	+	+	+	+	+				+
R. exulans	+	+	+						
R. surifer	+	+	+		+				+
R. sabanus .. .	+	+	+						+
R. cremoriventer		+	+						
Atherurus macrourus ..		+	+						
Ungulata									
Tragulus napu	+	+						+	
AVES									
Fregata andrewsi				+				+	
F. ariel				+					
Lonchura striata				+					
Graculus religiosa ..				+					
Aplonis panayensis ..				+					
Copsychus malabaricus ..				+					
Dissemurus paradiseus ..				+					
Collocalia maxima ..				+					

*Argasidæ. †Also Chelyetidæ. ‡Mainly Laelapidæ.

SOIL AND LITTER MEIOFAUNA

The soil and litter fauna of the Malaysian region seems to have received even less attention than has the other insectan fauna. Dammerman (1925 and 1937) described some of the macrofauna of the litter layer of various habitats in Western Indonesia including Sumatra and Java, but his technique was not intended to reveal the smaller forms, whilst Soehardjan (1957) has given some account of the Javan fauna. In this brief study, samples of both soil and leaf litter were extracted by means of rough Tullgren funnels, 10 in. in diameter, with a mosquito gauze disc 8 in. in diameter placed within them. The sample to be extracted was placed in the centre of the gauze leaving an air space around the outside to allow the escape of moist air and prevent condensation within the funnel. The funnels were kept in racks under the rest-house (Camp I) and the fauna was collected into 3 × 1 in. specimen tubes containing 70% ethanol. No repellent agent was used; samples were left to dry slowly, over a period of a week in most cases.

Soil samples were usually collected with a 2 in. diameter soil augur to a depth of 5 in., two such samples being bulked in each case. An exception to this was made on G. Kajang, the samples being taken with a metal trowel, but the same sampling pattern was maintained. Litter was collected from approximately one square foot, although this area was varied depending on the depth of litter sampled. In many cases the leaf litter occupied too great a volume to be placed in one funnel and often two or even three funnels were used. Soil samples were generally divided between two funnels.

After extraction, the samples were stored in 70% ethanol and were later sorted and identified as far as possible under a binocular microscope. When samples were clean, the contents of the tubes were shaken and tipped into a dish and examined straight away but if much soil or detritus had fallen into the tube a slightly more complicated technique was used. The ethanol was decanted into a dish and examined, and magnesium sulphate solution (S.G. 1.2) was added to the residue and the tube shaken vigorously. The soil was then allowed to settle and the fluid containing the floating arthropods tipped off. As a precaution, the residue was then treated with benzene and water, the tube again shaken and, after allowing the benzene and water to separate, the interface was examined for any arthropods which had been missed in the previous extraction.

Sampling Areas

Samples were taken from all the major ecological habitats with the exception of the coastal vegetation, but the greatest emphasis was placed on the primary forest where four samples were taken of soil and five of litter. Single samples were taken from each of the major ecological zones on G. Kajang (see General Introduction), except that leaf litter was not taken from the cleared summit or from the open elfin forest where no proper litter layer was apparent. In the cultivated areas, samples were taken from the rice-growing area, the coconut plantation and the area of regeneration as well as from the jungle edge. In addition, a litter sample was taken from an accumulation of leaves on a rock ledge by the river and a soil sample was taken from beneath an overhanging rock.

Forms Recorded

Crustacea. The crustacea were represented by members of two classes, Copepoda and Isopoda. Minute harpacticid copepods were found in a number of soil, as well as litter, samples and appeared to be generally distributed throughout the forest area. However, the vast majority occurred on G. Kajang and this is probably due to the moister conditions on the mountain. The group, according to Kuhnelt (1961) and others, is confined to water films on leaves and soil particles, and the generally damp conditions would thus be beneficial.

Isopoda were typical of the litter layer and both Armadillididæ and Oniscidæ were recorded, there being no indication of preferences within the forest.

Myriapoda. All four classes of myriapods were recorded in both soil and litter sample. Chilopods were poorly represented and the majority of forms were referable to the Geophilomorpha although a scolopendrid was also taken. The Diplopoda were better represented especially in the litter layer, and many different forms including oniscomorphs and juliforms were recorded, whilst one sample contained juvenile ?polyxenids. Pauropoda were not common but occurred in both soil and litter zones; Symphyla (probably Scolopendrellidæ) were commoner but similarly showed no preference.

Hexapoda: Apterygota. Diplura were represented in the soil by both campodeids and japygids, but in the litter layer only two specimens of the former family were recorded. Collembola, as might be expected, were amongst the commonest soil and litter forms. The majority of forms were referable to the several families of Arthropleona but a few Symphypleona were taken, especially in the litter layers. The range of forms included all stages of adaptation to a subterranean life. Protura were poorly represented whilst the Thysanura were represented by a single machilid taken amongst litter.

Exopterygota. The exopterygotes were generally poorly represented. The Orthoptera included only two small gryllids and Blattaria were obtained from two litter samples only; this scarcity is almost certainly due to their being able to escape during collection of the litter samples. Of the others, Isoptera were poorly represented, and Psocoptera were infrequent although occurring in both leaf and soil samples whilst Thysanoptera occurred in litter only. Various Hemiptera were obtained including a number of dipsocoroid bugs whilst the remainder were mostly immature Auchenorrhyncha.

Endopterygota. The majority of endopterygotes recorded were beetles or flies, although ants were frequent especially in the forest litter and two small lepidopterous larvæ and an adult chalcidoid wasp were found in the G. Kajang litter samples. The recording of alate adults always presents a problem, since they could easily be animals which fell into the funnels during extraction. For this reason, ipid wood-borers, which were common about the rest-house, were rejected in all the samples. The adult Diptera recorded from a heterogeneous group and although some may have fallen into the funnels others probably emerged from puparia in the samples and the several apterous adults (?Mycetophilidæ) recorded are typical litter-living forms. The larvæ again were fairly heterogeneous and many were not identifiable, although stratiomyids, chironomids and sciarids were present in the litter. With the exception of the Ipidæ, the adult Coleoptera were mainly staphylinids together with a few clavigerids, pselaphids and other small forms including some with setate wings, all of which may be considered as typical litter and soil types. Coleopterous larvæ were at times very numerous, the most frequent form being a typical campodeiform larva (?Staphylinidæ) but a few apodous curculionids and other types were recorded as well.

Arachnida. With the exception of acarines, no arachnids were found in great numbers. Microthelyphonids (Palpigradi) were found in two soil samples whilst pseudoscorpions were found in one soil sample and several litter samples. Single specimens of phalangids (2 Laniatores, and 1 Sironidæ?) were taken in three soil samples, and several small spiders were found, mainly in the litter layer. It is probable that both these groups are rather poorly represented in the sample due to their ability to escape both during collection and during extraction. The Acarina were the most abundant in nearly all samples and a number of families were represented of which the majority belonged to the Orobatei and Trombidiformes.

Non-arthropodans. Very small gastropod snails (possible juvenile *Microcystina*) and several oligochæte worms were recorded, the latter chiefly in the litter samples.

The Samples (Tables 13 and 14)

Cultivated Land. The samples taken on cultivated land of all sorts including regeneration, showed a somewhat depleted fauna. In the coconut plantation, the soil was virtually devoid of life, only beetle larvæ and mites being recorded, whilst the litter was scarcely better, with a small bug and two Psocoptera in addition to the mites and beetle larvæ. In the rice-growing area, rather more life was present, with many mites dominating the fauna of one soil sample, together with a very few ants, collembolans, beetles, flies, and worms. The litter contained many mites and collembolans, together with a symphylan, several Diptera and a staphylinid. The presence of a small bug and of phlæothripids is obviously associated with the rice field fauna. On the regenerated land, the soil fauna was more varied with typical soil dwellers such as geophilomorph centipedes, small millipedes (?Polyxenidæ) and a proturan appearing. The leaf litter community was not particularly large with only mites present in numbers.

Primary Forest. The two soil samples taken at the forest edge showed little difference from that on the regeneration. One sample contained numerous mites, one collembolan and a campodeid, whilst the second was chiefly of interest in that it contained two Harpacticidæ, a pseudoscorpion and a markedly increased number of Collembola. A sample taken under an overhanging rock in this locality showed a very reduced fauna, only two mites and a nymphal bug being recorded. This is hardly surprising, since the soil was very dry and dusty and probably was rarely wetted.

At about 500 ft. a.s.l., a single soil sample was taken on level ground and this showed greater diversity than previous samples, with diplopods, symphylans and a japygid present, together with relatively large numbers of collembolans, mites and beetle larvæ, whilst the only specimen of Sironidæ was taken here.

In the region of Camp II, three soil samples and five litter samples were taken. The first soil sample contained a very poor fauna, although a japygid was included. Both the other samples contained a large number of beetle larvæ, the majority of which were typical campodeiform larvæ, but with a sprinkling of a curculionid type. Symphyla were well represented in one sample which also contained a microthelyphonid, a mygalomorph spider and a proturan. The other of these two contained at least ninety-two beetle larvæ, as well as appreciable numbers of mites and collembolans. The leaf samples showed even greater diversity, with very large numbers of mites in all of them and a high collembolan population in all save one. Pauropods appeared in two samples and harpacticids in four and between them these five samples almost completely covered the range of litter dwelling orders recorded. Ants were present in four, and prominent in two, samples, whilst termites, Thysanoptera and Diplura (Campodeidæ) were all represented in one sample.

A "special" habitat examined in this region was an accumulation of leaves and humus on a rock ledge. This yielded a large number of beetle larvæ, over twenty mites, a few fly larvæ, a collembolan and two harpacticids.

The soil and litter samples taken in the different zones on G. Kajang showed some differentiation from those taken at 1,000 ft. The count of harpacticids was greatly increased especially in the topmost zone, a possible result of the damper conditions, and the fact that these samples were taken in rain may have been a contributory factor. The Collembola were markedly reduced, especially in the litter layer, as were also the beetle larvæ and of these the campodeiform larva, which formed the bulk of the numbers at 1,000 ft., was absent.

TABLE 13

The soil fauna

	Coconut	Ricefield		Regeneration		Forest edge		Camp II 1,000 ft.			500 ft.	Under rock overhang	Summit	Gunong Kajang: Moss forest	Gunong Kajang: Elfin forest	Gunong Kajang: Bamboo forest	Gunong Kajang: Primary forest
No. of samples ..	1	1	2	1	2	1	2	1	2	3	1	1					
Copepoda ..							2						15	5		1	
Isopoda ..				2													
Chilopoda ..					2								2				
Diplopoda ..				5					2		1				4		
Pauropoda ..													2				
Symphyla ..								1	6		2						
Diplura ..						1		1			1				2		
Protura ..					1				1					1			
Collembola ..			4	7	4	1	15	1	6	12+	30		3	4	9		1
Orthoptera ..										1							
Isoptera ..															2		
Psocoptera (apterous)										1			1	1			
Hemiptera ..				3			1		2	3		1		2		3	
Diptera adult ..						1					1		1		2	2	
larvæ ..									1		2		2	1		3	
Coleoptera adult ..			1	1	1		1	1	2		7		2		1	2	4
larvæ ..	2		2	8	1	2	1	3	42	92+	27		3	4	3	3	1
Formicidæ ..		1	1		1			1	3	1	5		1	1		5	7
Chelonethida ..							1										
Microthelyphonida									1						1		
Aranea ..									1					1			
Phalangida ..							1		1		1						
Acarina ..	2	M	7+	23	25	M	17		22	20+	36	2	24	30	19	M	3
Gastropoda ..				1													
Oligochæta ..		2		1													

+ = Rather more than the indicated number.

TABLE 14

The litter fauna

	Coconut	Ricefield	Regeneration	Camp II 1,000 ft.			Gunong Kajang					
									Moss forest	Bamboo forest	Primary forest	Rock ledge by river
No. of samples ..	1	1	1	1	2	3	4	5	1	1	1	1
Copepoda ..				1	2		2	1	1		8	2
Isopoda ..				1	1		1	2	2	1	2	
Chilopoda ..								3				
Diplopoda ..				7			2	6	3	2		
Pauropoda ..							3	2				
Symphyla ..		1		1	1		4	1		2		
Diplura ..							2					
Protura ..				1								
Collembola ..		M	2	28	41+		58	VM	10	1	10	1
Thysanura ..				1								
Orthoptera ..						1						
Blattaria ..				2			4					
Isoptera ..							11					
Psocoptera ..	2				1							
Hemiptera ..	1	3	1	2	4		6					
Thysanoptera ..		4					11					
Lepidoptera (larvæ)									2			
Diptera												
adults ..				2	3		1	4	2	3		
larvæ ..		8	3	40	12		15	3	4	2	3	8
Coleoptera												
adults ..		1		4	5	1	6	7	6	4	4	
larvæ ..	1		3	6	11		4	4		2	1	40+
Formicidæ ..				5	3		30	20	10	3	2	
Chalcidoidea ..										1		
Chelonethida ..				3			1	4	2			
Aranea ..			1	2	1		4	2			1	
Acarina ..	12	VM	26	75+	73+	VM	100+	VM	50+	42	44	20
Oligochæta ..				6	4		2	3				
Gastropoda ..			1				1					+

+ = Rather more than the indicated number. M = many, i.e. over 100. VM = very many.

DISCUSSION

The fauna of Pulau Tioman presents considerable diversity of form and few orders and families which are normally found on the Malayan mainland are not represented. There is, however, a notable imbalance apparent which will become more well defined as the specific representation is worked out. An outstanding example is the presence of the panorpid which was one of the commonest insects of the herb layer of Tioman but is encountered infrequently on the mainland. Similarly, although aquatic insects were well represented, the cryptoceratan Heteroptera were virtually absent and aquatic Coleoptera were poorly represented. Amonst the terrestrial forms, a number of forms including reduviids and mantids were decidedly less abundant than on the mainland whilst others, including some Grylloidea and various Coleoptera were more frequently encountered. However, even where groups were very abundant, there was a general impression of a paucity of species. Thus, the Tabanidæ were a prominent and uncomfortable component of the fauna but all the specimens collected are referable to a single species, *Chrysozona lunulata* (Macquart), and the same appeared to be true for a number of other families including Tetrigidæ and Celyphidæ. This cannot be regarded as a general rule, however, since other groups had much broader representation; the small but prominent family of the Cicindelidæ contained at least six species with two other possible species or sub-species.

In the cultivated areas, the specific composition of the fauna appeared to be considerably reduced with the possible exception of the rice growing areas. This impression was to some extent confirmed by the examination of soil and litter samples, although it must be reiterated that this study is incomplete both from the methods of extraction and the few samples which could be treated.

The general impression is that the arthropodan fauna is numerically abundant but specifically depleted and atypical. Medway (see earlier) has found it necessary to postulate an over-water colonisation to explain a similar phenomenon in the mammals. Although such a hypothesis cannot be rejected for the arthropods, especially since the distance involved is slight and even so is relieved by the presence of the inner islands of the Johore Archipelago, the possibility of the fauna being relict seems more acceptable for the forest forms at any rate. This is rendered the more likely from our knowledge of a land link with the Malayan mainland in recent (Pleistocene) times. Comparison of the fauna with that of acknowledged oceanic types (cf. Gressitt, 1954) is invalidated by the short distance involved in this case. Pulau Jarak in the Straits of Malacca offers a rather better comparison although, due to its small size and greater isolation, such a comparison must not be taken too far. Harrison (1950) has reported an extremely impoverished fauna and although on a recent visit I (Bullock, 1964) found a rather greater arthropodan fauna than is indicated in his paper, it is apparent that few arthropods have reached the island[24]. Even of those which are present, none are particularly abundant with the possible exception of a few spiders. This contrasts strongly with the abundance on Tioman, suggesting that, whereas on Jarak the forms present are casual immigrants, not well suited to conditions but able to survive and maintain themselves, on Tioman they are adapted to their environments. Moreover, few flightless forms, except for spiders and mites, are present on Jarak and the presence of these is readily explained by the wind-dispersion techniques

24. This statement excludes the soil fauna which appeared to be reasonably well represented. This is possibly explained by Tweedie's (1950) suggestion that both flora and fauna were eliminated by deposits of volcanic ash in the late Pleistocene/early post-Pleistocene. It is probable that the soil fauna could survive such conditions which annihilated the unprotected above-soil forms.

of the spiders and the fact that all recorded mites are either ectoparasites or soil-dwellers. On Tioman, all arachnid orders which are known to occur in Malaya were recorded and many myriapods were found including the small and delicate Symphyla and Pauropoda.

It therefore seems preferable to regard this fauna as relict, the atypical composition having arisen since the isolation of the island. Since little is known of the ecological requirements of Malayan arthropods, a detailed analysis is not possible It is however apparent that climatic changes could temporarily destroy an ecological niche throughout the island resulting in the elimination of the forms occupying it. This niche would then be reoccupied by other forms which were unable to compete with the previous occupants but in their absence could utilise it. Thus, in aquatic habitats, drought could have caused the reduction of the freshwater habitats to an extent that predatory forms were considerably reduced and, in the case of Heteroptera, eliminated. The surviving forms have since resurged, presenting the general picture already described.

The presence of distinct sub-species, as has already been shown in the Rhopalocera (Corbett and Pendlebury, 1956; Stubbs, 1961) and in one species of odonate, *Devadatta argyroides tiomanensis* Laidlaw (quoted in Lieftinck, 1954), does not disprove this explanation, since the principles of genetic drift apply as much to a small relict fauna as to an oceanic type.

It is not claimed that there has not been recruitment from the mainland and it is probable that immigration has occurred from time to time, the colonist establishing itself successfully where it was not directly competing with forms already established. This is especially true of the cultivated areas, which have all arisen well after the last inundation of Sundaland. It follows that the animals now found in the cultivated areas have either moved in from the forest or reached the land subsequent to the clearing of the land. Probably one of the most recent colonists is a mollusc, *Achatina fulica* (Giant African Snail) (see Appendix 2) which was recorded on the east side but not on the west.

ARTHROPODA OF PULAU TULAI

P. Tulai was only visited for two short periods during our stay on Tioman, and hence the arthropodan fauna was even less fully collected than on the main island. The general impression of the fauna was of impoverishment as compared with P. Tioman although it included a few forms which were not found on the main island. These included two species of Buprestidæ which were found flying around a tall tree on the highest part of the island. The absence of freshwater on the island precluded the occurrence of aquatic forms except for culicids, some of which are tolerant of brackish conditions whilst others breed in small rain water pools. Odonates, of which several species were taken, had probably crossed from Tioman and several specimens, as well as butterflies, were observed making the crossing. Examination of a small marshy area failed to reveal the presence of odonate nymphs or of any aquatic insect life.

The strand fauna differed little from Tioman. Diptera, chiefly Muscidæ and Sarcophagidæ, were very abundant and were preyed on by asilids and odonates. The flat plain behind the strand was planted with coconut, and due to sea water incursion was dotted with open areas and brackish pools about which grass grew to 2–3 ft. in height. Many Acrididæ were found here as well as several mantids and various spiders including one of the two nephiline argiopids which were recorded from a similar habitat on Tioman, whilst grylloids were plentiful on the ground. The rather lush vegetation about the marshy area was populated by a number of forms including tylid and neriid flies and gallerucid and cassid beetles.

Above the coastal plain, the partially cleared jungle was rather lacking in insects. Butterflies were common in the air, but these, like the odonates, could have quite easily flown across from Tioman. In the leaf litter, termites, ants, and cockroaches were frequent.

On the east coast, a few insects were found on the coral littered beach including small apoids and a small beetle (Cantharidæ?). On rocks well above high-tide mark a few small brackish pools, presumably resulting from a mixture of rain-water and spray, contained Cladocera and culicid larvæ, whilst a number of old wasp nests were found under a rock over-hang, and a machilid was living inside one of these. A large spreading tree which overhung the beach was carrying a heavy infestation of cercopid nymphs which caused a constant rain of watery fluid. According to Wyatt-Smith (quoted in *Malay. Nat. J.*, 1958, 4 (1) : 95) this is an unusual phenomenon; unfortunately no specimen of the tree was taken for identification.

Insects not recorded on P. Tulai although apparently suitable habitats existed included cicadas, cicindelids, curculionids, cerambycids, diopsids, celyphids, tettigonids and panorpids. Although a longer stay might have revealed some of these, it is certain that some at least were not present. These absences appear to be explicable in one of two ways. The clearing of land and subsequent planting of coconut may have so changed the ecology, especially in the early years, that these insects were wiped out and have failed to recolonise the land; or the island might have been completely submerged since the last disappearance of the Sunda shelf. This latter possibility is not untenable since the highest point of the island is only c. 300 ft., but one would anticipate that forms such as cicadas would be capable of recolonising the island from Tioman fairly quickly.

SUMMARY

In a broad survey of the principal terrestrial and freshwater habitats on Pulau Tioman, the principal arthropodan groups are listed and their possible role in the ecology indicated. Ectoparasitic forms are listed in relation to their hosts and identifications of the Siphonaptera are shown in Appendix 1. (Identifications of the Acarina are given in Nadchatram *et al.*, this *Bulletin*, p. 129). The results of a brief study of the soil and litter meiofauna are discussed and the numbers of specimens tabulated. Passing mention is made of the fauna of Pulau Tulai, and the other invertebrates collected, together with additional information on the molluscs obtained by Mr. E. R. Alfred, are shown in Appendix 2.

The origin of the fauna is discussed in relation to the possibilities of its being relict or the result of over-water colonisation. It is suggested that, as far as can be judged, much of the fauna is relict although a certain amount of re-establishment or recruitment, especially in the cultivated areas, has probably occurred since the separation from the mainland.

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Assistance in the preparation of Table 12 was given by Mr. M. Nadchatram. Dr. A. J. Berry kindly identified the mollusc collection and further records of this group were provided by Mr. E. R. Alfred of the Singapore National Museum from material collected by him in 1958 and identified by Mrs. W. S. S. van Benthem-Jutting.

To all these people I am most grateful.

APPENDIX 1

Siphonaptera recorded from Tioman Mammals
(from data supplied by R. Traub, Department of Microbiology, University of Maryland School of Medicine.)

Stivalius robinsoni. This form was recorded from most of the rodents although the most frequent host was *Tupaia glis tionis.*

Host List: *Tupaia glis; Rattus* sp. *tiomanicus; R. sabanus; R. surifer; Lariscus insignis; Sundasciurus tenuis; Callosciurus notatus; C. nigrovittatus; Iomys horsfieldi;* and domestic cat (*F. domestica*).

Stivalius klossi. Only four specimens were taken from three host species, only single specimens being taken from each host animal.

Host List: *Tupaia glis; Rattus* sp. *tiomanicus;* and *R. surifer.*

Stivalius n.sp. near *S. robinsoni.* Two males were taken from a single specimen of *Lariscus insignis.*

Stivalius sp. Two single females which have not so far been identified to species were recorded from *Tupaia glis* and *Lariscus insignis.*

Ctenocephalus felis felis. Four specimens were taken from a single domestic cat.

Ctenocephalus felis orientis. A single specimen of this sub-species was taken from *Tupaia glis.*

APPENDIX 2

Notes on other Invertebrates recorded from Pulau Tioman

No special attention was paid to free-living invertebrates other than arthropods, but a number of forms were collected and, for the sake of completeness, I have included a few notes on these.

PLATYHELMINTHES: TURBELLARIA: TRICLADIDA:

BIPALIIDAE

Terrestrial planarians were frequently encountered on the forest floor and appeared to be much more abundant than in similar mainland habitats. The specimens collected are referable to two species of the genus *Bipalium, admarginatum* de Beauchamp and *simrothi* Loman, both of which were recorded by de Beauchamp (1933) from material collected on Pulau Tioman. De Beauchamp's locality of Sedagong" on the island is probably synonymous with our "Camp II". A third possible species with a greatly expanded head was also seen but the specimen collected were ruined by a fungal infestation.

ANNELIDA: HIRUDINEA:

HIRUDIDAE

Land Leeches of the genus *Hæmadipsa* were present throughout the forest and were particularly abundant in the vicinity of Camp V.

ANNELIDA: OLIGOCHÆTA:

Juvenile oligochætes were extracted from soil and litter samples and larger specimens were seen from time to time on the soil surface. None of these survived storage in a recognisable state.

MOLLUSCA: GASTROPODA:

A number of fresh-water and terrestrial gastropods were collected; these have been identified by Dr. A. J. Berry. They are summarised below together with a note of where they were found. Records marked (E.R.A.) refer to specimens collected by Mr. E. R. Alfred in 1958 and identified by Dr. W. S. S. van Benthem Jutting.

ACHATINIDÆ

Achatina fulica Bowdich — several specimens were recorded amongst the coconut plantations at Kg. Juara but were not recorded elsewhere on the island.

BUCCINIDÆ

Anentome sp. — several specimens were taken from rocks in a small stream at 1,000 ft. near Camp II.

CYCLOPHORIDÆ

Cyclophorus perdix-aquila (Sowerby) — specimens were found on the ground in primary forest (also E.R.A.).

Cyclophorus sp.(juveniles) — specimens were taken in both primary forest and regenerating vegetation.

Leptopoma sp. — a number of specimens were taken on the leaves of palms, etc., in primary forest.

HELICARIONIDÆ

Dyakia salangana (Martens) — specimens were taken on the ground in primary forest.
Dyakia ?kintana de Morg. — on land (E.R.A.).
Hemiplecta humphreysiana (Len.) — on land (E.R.A.).
Microparmarion malayanus Collinge — specimens were taken on foliage in primary forest.

?Microcystina sp. (juveniles) — three specimens were taken from litter samples extracted in the Tullgren funnels.

LITTORINIDÆ

Littorina scabra Linn. — a specimen was taken on leaves in the mangrove at Kg. Tekek.

NERITIDÆ

Neritina pulligera Linn. — taken from fresh-water streams from coastal plain to 1,000 ft. (E.R.A.).
N. zigzag Lam. — from brackish water on the coastal plain (E.R.A.).

THIARIDÆ

Melanoides riqueti (Grat.) — in freshwater (E.R.A.).
Thiara scabra (Mull.) — in freshwater (E.R.A.).

ZONITIDÆ

Trochomorpha sp. — a single specimen was taken in a cave, Gua Sinah, at *c.* 2,000 ft.

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