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# Report on a study of Some Freshwater Habitats in Rangoon with Special Reference to the Ecology of *Culex pipience fatigans*[1,2]

by

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(With 10 Text Figures)

## SYNOPSIS

Twenty-one freshwater habitats were investigated in Rangoon during February 1963 in relation to the ecology of *Culex pipiens fatigans* (Wiedemann). Ten of them were positive for this mosquito and eleven negative for it at the time of the study. The habitats represent a fair range of freshwater habitats in Rangoon and show a range of pollution conditions.

The fauna and flora show an over-all reduction with increase of pollution and amongst the fauna a high proportion of "Pan South-East Asian" species occur in polluted habitats. The bacterial flora was studied very cursorily and needs more detailed investigation.

In *fatigans* the tolerance for most natural organic and inorganic materials is high. Physial factors may influence densites. Oviposition sites may be of considerable importance for high densities of *fatigans*.

High densities of this insect are associated with decaying organic matter, unsuitability for other fauna and flora in general and the accompanying reduction of predatory animals, especially insects. The Notonectidae are perhaps the most important predators of *fatigans* and these penetrate into polluted waters too. In the most havily polluted habitats *Armigeres* might well prove a competitor and even a predator of *fatigans*.

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## INTRODUCTION

This report is based on a month's study in Rangoon with the World Health Organization's Filariasis Research Unit, on certain aspects of freshwater biology which I hope will be of some value as a contribution to the ecology of *fatigans* larvae.

The short time available to me was devoted to making preliminary studies of as many small larval habitats as possible covering the broad range of conditions under which *fatigans* was present or likey to be found at other times of the year. In addition, a few habitats outside the normal range of *fatigans* were studied for purposes of comparison.

The methods used were somewhat limited by the facilities available and the time at my disposal. They conform, however, to fairly standard techniques which of course were modified to suit the circumstances. Physical, chemical and biological data were gathered with a view to planning future work.

The larval habitat represents a concentration of individuals or potential adults and as such would seem an obvious point of attack in the control of mosquitoes. *C. pipiens fatigans* affords an extreme case where urbanization and pollution have concentrated the effective population in relatively restricted habitats. The habitats of *fatigans* have not, however, been studied sufficiently critically. Polluted habitats, the ones most productive of *fatigans*, are considered to pose a problem for elimination rather than to warrant detailed study in themselves. This is because small polluted habitats cannot be studied effectively by standard methods of freshwater biology. The analytical approach and the study of individual factors must in my opinion be secondary to the characterization of habitats as a whole based on physical, chemical and biological data. Polluted habitats of small size and undergoing rapid changes in a monsoonal climate as in Rangoon, pose special problems. Any study of the larval habitats of *fatigans* necessitates using the rather specialized techniques used in the study of pollution. It is on these lines that a fruitful programme of research is more likely to develop.

The conclusions which can be drawn from this short study are meagre. A basic knowledge of the flora and fauna will, I hope, be useful to future investigators in Rangoon. The description of habitats and the chemical data give an idea of methods suited for further work. The study of parasites and predators of larvae and other factors responsible for natural control of *fatigans* density will, of course, form the central theme for those interested in the control of the vector. The conditions under which *fatigans* reaches high densities needs detailed study. The biology of this insect studied under a wide range of conditions will form the basis of any rational means of control.

## FRESHWATER HABITATS IN RANGOON

There is no dearth of freshwater habitats in the Rangoon city area and the surrounding neighbourhoods (greater Rangoon). At the time this study was made the dry season had fairly set in. The smaller habitats, except those supplied with water from some artificial source had been eliminated or reduced to liquid mud. The exception mentioned is not uncommon especially in the newly built parts of the town, e.g. Okkalapa. The parts bordered by the Rangoon River and Pazuduang Creek (Figs. 1 and 2) are subject to tidal influence as is shown by the relatively high salinity and the presence of a brackish water fauna intermingled with freshwater forms. A typical mangrove flora including *Nipa* occurs along the margins of the river and creek. The city area and the parts immediately surrounding it are flat with very few undulations of the land. Ponds and small lakes are numerous, and streams flow in the shallow valleys. Many of the streams and ponds are polluted and heavily silted.

The range of freshwater habitats is typical of a relatively flat area in a tropical monsoonal climate. The proximity to built up areas and the poor sanitation make the proportion of polluted habitats relatively high.

The *fatigans* habitats which are all made or influenced by man have no doubt individual histories, but their perpetuation is often linked with the day-to-day habits of the people and the lack of effective measures for sanitation and drainage.

## METHODS

Twenty-one freshwater habitats covering a range in size and degree of pollution were chosen. Some were within the same water body but differed in degree of pollution or were isolated sufficiently to have different conditions. Also the water from a vessel used in the laboratory for raising larvae of *fatigans* was studied.

The chosen habitats were investigated as follows :

1. Physical characteristics
2. Chemical features
3. Flora and fauna.

*Physical characteristics*

Depth, type of bottom, marginal and surface vegetation and any other features which were considered at the time of study to be likely factors influencing the biology of the mosquito larvae, were recorded.

*Chemical features*

The dissolved oxygen was determined by the standard Winkler technique. For highly polluted water this method is not reliable due to interference by organic matter and certain inorganic ions. The biological oxygen demand (B.O.D.) and oxygen consumed from permanganate (Tidy value) were determined. In the former case samples were incubated at room temperature (27-30°C) for 24 hours at dilutions of 1/10-1/100 and in the latter they were boiled for 20-30 minutes with permanganate, the iodine liberated by the residual permanganate being titrated with thiosulfate. Albumunoid and free ammonia were determined by comparator. A few samples were treated by standard Kjeldahl techniques as a check. Chloride was titrated (after dilution if necessary) with silver nitrate. Nitrates were estimated roughly using L. napthylamine and sulfanalic acid in 1/10 dilution. pH was measured using a Lovibond comparator.

*Flora and Fauna*

Some of the macrophytic vegetation was collected or, if common, noted. A pond net was used to collect the larger plants and animals and a plankton net to collect both microflora and microfauna. In case of very shallow or highly polluted habitats a sample of water was taken back to the laboratory in a large container and centifuged for examination under the microscope.

## HABITATS—GENERAL

As already mentioned, 21 habitats were investigated. Ten of them had *fatigans* and 11 had no *fatigans* during the period of sampling. The choice of habitats was based on two main considerations :

(*a*) the presence of a high density of *fatigans* in the vicinity of such habitats ;
(*b*) habitats which were typical and provided a range of size and pollution.

A larval survey had already been carried out in some areas of Rangoon by Dr. P. Mattingly before I arrived. I was thus able to utilize his observations and examine a fairly representative series. The short time available did not warrant a very critical re-examination of the whole area before deciding on what habitats to select for investigation.

The locations of habitats studied are shown in Figs. 1 and 2.

*Classification of habitats*

The classification of small freshwater habitats can be based on various criteria. For the purpose of this study the emphasis has been on the degree of pollution.

The habitats in the area which are likely breeding sites can be classified as follows :

1. *Catch pits and septic tanks*

These are of varying construction. There are open and closed types in the case of catch pits and they may be relatively dry or carry water, the latter being the type posing a mosquito hazard. Many catch pits do not have a marked offensive odour and are thus both dealing efficiently with the faecal matter and providing food for larvae. The septic tanks are of standard construction.

2. *Stagnant drains*

A feature of many parts not served by an underground sewerage system is stagnant, polluted drains. Faecal pollution is not uncommon but on a relatively small scale usually. Organic decomposition is not as rapid as in the more efficient catch pits but nutritive materials directly available to larvae may be constantly supplied. Sometimes these drains are bunded for irrigation. The bund is removed periodically and the drains may be practically dry after this for a short period.

3. *Slow-flowing drains and streams*

Natural streams polluted with household waste and faecal matter and drains in various stages of disrepair. They differ little from (2) except that the area suitable for breeding is small in comparison to the total area.

4. *Isolated parts of streams and ponds*

Streams and ponds which are polluted only in parts isolated from the main body of water.

5. *Ponds with little or no pollution*

Some of these are typical freshwater habitats. Others receive wastes of various kinds but cannot be considered polluted.

## HABITATS INVESTIGATED

A. Waybagi Road, between Kemadine Road and Medawi Road, North Okkalapa.

Stagnant stream about 1 m wide and 0·3 m deep. Edges free of aquatic vegetation. Grasses at the edge project into water. Bank about 15-30 cm from water level. Bottom muddy. Water cloudy, with a thin scum on the surface. Samples of water were taken near a temporary bund (Fig. 3) of mud which is breached every week or so to let the water out and replaced to collect "fresh" water draining into the stream from standpipes along he stream.

B and C. Waybagi-Kemadine Road Junction, North Okkalapa.

Pond 20 × 30 m. Maximum depth 0·5 m. Borders the back of a house, the edge nearer the house having a growth of *Ipomoea aquatica* which encroaches into the water (2–3 m in some places). The water is greenish with much suspended particulate matter. Bottom muddy and uneven. This pond is probably the remains of a far more extensive body of water. The edge bordering the house receives household and faecal overflow from the kitchen and latrine respectively. There is a certain amount of mixing in the polluting material but the two fractions enter the pond in two fairly discrete parts. B is the part where the kitchen waste enters the pond and C about 1 m from where the faces reach the pond. The actual spot where the polluting materials enter is too soggy and shallow for water sampling. (Fig. 4).

D. East Corner of Waybagi-Kemadine Road, North Okkalapa.

Catch pit limited by wicker lining (Fig. 5). The pit is open but overgrown with creepers which provide a measure of shade.

E. East Corner of Hkayama-Waybagi Road, North Okkalapa.

Catch pit limited by wicker lining and covered by wicker shade. The water in the catch pits was brownish with abundant suspended materials. The odour whilst strong was not as offensive as might be expected. The bacterial inoculum seems very efficient.

F. U. Chit Maung Street.

Drain in front of house. 1·5 m wide and about 0·25 m deep (Fig. 6), interrupted by wooden bridge. Bottom muddy and water with considerable particulate material in suspension. Polluted by household waste and refuse which accumulates on the bottom and also floats at the surface.

G, H and I. Inya Avenue, stream.

G. Shallow pools, overgrown with vegetation and containing decaying leaves. Maximum depth of water 10 cm. Water blackish in colour.


*Fig. 1.* *Rangoon City and Greater Rangoon showing location of habitats investigated.*

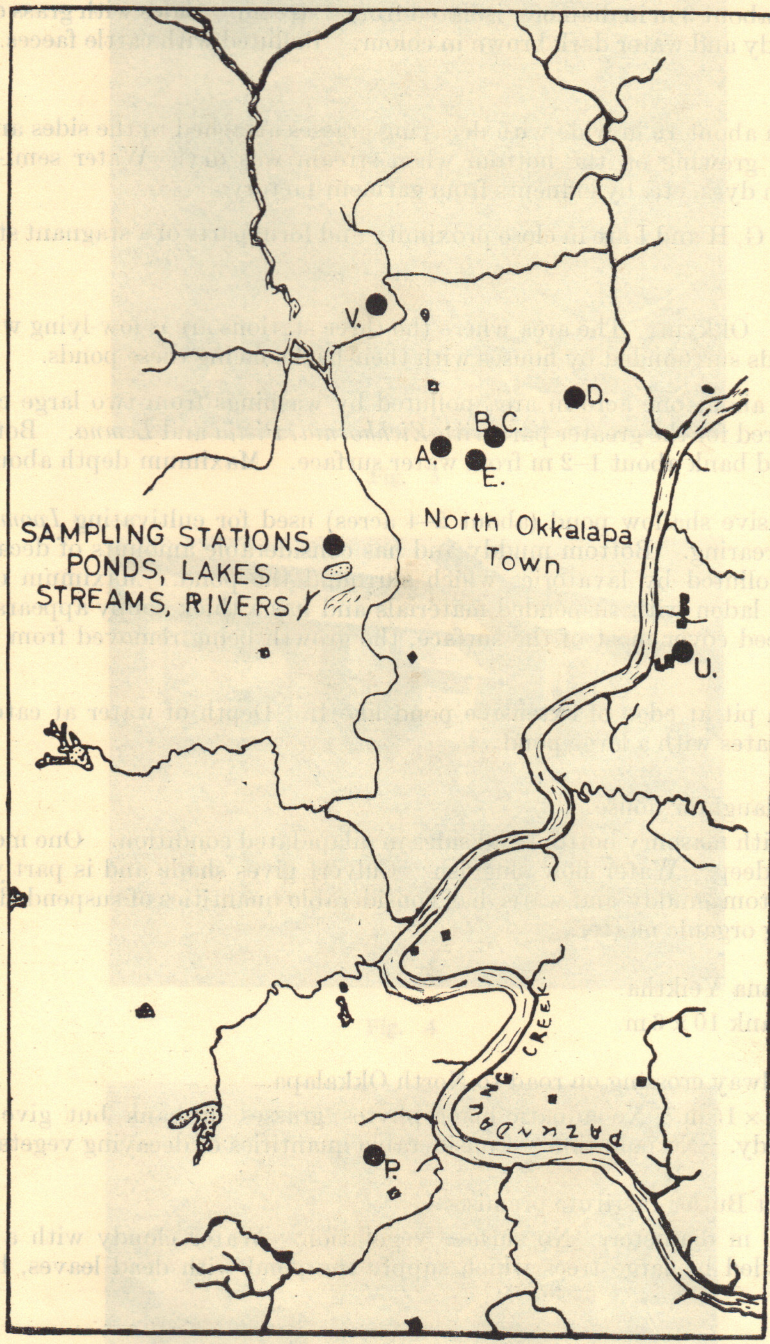


Fig. 2. Rangoon North Okkalapa area showing location of habitats investigated.

H. Pond about 3 m in diameter isolated from a stream. Sides with grass overhanging. Bottom muddy and water dark brown in colour. Polluted with cattle faeces. Rich algal growth.

I. Stream about 10 m wide with decaying grasses attached to the sides and fallen into the water or growing on the bottom when stream was dry. Water semi-transparent. Polluted with dyes, etc. by effluents from garment factory.

Stations G, H and I are in close proximity and form parts of a stagnant stream behind a cowshed.

K, L and M. Okkyin. The area where the three stations are is low-lying with extensive polluted ponds surrounded by houses with their backs facing these ponds.

K. Pond about one acre in area polluted by washings from two large chicken pens. Surface covered for the greater part with *Eichhornia*, *Pistia* and *Lemna*. Bottom muddy, sides bare and bank about 1–2 m from water surface. Maximum depth about 1–2m.

L. Extensive shallow pond (about 2–4 acres) used for cultivating *Ipomoea aquatica*, and for fish rearing. Bottom muddy and has considerable amounts of decaying organic material. Polluted by lavatories which surround the pond. Maximum depth 0·5 m. The water is laden with suspended materials and has a thick soupy appearance. *Pistia* and pond weed cover most of the surface, the growth being removed from time to time (Fig. 8).

M. Catch pit at edge of extensive pond like L. Depth of water at catch pit 0·2 m. It communicates with a large pond.

N. Cattle slaughter-house.

Drain with masonry bottom and sides in dilapidated condition. One meter wide and about 0·2m deep. Water flow sluggish. Culvert gives shade and is partly blocked by debris. Bottom muddy and water has considerable quantities of suspended material, oil and decaying organic matter.

O. Tha Thana Yeiktha.

Septic tank 10 × 6 m.

P. Near railway crossing on road to North Okkalapa.

Pond 50 × 15 m. No aquatic macrophytes, grasses on bank but give little shade. Bottom muddy. No pollution. Considerable quantities of decaying vegetation present.

Q. Harcourt Butler Institute premises.

Pond 30 m diameter. No surface vegetation. Water cloudy with a dirty brown colour. Shaded by large trees which supply the pond with dead leaves, broken twigs, seeds, etc.

R. Zoological Gardens.

Stream 10 m wide and 0·25–0·5 m deep. Bottom muddy and sides overgrown with grasses. Edges very shallow and contain masses of blue green algae. Some *Eichhornia* is found at the sides. Slow flowing.

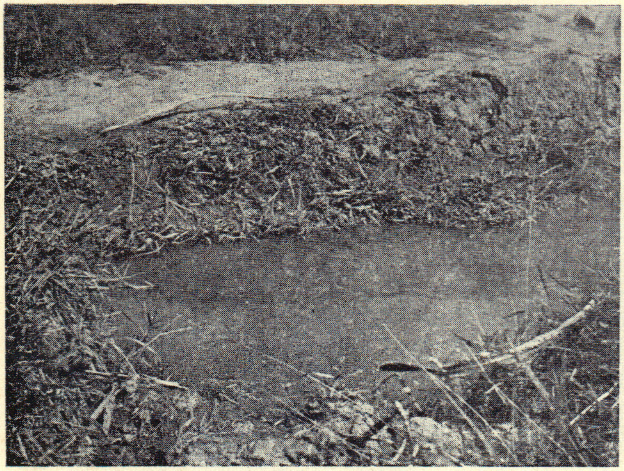

Fig. 3

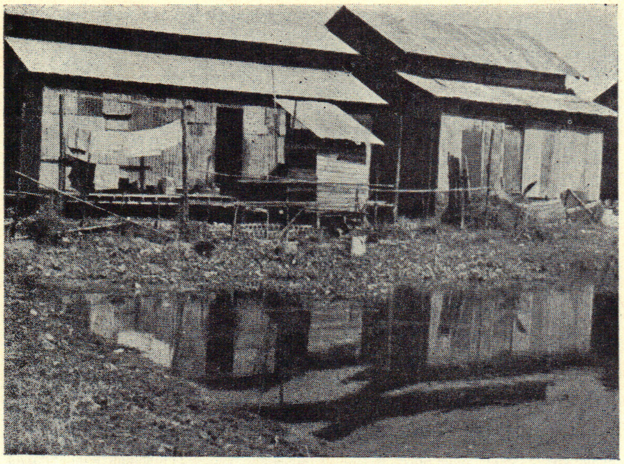

Fig. 4

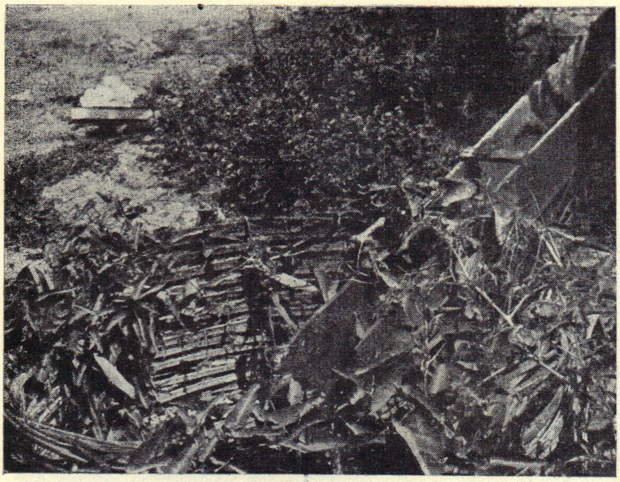

Fig. 6

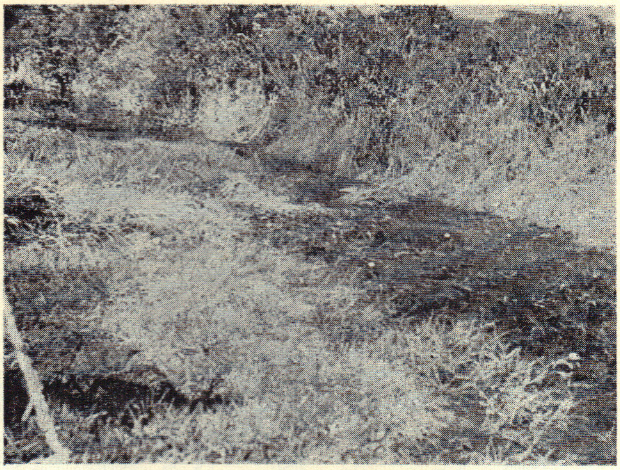

Fig. 7

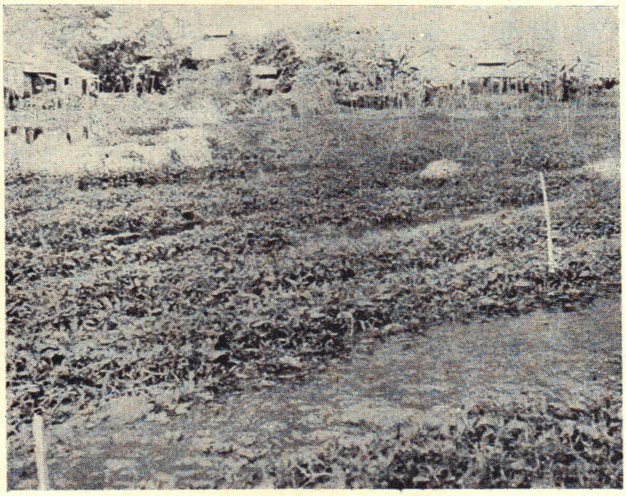

Fig. 8

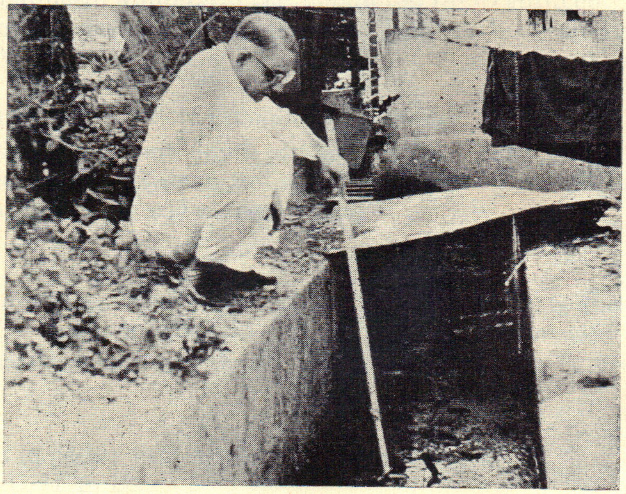

Fig. 9

Fig. 10

S. Dalhousie Street-Duffrein Street corner.

Masonry drain one metre wide and at the maximum 10–15 cm deep. Bottom contains a rich supply of miscellaneous debris. Polluted by latrines, household refuse and wastes, including oil (Fig. 9).

T. Morton Street, near gate of Port Commission entrance.

Drain 0·5 m wide. Maximum depth of about 10 cm. Throughout most of its course it is blocked by miscellaneous refuse including waste paper, coconut husks, waste food and other refuse from grocery shops and eating houses.

U. Dawegung.

Pond about 50 m square, bunded on sides. The water level is about 1·5 m from the surface of the bund. Edges invaded by grasses and surface covered for most part by *Nelumbium*. Estimated maximum depth 2–3 m. The water is used for household purposes.

V. North Okkalapa in paddy field across Pazunduang Creek.
Pond similar to U. (Fig. 10).

W. Water used for raising *fatigans* in the laboratory.

## FAUNA AND FLORA

*Mosquitos*

The larvae from each habitat were identified by Dr. P. Mattingly. A list of species their occurrence and density are given in Table 1.

Of 21 "natural" habitats examined 10 had *fatigans* and 11 no *fatigans*. The habitats of *fatigans* are in general agreement with those mentioned by previous workers; Reid (1956), Colless (1957) and Macdonald (1958)—Malaya: Chow & Thevasagagam (1957)—Ceylon. *C. fatigans* also occurs in water storage containers and small habitats which are unpolluted, but at very low density.

The other species recorded included *C. tritaeniorhynchus*, usually found in unpolluted habitats. It did occur, however, in polluted habitats too (B and H). *C. gelidus* was found in a small pond with much decaying vegetation (H) and in a catch pit (M). This species occurs fairly commonly in typical *fatigans* habitats. *C. gelidus*, *C. tritaeniorhynchus* and *C. fuscocephalus* were found together in one habitat.

In only one habitat was *Pistia* abundant (L). Two species of *Mansonia* were found in this. The anophelines were recorded only in unpolluted, typical freshwater habitats whilst *C. bitaeniorhynchus* and *Ficalbia chamberlaini* were present in a pond choked with floating vegetation

*Other fauna and flora*

The fauna and flora recorded are given in Tables 2–3. The lists are by no means comprehensive but give an indication of the faunal and floral composition. The unpolluted habitats have species characteristic of typical freshwater habitats (U and V).

TABLE 1

| | | |
|---|---|---|
| + | Rare | (low density) |
| ++ | Common | (medium density) |
| +++ | Abundant | (high density) |

| *Habitat* | *Species* | *Density* |
|---|---|---|
| A | *C. tritaeniorhynchus* S.1. | + |
| B | *C. tritaeniorhynchus* S.1. | + |
| | *C. fuscocephalus* | + |
| C | *C. tritaeniorhynchus* S.1. | + |
| | *C. p. fatigans* | +++ |
| | *Armigeres subalbatus* | ++ |
| E | *C. p. fatigans* | + |
| | *Armigeres subalbatus* | +++ |
| F | *C. p. fatigans* | +++ |
| G | *C. p. fatigans* | ++ |
| H | *C. tritaeniorhynchus* S.1. | + |
| I | *C. tritaeniorhynchus S.*1, | + |
| | *C. gelidus* | + |
| | *C. fuscocephalchus* S.1. | + |
| K | *C. bitaeniorhynchus* | + |
| | *Ficalbia chamberlaini* | + |
| L | *Mansonia annulifera* | + |
| | *M. indiana* | + |
| M | *C. p. fatigans* | +++ |
| | *C. gelidus* | + |
| N | *C. p. fatigans* | + |
| O | *Armigeres subalbatus* | +++ |
| P | *Anopheles annularis* | + |
| | *A. barbirostris* | + |
| | *A. vagus* | + |
| | *C. fuscocephalus* | + |
| Q | *C. tritaeniorhynchus* S.1. | + |
| R | *C. p. fatigans* | +++ |
| S | *C. p. fatigans* | +++ |
| T | *C. p. fatigans* | +++ |
| U | *C. tritaeniorhynchus* S.1. | + |
| V | *Anopheles barbirostris* | + |
| | *A. hyrcanus grp.* | + |
| | *A. annularis* | + |

TABLE 2

*Flora of Habitats*

| SPECIES \ HABITATS | | A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aphanocapsa pulchra* Kutz Rbh. | .. | | | | | | | | | | | | | | | | | | | | | * |
| *Merismopedia minima* G. Beck | .. | | | | * | | | | | | | | | | | | | | | | | |
| *M. tenuissima* Lemm. | .. | | | | | | | | | | * | | | | | | | | | | | |
| *Anabaena* c.fr. *variabilis* Kutz. | .. | | | | | | | | | | | | | | | | | | | | | |
| *Anabaena* sp. | .. | | | | | | | | | | | | | | | | | | | | * | |
| *Spirulina major* Kutz. | .. | | * | | | | | | | | | | | | | | | | | | | |
| *Sp. gigantea* Schmudle | .. | | | | | | | | | | | | | | | | | | | | * | |
| *Sp. subtissima* Kutz. | .. | | * | | | | | | | | | | | | | | | | | | | |
| *Oscillatoria proteus* Skuja | .. | * | | | | | | | | | | * | | | | | | | | | | |
| *Os. ornata* Kutz. var. *crassa* Rao. | .. | * | * | * | | | | | | | | | | | | | | | | | | |
| *Os. tenuis* Ag. | .. | | * | | | | | | | | | | | | | | | | | | * | |
| *Os. okeni* Ag. | .. | | * | | | | | | | * | | * | | | | | | | | | * | |
| *Os. geminata* Uenegh. | .. | | * | | | | | | | | | | | | | | | | | | | |
| *Os. toreauii* Fremy | .. | | * | | | | | | | | | | | | | | | | | | | |
| *Os. fanus* Skuja | .. | | * | | | | | | | | | | | | | | | | | | | |
| *Os. amphibia* Ag. | .. | | | | * | | | | | | | | | | | | | | | | | |
| *Os. animalis* Ag. | .. | | | | | | | | * | | | | | | | | | | | | | |
| *Os. chalybea* (Mert.) Gom. | .. | | | | | | | | * | | | | | | | | | | | | | |
| *Os. subtissima* Kutz. | .. | | | | | | | | * | | | | | | | | | | | | | |
| *Os. angustissima* W. et. G. West | .. | | | | | | | | | | | | * | | | | | | | | | |

TABLE 2—(*Contd.*)

*Flora of Habitats*

| SPECIES | HABITATS A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pinnularia mescolopta* (Er.) W. Sym. .. | | | | | | | | | | | * | | | | | | | | | | |
| *P. interrupta* W. Sym. var *minor*? B. Peters .. | | | | | | | | | | | * | | | | | | | | | | |
| *P. microstomum* Er. .. | | | | | | | | | | | | | | | | | | | | * | |
| *Pinnularia* sp. .. | | | | | | | | | | | * | | | | | | | | | | |
| *Gomphonema parvulum* (Kutz.) Grun. .. | | | | | | | | | | * | * | | | | | | | | | | |
| *G. olivaceum* (Lyngb). Kutz. .. | | | | | | | | | | * | | | | | | | | | | | |
| *Rhophalodia gibba* (Er.) O. Mull. .. | | | | | | | | | | | | | | | | | | | | | * |
| *Fragillaria construens* (Er.) Grun. .. | | | | | | | | | | * | * | | | | | | | | | | |
| *Nitzschia subtilis* Grun. .. | | * | | | | | | | | | | | | | | | | | | | |
| *N. hantzschiana* Rbh. .. | | * | | * | * | | | | | | | | | | | | | | | | |
| *N. dissipata* (Kutz). Grun. .. | | | | * | | | | | | | | | | | | | | | | | |
| *N. palea* (Kutz.) W. Sym. .. | | | | * | * | | | | | * | | | | | | | | | | | |
| *N. linearis* W. Sym. .. | | | | * | | | | | | | | | | | | | | | | | |
| *N. thermalis* Kutz. .. | | | | | * | | | | | | | | | | | | | | | | |
| *N. frustulum* Kutz. Grun. var *asiatica* Skuja .. | | | | | * | | | | | | | | | | | | | | | | |
| *N. sublinearis* Hust .. | | | | | | | | | | * | * | | | | | | | | | | |
| *N. gracilis* Hantzsch. .. | | | | | | | | | | * | | * | | | | | | | | | |
| *N. obtusa* W. Sym. var *scalpelliformis* Grun. .. | | | | | | | | | | | * | | | | | | | | | | |
| *N. closterium* (Er.) W. Sym. .. | | | | | | | | | | | | | | | * | | | | | | |

TABLE 2—(*Contd.*)

*Flora of Habitats*

| SPECIES | HABITATS A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *N. longissima* (Breib) *Palfs.* var *reversa* W. Sym. | | | | | | | | | | | | | | | * | | | | | | * |
| *Nitzschia* sp. .. | | | | | | | | | * | | | | | | | | | | | | * |
| *Ipomoea aquatica* Forsk. .. | | * | * | | | | | | | * | * | | | | | | | | | | |
| *Eichhornia crassipes* (Mart.) .. | | | | | | | | | | * | | | | | | | | | | | |
| *Lemna* .. | | * | * | | | | | | | * | * | | | | | | | | | | |
| *Pistia stratiotes* L. .. | | | | | | | | | | * | * | | | | | | | | | | |
| Submerged grasses | | | | | | | | | | * | | | | | | | | | | * | * |

TABLE 3

*Flora of Habitats*

| SPECIES | | HABITATS A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PROTOZOA** | | | | | | | | | | | | | | | | | | | | | | |
| *Actinophrys* sp. | .. | | | | | | | | | | | | | * | | | | | | | | |
| *Paramaecium* sp. | .. | | | | | | | | | | | | | * | | | | | * | | | |
| *Stylonychia* sp. | .. | * | | | | | | | | | | | | | | | | | | | | |
| *Vorticella* sp. | .. | | | | | | | | | | | | | | | | | | | | * | * |
| *Epistylis* sp. | .. | | * | | | * | | | * | | | | | | | | | | | | * | |
| Unidentified ciliates | .. | * | | | | * | | * | | | * | * | * | * | | * | | * | * | * | * | * |
| *Astasia* sp. | .. | | | | | | | | * | | | | | | | | | | | | | |
| *Astasia dangeardii* Lemm. | .. | | | | | | | | | | | | | | | * | | | | | | |
| *Ceratium furcoides* (Lev.) | .. | | | | | | | | | | | | | | | | | | | | | * |
| *Euglena polymorpha* Dang. | .. | | | | | * | | | | | | | | | | | | | | | | |
| *E. pisciformis* Klebs | .. | | | | | | | | * | | | * | | | | | | | | | | |
| *E. granulata* Dang. | .. | | | | | | | | | | | * | | | | * | | | | | | |
| *E. variabilis* Dang. | .. | | | | | | | | | | | | | | | | * | * | | | | |
| *E. acus* var *rigida* Hubner | .. | | | | | | | | | | | | | | | * | | | | | * | |
| *Peridinium gutunense* Nyg. | .. | | | | | | | | | | | | | | | | | | | | * | |
| *Phacus puscillus* Lemm. | .. | | | | | | | | | | * | | | | | | | | | | | |
| *Trachelomonas volvocina* Er. | .. | | | | | | | | | | | | | | | | * | | | | * | * |
| *T. oblonga* Lemm. var a Henuata Playf. | .. | | | | | | | | | | | | | | | * | | | | | | |
| *T. armata* (Er.) Stein var *coronata* Delft | .. | | | | | | | | | | | | | | | * | | | | | | |
| *T. stokesiana* Palmer var *dangiardii* (Delft) | .. | | | | | | | | | | | | | | | * | | | | | | |

TABLE 3—(*contd.*)

*Flora of Habitats*

| HABITATS<br>SPECIES | A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RHABDOCOELES .. | | | | | | | | | | | * | | | | | | | | | | |
| ROTIFERA .. | | * | | | | | | | | * | * | | | | | | | | | * | * |
| ANNELIDA .. | | | | | | | | | | | | | | | | | | | | | |
| *Limnodrilus hoffmeisteri* Clap. .. | * | * | * | | | | | | | * | * | | | | | * | | | | | |
| *Placobdella* sp. .. | | | | | | | | | | * | | | | | | | | | | | |
| *Glossiphonia heteroclita* L. .. | | | | | | | | | | * | | | | | | | | | | | |
| *Hemiclepsis marginata* Mull. .. | | | | | | | | | | | | | | | | * | | | | | |
| NEMATODA .. | | | | | | | | | | | | | | | | | | | | | |
| *Dorylaimus* sp. .. | * | | * | * | | | | | | | | | | | | | | | | | |
| *Mononchus* sp. .. | * | | * | | | | | | | | | | | | | | | | | | |
| CRUSTACEA .. | | | | | | | | | | | | | | | | | | | | | |
| *Ceriodaphnia rigaudi* Richard .. | | | | | | | | | | | | | | | | * | | | | * | * |
| *Moina* sp. .. | | | | | | | | | | | | | | | | * | | | | | * |
| *Scapholeberis mucronata* (Muller) .. | | | | | | | | | | | | | | | | * | | | | | |
| Other Cladocera .. | | * | * | | | | | | | * | | | | | * | * | | | | * | * |
| Ostracoda .. | * | * | * | | | | | | | * | * | | | | * | | | | | * | * |
| *Cyclestheria hislopi* (Baird) .. | | | | | | | | | | | | | | | | * | | | | | |
| *Mesocyclops hyalinus* (Rebh.). .. | | | | | | | | | | * | * | | | | * | * | | | | * | * |
| *Neodiaptomus meggitti* (Kief.). .. | | | | | | | | | | | | | | | * | * | | | | * | * |

TABLE 3—(*contd.*)

*Flora of Habitats*

| HABITATS<br>SPECIES | A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Caridina propinqua* de Man .. | | | | | | | | | | * | | | | | | | | | | | |
| *C. thambipillai* ? Johnson .. | | | | | | | | | | | * | | | | | | | | | | * |
| *C. bengalensis* ? de Man .. | | | | | | | | | | | | | | | | | | | | | * |
| *Macrobrachium lamarrei* H. M. Edw. .. | | | | | | | | | | | | | | | | | | | | * | |
| *M. lanchesteri* de Man .. | | | | | | | | | | | | | | | | | | | | | * |
| *Metapenaeus lysianassa* Young .. | | | | | | | | | | | | | | | * | | | | | | |
| *Varuna litterata* F. .. | * | | | | | | | | | | | | | | | | | | | | |
| Collembola (*Onychiurus* sp.) .. | | | | | | | * | | | | | | | | | | | | | | |
| ODONATA .. | | | | | | | | | | | | | | | | | | | | | |
| *Crocothemis servilia* Dr. .. | | * | | | | | | | | * | | | | | | * | | | | | * |
| *Ceriagrion* sp. .. | | | | | | | | | | * | | | | | | | | | | | |
| *Ischnura* sp. .. | | | | | | | | | | * | | | | | | | | | | | |
| *Agriocnemis* sp. .. | | | | | | | | * | * | * | | | | | | | | | | | |
| Coenagrionidae .. | | | | | | | | | | | | | | | * | | | | | | |
| EPHEMEROPTERA | | | | | | | | | | | | | | | | | | | | | |
| *Cloeon* sp. .. | * | * | * | | | | | | | | | | | | | | | | | | |
| *Caenis* sp. .. | | | | | | | | | | * | | | | | | | | | | | |
| HEMIPTERA .. | | | | | | | | | | | | | | | | | | | | | |
| *Microvelia* sp. .. | | * | | | | | | * | * | * | * | | | | | | | | | * | * |
| *Mesovelia orientalis* Kirk. .. | | | | | | | | | | | * | | | | * | | | | | * | * |
| *Hydrometra* sp. *greeni* ? Kirk. .. | | | | | | | | * | * | * | * | | | | | | | | | | * |
| *Ranatra filiformis* F. .. | | | | | | | | | | | | | | | * | | | | | * | * |

TABLE 3—(*contd.*)

*Flora of Habitats*

| SPECIES \ HABITATS | A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sphaerodema rusticum* (F.) .. | | | | | | | | | * | * | * | | | | | | | | | | * |
| *Micronecta scutellaris* (Stal.) .. | * | | * | | | | | | | | | | | | | | | | | | |
| *M. ludibunda* Bredd. .. | * | | * | | | | | | | * | * | | | | | | | | | | |
| *M. quadristrigata* Bredd. .. | * | | * | | | | | | | * | | | | | * | | | | | | * |
| *Tropocorixa connexa* (Lundb.) .. | * | | * | | | | | | | | | | | | | | | | | | |
| *Agraptocorixa hyalinipennis* (F.) .. | | | * | | | | | | | | | | | | | | | | | | |
| *Anisops bouvieri* Kirk .. | * | | | | | | | | | | | | | | | | | | | | |
| *A. breddini* Kirk. .. | * | | * | | | | | | | * | | | | | * | * | | | | * | * |
| *Enithares mandalayensis Dist.* .. | | * | | | | | | | * | | | | | | | * | | | | | * |
| *Limnogonus nitidus* Mayr .. | | | | | | | | | | | | | | | | * | | | | | |
| *Plea liturata* Kirk. .. | | | | | | | | | | * | | | | | | | | | | | |
| *P. frontalis Fieb.* .. | | | | | | | | * | * | | | | | | | | | | | * | |
| MOLLUSCA .. | | | | | | | | | | | | | | | | | | | | | |
| *Indoplanorbis exustus* (Desh) .. | | * | | | | | | | | * | * | | | | | | | | | * | * |
| *Melanoides tuberculata* (Mull.) .. | | | | | | | | | | | | | | | * | | | | | | * |
| *Pila ampullacea* (L.) .. | | | | | | | | | | | | | | | | * | | | | | |
| *Bellamya bengalensis* (Lam.) .. | | | | | | | | | | | | | | | | * | | | | | |
| *Lymnaea luteola Lam.* .. | | | | | | | | | | * | | | | | | * | | | | | |
| *Helicorbis caenosus* ? Bins. .. | | | | | | | | | | | * | | | | | | | | | | |

TABLE 3—(*contd.*)

*Flora of Habitats*

| SPECIES | HABITATS A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLEOPTERA | | | | | | | | | | | | | | | | | | | | | |
| *Enochrus esuriens* Walk. .. | | | | | | | | * | | | * | | | | | * | | | | * | * |
| *Berosus indicus* Motsch. .. | | | | | * | | | * | * | | | | | | | | | | | * | * |
| *Berosus* sp. .. | | | | | * | | | | | | | | | | | * | | | | * | |
| *Helochares anchoralis* Sharp .. | | | | | | | | | | | | | | | | | | | | * | * |
| *H. abnormalis* Sharp .. | | | | | | | | | | | | | | | | | | | | * | * |
| *Amphiops pedestris* Sharp .. | | | | | | | | | | | | | | | * | | | | | | |
| *Amphiops* sp. .. | | | | | | | | | | | | | | | | * | | | | * | * |
| *Regimbartia attenuata* F. .. | | | | | | | * | * | | | | | | | | | | | | | |
| *Sternolophus rufipes* F. .. | | | | | | | | * | * | | | | | | | | | | | | * |
| *Canthydrus flammulatus* Sharp .. | | * | * | | | | | * | * | * | * | | | | | * | | | | * | |
| *C. ritsemae* Reg. .. | | | * | | | | | | * | | | | | | | * | | | | * | |
| *C. flavus* Mots. .. | | * | | | | | | | | | | | | | | | | | | * | |
| *Hydrovatus pumilus* Sharp .. | | | | | | | | | | | | | | | | | | | | * | * |
| *Guigotus* sp. .. | | | | | | | | | | | * | | | | | | | | | | |
| *Laccophilus chinensis* Walk. .. | | | | | | | | * | * | * | | | | | | * | | | | * | * |
| *Laccophilus* sp. .. | | | | | | | | | | | | | | | | | | | | * | |
| *Peltodytes* sp. .. | | | | | | | | | | | | | | | | | | | | * | |
| *Dineutes indicus* Aube .. | | | | | | | | | | | | | | | | | | | | * | |
| DIPTERA | | | | | | | | | | | | | | | | | | | | | |
| Stratiomyid .. | | | | | | | | | | * | | | | | | | | | | | |
| *Chironomus* sp. A .. | * | * | | | | | | | | | * | | | | | | | | | | |

TABLE 3—(*contd.*)

*Fauna of Habitats*

| SPECIES \ HABITATS | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chironomus* sp. B .. | | * | | | | | | | | | | | | | | | | | | | | |
| *Tanypus* sp. .. | | * | | | | | | | | | | | | | | | | | | | | |
| *Telmatoscopus albipunctatus* Say* | | | * | * | | | | | | | | | | | | | | | | | | |
| Hydracarina .. | | | | | | | | | | | | | | | | * | | | | | | |
| PISCES | | | | | | | | | | | | | | | | | | | | | | |
| *Panchax panchax* (Day) .. | | | | | | | | | | * | * | | | | | | | | | | | |
| *Anabas testudineus* (Bloch) .. | * | | | | | | | | | * | * | | | | * | | | | | | | |
| *Esomus danrica* (Val.) .. | | | | | | | | | | | | | | | * | | | | | | | |

With increasing pollution (A and Q), the fauna becomes restricted. In habitats A and P there are brackish (saline water) species in *Metapenaeus* and *Varuna*. These two habitats are in an area with some tidal influence.

The fauna of the polluted habitats besides being restricted in species contains a high proportion of "Pan South-East Asian" species. Leaving aside such groups as the Protozoa, Rotifera, cyclopoid copepods and Cladocera which have a fair number of cosmopolitan species and the Oligochaeta represented by a single species (*Limnodrilus hoffmeisteri* Clap.) typical of polluted waters all over the world, three leeches were found, two of which are widely distributed in South-East Asia. Of the Mollusca, *Indoplanorbis exustus*, *Melanoides tuberculata*, *Pila ampullacea* and *Lymnaea luteola* are the most widely distributed species of their respective genera. There were no crustacea other than the saline water forms which occurred in slightly polluted habitats. The Hemiptera and Coleoptera recorded are almost without exception widely distributed in South-East Asia and constitute the most numerous element of mildly polluted habitats. They are absent at the extremes of pollution. The Chironomidae occur as expected in relatively highly polluted places. A psychodid was found in catch pits.

Of the fishes found, one is a surface form (*Panchax panchax*), another an air breather (*Anabas testudineus*) and the third a cyprinid (*Esomus danrica*). All three are very widely distributed in South-East Asia.

All the species found in the small polluted habitats have a wide tolerance of external conditions and an ability to disperse in the case of the Hemiptera and Coleoptera (Fernando 1963B). Many are detritus feeders—Corixidae, Chironomidae, Mollusca and Oligochaeta —or predators, e.g. the Notonectidae.

The flora shows a predominance of blue-green algae which is a common feature of polluted habitats. Higher plants are represented by surface forms—*Lemna*, *Pistia* and those cultivated for human or animal food, namely, *Eichhornia* and *Ipomoea aquatica*.

A very cursory study was made of the bacteria in a few of the habitats. A classification is given in Table 4. The habitats can be characterized by their bacterial flora. The bacteria play an important role in the productivity of polluted habitats and as such should be investigated more thoroughly. Unfortunately, facilities were not available for a more detailed study.

The faunal and floral composition are of prime importance in indicating what physical, chemical and biological conditions prevail, provided that there is prior knowledge of the range of the species recorded. If as in tropical Asia little is known of the biology of the species, their range within the freshwater habitats studied should at least be ascertained. It is of importance to know both the biology and the range of the species, especially in the case of predators of mosquito larvae.

If we concentrate our attention on the mosquito, two important questions arise—

(1) What constitutes the food of *fatigans* in habitats with a high larval density and what factors are responsible for the abundance of food ? (2) The extent to which *fatigans* density is dependent on predators, parasites and physical and chemical factors in the habitat.

The habitats of *fatigans* are often characterized by almost complete lack of fauna and flora (except bacteria). The physical factors seem somewhat variable and the chemical factors unfavourable for most animals. The absence of most groups of animals and plants in *fatigans* habitats shows that *fatigans* can survive outside the competitive area and the habitats which have an abundance of food thus have a high density of *fatigans* and very little else.

TABLE 4

*Bacterial flora of some "freshwater" habitats*
*(mainly a classification of types)*

| *Habitat* | *Bacterial flora* (*Classification*) |
|---|---|
| A & B | Unclassified. |
| C | Class II medium resistant to sunlight. |
| D | *B. neopolitanus.* Class II medium resistant to sunlight. |
| E | *B. schafferi.* Class I susceptible organisms associated with recent and undesirable pollution. |
| F | Class I susceptible organisms associated with recent and undesirable pollution Group I. |
| H | Unclassified. |
| I | Class III medium resistant to sunlight. Group 2 "B 67". |
| L | Class II medium resistant to sunlight. *B. neopolitanus.* Group 3. |
| M | Class I susceptible organisms associated with recent and undesirable pollution *B. schafferi.* Group I. |

## PREDATORS

Under natural conditions mosquito larvae are no doubt subject to varying degrees of predation. Many predators have been listed, but the extent to which they influence density has not been studied sufficiently accurately. Circumstantial evidence (e.g. lack of larvae in habitats with supposed predators) has often been cited. Larvae feature amongst the food of many fishes, some species of which have been introduced from country to country for larval destruction with varying results. There is an extensive literature on this subject.

Of the three species of fish recorded in Rangoon, all take mosquito larvae but none of them extends into very polluted habitats. Of the other predators the carnivorous Hemiptera are perhaps the most important. This subject has been reviewed by Hinman (1934) and Laird (1956). Fernando (1963B) attributed the lack of mosquito larvae in a habitat he studied for one year mainly to the Notonectidae present, and found no mosquitos in ponds with Notonectidae in Ceylon (Fernando and Leong 1963C). Hati & Gosh (1963)allege that a single *Sphaerodema annulatum* consumes 13,000 larvae during its lifetime ! More direct evidence of predation by *Anisops breddini* under field conditions has been provided by Zaman, Fernando & Chelappah (1962). In the habitats investigated in Rangoon, the presence of fish, predatory aquatic insects (Mesoveliidae, Veliidae, Gerridae, Notonectidae and Belostomatidae) was usually accompanied by the absence of larvae of very low larval densities. It must be stated, however, that these predators do not extend into highly polluted water. A likely explanation is that *fatigans* is restricted to the more highly polluted habitats (or household containers which these predators cannot reach) by their constant predation. The habitats of *fatigans* are usually open drains and ponds which are ideal for predation by notonectids living near the surface and feeding mainly at the surface. Moreover, the notonectids (*Anisops* and *Enithares*) can survive in polluted habitats (B), though not in catch pits (D and E) which they could have reached. *Sphaerodema* lives amongst vegetation and is probably of less importance under field conditions. The surface-living Hemiptera are perhaps of importance in the destruction of eggs, but few were found in typical *fatigans* habitats in Rangoon.

Of the other aquatic insects, the larger Dytiscidae are sometimes found in polluted habitats, e.g. *Hydaticus* and *Eretes*. They are known to be predacious. *Armigeres subalbatus* lives together with *fatigans* and sometimes apparently displaces it. It is perhaps both a competitor and predator of *fatigans*.

## PHYSICAL AND CHEMICAL FACTORS INFLUENCING THE DENSITY OF *FATIGANS*

*Culex p. fatigans* is known to breed in a wide range of habitats both as regards physical conditions (water storage containers, small polluted ponds and streams, stagnant drains, catch pits and septic tanks) and chemical conditions. The high densities of *fatigans* are almost invariably associated with pollution. Physical factors may influence density indirectly. Jobling (1936) found that dark places attract ovipositing females. In Rangoon it was noted that the females rest on objects close to the ovipositing site for a relatively long period (5–15 minutes ?). The wicker margins of catch pits, the cemented walls of septic tanks and any floating material in the water serve as resting sites for the females just prior to oviposition. The extent to which a particular type of resting site is selected and used by the females needs further study. The use of residual insecticides might be greatly facilitated if resting sites are a normal requirement of oviposition. The chemical factors determined in the habitats are given in Tables 5 and 6. If we compare the *fatigans* habitats with habitats with no *fatigans* certain obvious chemical differences are apparent. The dissolved oxygen is very low in *fatigans* habitats, in which the B.O.D. is generally higher. The Tidy value is variable in both types of habitat. The ammonia content (a good indicator of organic pollution) is characteristically high in *fatigans* habitats. Also, larval *fatigans* are able to survive in high salinities (over 1000 p.p.m. was recorded in a *fatigans* habitat in Rangoon—Table 5). In the laboratory they were successfully reared at a chloride concentration of 15 p.p.m. A high content of organic matter is generally favourable for *fatigans*. More critical studies on the various ions might be of some interest but from its wide range *fatigans* is probably not limited by the ordinary run of ions within the limits animals tolerate in fresh waters. The factors limiting distribution of freshwater animals have been critically reviewed by Macan (1961).

TABLE 6

*Some chemical features of habitats without* **Culex fatigans**

| Habitat \ Chemical Factors | Dissolved $O_2$ p.p.m. | B.O.D/24 hours at 28°C | Tidy value | Free ammonia | Albumunoid ammonia | Nitrite (qualitative) | Chloride p.p.m. | $H_2S$ (qualitative) | pH |
|---|---|---|---|---|---|---|---|---|---|
| A | 2.4 | 40 | 5 | 0.32 | — | — | 15 | — | 7.1 |
| B | 3.8 | 10 | 47 | 14 | — | + | 590 | — | 7.4 |
| H | 4.0 | 80 | 180 | 3 | 11 | — | 65 | — | 9.7 |
| I | — | 200 | 72 | 3 | 9 | — | 56 | — | 10.5 |
| K | 7.6 | 10 | 2 | — | — | — | 63 | — | 7.1 |
| L | 8.8 | 20 | 20 | 0.76 | — | — | 360 | — | 7.6 |
| O* | — | 120 | 86 | 360 | ? | — | 140 | — | 6.9 |
| P | 6.0 | 2.8 | 22 | 0.22 | — | — | 322 | — | 7.2 |
| Q | 0.2 | 4.8 | 81 | 2.2 | — | — | 70 | — | 6.6 |
| U | 8.8 | 1 | 2.4 | — | — | — | 60 | — | 6.6 |
| V | 8.0 | 0.2 | 6.8 | — | — | — | 80 | — | 7.4 |

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*Septic Tank.

## REFERENCES

Besides papers referred to in the text, this list contains selected titles on the taxonomy and biology of the fauna and flora found in Rangoon. Also, some general works on polluted fresh waters are included. Many taxonomic papers useful to the freshwater biologist in Burma are to be found in The Records of the Indian Museum and Archiv fur Hydrobiologie. The *Fauna of British India* is out of date in most cases, but may nevertheless still be found useful. The volume on Hirudinea is still serviceable, for example.


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## ERRATUM

Throughout the tables, the abbreviations "Er", "Kutz" and "Mull" should read "Ehr," "Kütz" and "Müll", respec ively.