Bull. Org. mond. Santé
Bull. Wld Hlth Org. } 1974, **51**, 133-143

# Entomological aspects of filariasis control in Sri Lanka

F. L. LAMBRECHT [1]

*Historical events and suitable environmental conditions in the southwestern coastal areas of Sri Lanka have led to the establishment of a zone of endemic filariasis caused by* Wuchereria bancrofti *and transmitted by* Culex pipiens fatigans. *The previous* Brugia malayi *foci, scattered over widely dispersed areas of the island, were apparently completely eliminated as a result of control of the* Mansonia *vectors by the destruction of the larval host plants in their swamp habitats. Control measures by the Anti-Filariasis Campaign against* W. bancrofti *and* C. p. fatigans *have greatly reduced the human infection rates in the endemic coastal belt and have kept the rate in the dense population to less than 1 % over the last several years. This paper assesses the entomological aspects of the control programme during the years 1970–72.*

Elephantiasis has been known in Sri Lanka for many centuries. Surveys during the late 1930s showed widespread, scattered foci of *Brugia malayi* in many parts of the island (Dassanayake, unpublished report, 1939). The transmission of this parasite was successfully controlled by the elimination of the *Mansonia* mosquito vectors during the 1947–52 campaign for the destruction of larval host plants in their swamp habitats. During those same years, however, the incidence of filariasis caused by *Wuchereria bancrofti* rose rapidly in the southwestern coastal areas where now the disease has become endemic and is transmitted by *Culex pipiens fatigans* mosquitos, which multiply under extremely favourable conditions. Control measures, based upon case finding and treatment, and mosquito control by the use of larvicides (e.g. fenthion) are carried out from several stations maintained by the government-financed Anti-Filariasis Campaign.

An analysis of current and earlier entomological data indicates that the present mosquito control measures are inadequate to prevent the circulation of the parasite. This is confirmed by the persistence of infections in the vector which, even if low, casts doubt on the finding (by the thick smear technique) of human infection rates of less than 1 %.

[1] Acting Project Leader, Arbovirus Vector Research Unit, P.O. Box 104, Enugu, Nigeria.

## GEOGRAPHY

Sri Lanka lies in the Indian Ocean between 5°55′ and 9°50′ north latitude, and between 79°42′ and 81°52′ east longitude. The island is located within the monsoon belt, where the predominant wind directions are from the southwest during May to September, and from the northeast during December to February, and where weather conditions are variable during the intermonsoon periods. Climate and topography divide the island into a " wet zone " in the southwest, and an " intermediate zone " and a " dry zone " in the rest of the island. This accounts for the distribution of different types of vegetation, ranging from wet tropical evergreen forests in the southwest to tropical dry savannah forests in the north, as well as forests in the central mountain range and various types of intermediate evergreen or deciduous vegetation in the rest of the island (Fig. 1).

The high rainfall in the southwest, in conjunction with other factors, has encouraged the settlement of people who now average over 386 per km$^2$ in the coastal areas. The climatic conditions and the dense human population, which is distributed in an almost unbroken string of coastal towns with often very poor sanitation, have created ideal conditions for the breeding of *C. p. fatigans* and the transmission of *W. bancrofti* all the year round.

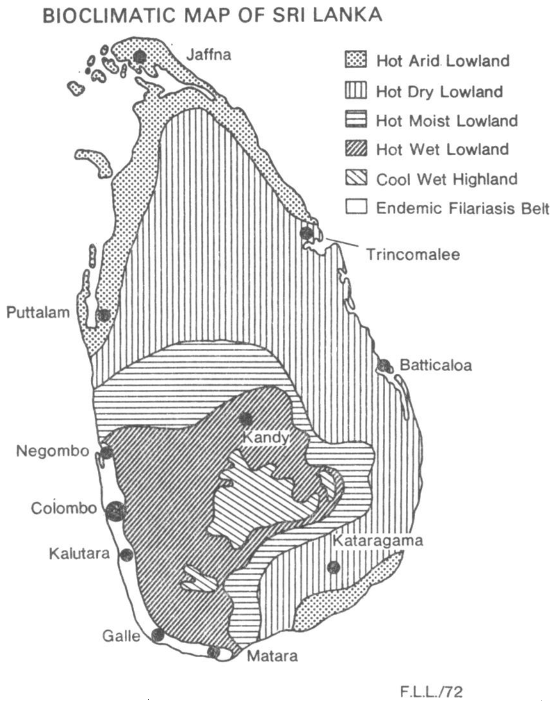


Fig. 1. Map showing major bio-geographic regions in Sri Lanka. Ecologically, both the hot wet lowland and parts of the moist lowland would seem suitable for transmission of *W. bancrofti* throughout the year. Because of its high degree of urbanization, Jaffna, in the north, would also seem a potentially suitable area for the transmission of filariasis.

## ENDEMIC AREAS AND SUSCEPTIBLE AREAS

Endemic filariasis is localized in the southwestern coastal zone, a 5-km-wide strip from Negombo to Matara, a distance of about 200 km, with a population at risk of roughly 2 million. Scattered cases of filariasis are found in adjacent areas and in a number of large towns inland, owing mainly to the movements of people. As indicated earlier, the present human infection rates have been brought down to less than 1% and have hovered around the 1% mark for the last several years.[a] The total infection rate in *C. p. fatigans* has remained largely stationary between 2.0% and 1.2%, with no change in the infectivity rate of around 0.6%

It is thus clear that an equilibrium has been reached between the different factors concerned with filarial transmission, i.e., the efficiency of mosquito control and parasite control, selection of vector and parasite strains, and movements and increase of population. No marked change in the infection rates are expected to occur as long as this equilibrium remains unbroken.

The fact that the introduction of *W. bancrofti* parasites by human carriers into towns outside the endemic zones could start satellite foci was demonstrated by Wijetunge (7) in a survey of the student population at Peradeniya University, near Kandy. An examination of night blood from 7 467 students in 1957–62 revealed *W. bancrofti* parasites in 154, giving an infection rate of 2%. Dissection of 160 *C. p. fatigans* mosquitos from the campus dormitories showed that 6 carried *W. bancrofti* larvae, giving a mosquito infection rate of 3.7%.

The failure of transmission of *W. bancrofti* in the rest of the island in the presence of *C. p. fatigans* cannot easily be explained, unless it is assumed that the disease in the endemic belt was brought down in time to a level low enough to prevent its further spread inland. However, the movements and resettlement of people could not have failed to introduce *W. bancrofti* infections into many areas. The circumstances that led to the start of a small focus in Peradeniya, described above, could be easily repeated in other densely populated cities. In Fig. 2 are given the numbers of bus passengers travelling between the infected coastal towns and important inland towns. Since about 1% of the passengers from the endemic areas could be presumed to be infected, the frequent introduction of infected cases to any inland town could lead to the establishment of an independent focus of disease in that town.

During the investigations in 1972, 3 098 *C. p. fatigans* mosquitos from 28 different locations outside the endemic filariasis belt were dissected. Infected mosquitos were found in two towns only: Puttalam (2 infected mosquitos in 908), 100 km north of Negombo (considered to be the northern limit of the endemic zone), and Polgahawela (1 infected mosquito in 133), about 25 km east of the eastern limit. The spread of *W. bancrofti* from the coastal areas into other parts of the wet lowlands must therefore be considered to be possible when human population densities and the number of introduced cases have reached a critical level.

What, then, are the chances for the spread of

[a] The Millipore technique would perhaps demonstrate a much higher infection rate by detecting cases of low parasitaemia missed by the thick smear technique. This would explain the consistent finding of infections in the vector.

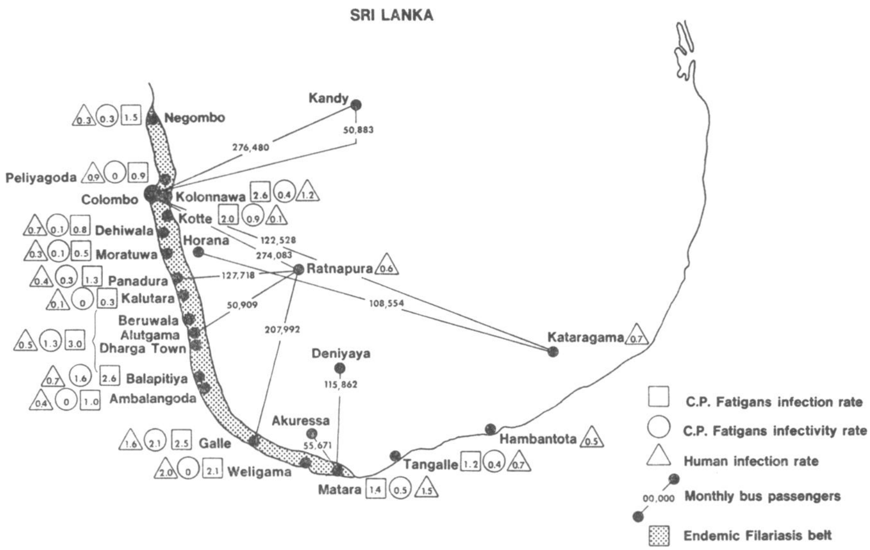


Fig. 2. Map of the endemic filariasis belt (shaded areas) showing the 15 control stations along the coast and their infection rates in host and vector. The figures along the lines connecting coastal areas with inland towns are the average numbers of bus passengers travelling between these points every month.

bancroftian filariasis into other climatic zones of Sri Lanka? Areas such as Jaffna peninsula in the north are extremely densely populated and the absence of filariasis in the presence of *C. p. fatigans* mosquitos is difficult to explain, unless the transmission of *W. bancrofti* is inhibited by certain factors in those areas. One such factor could be a shorter life-span of *C. p. fatigans*, perhaps resulting from unfavourable climatic conditions. The normal development cycle of *W. bancrofti* in *C. p. fatigans* in Sri Lanka takes from 10 to 12 days (4,6). Shorter periods, however, were demonstrated by Abdulcader et al. (4), who found that *W. bancrofti* microfilariae did not develop beyond the first stage at Nuwara Eliya, a hill station at about 1 900 m above sea level, although the vector itself was commonly found there. Development was normal, however, when *C. p. fatigans* mosquitos from Nuwara Eliya were used in experiments carried out at the laboratory in Colombo. It would seem that, all the other factors being equal, the climate at the hill station (average annual temperature: maximum 20°C, minimum 12°C; compare with Colombo, average temperature: maximum 29°C, minimum 23°C) was responsible for the failure of *W. bancrofti* to develop at Nuwara Eliya. The possibility of a shorter life-span of *C. p. fatigans* mosquitos, owing to climatic conditions, in the dry zones of Sri Lanka should not be excluded, and this might explain the absence of transmission of bancroftial filariasis in those areas.

Age-grading, determined from ovariole dilatations by Detinova's method (5), of *C. p. fatigans* mosquitos from various areas of the endemic belt and from localities in the dry zones, during 1971, indicated a generally shorter life-span for mosquitos from the latter (Lambrecht & Fernando, unpublished report to WHO, 1972). Thus, the average proportions of *C. p. fatigans* mosquitos in the P3 and P4 groups, i.e., old enough to harbour mature *W. bancrofti* larvae, was 8.3% (range 3.3–13.6%) from the endemic belt but only 2% (range 1.0–3.0%) in the dry zones. Among the factors influencing longevity, climatic conditions would seem of major importance, especially the relative humidity. Meteorological data from the wet and dry zones, however, show only slight differences between the averages for relative humidity, in spite of a marked difference in rainfall between the 2 zones. Thus, although some gross meteorological characteristics do not seem to be relevant, it is possible that the micro-climatic characteristics of the resting places of *C. p. fatigans* mosquitos may help to explain the differences in life-span.

BIONOMICS

The following 25 mosquito species have been identified from collections of adults and larvae in the filarial areas of Sri Lanka:

Nine *Culex*: *bitaeniorhynchus*, *fatigans*, *fuscanus*, *fuscacephalus*, *gelidus*, *minutissinus*, *nigropunctatus*, *sitiens*, and *tritaeniorhynchus*.

Six *Anopheles*: *barbirostris*, *hyrcanus*, *jamesi*, *subpictus*, *tesselatus*, and *vagus*.

Six *Aedes*: *aegypti*, *albopictus*, *lineatopennis*, *pallidostritatus*, *piperselatus*, and *vexans*.

Three *Mansonia*: *annulifera*, *crassipes*, and *uniformis*.

One *Armigeres*: *subalbatus*.

It is to be noted that *Anopheles culicifacies*, the sole known malaria vector in Sri Lanka, is found mainly in the dry and intermediate zones, where it breeds almost entirely in riverbed pools formed during periods of minimal rainfall. It is rarely found in the lowland streams of the coastal filarial areas where the rainfall is regular and the rivers are swift.

A major problem in the filariasis control programme is that there is no natural barrier, which might help to contain the infection, on the land side of the usually described endemic belt.

Filarial infections are carried and maintained in the populated coastal towns, between which are situated coconut plantations and small hamlets. Owing to budgetary limitations, mosquito control is carried out, in practice, only in the densely populated areas which, of course, harbour the highest numbers of filaria carriers. This piecemeal method is detrimental to the efficiency of mosquito control as a whole and makes evaluation difficult. Besides, although both controlled and uncontrolled zones belong to the same natural environment, the congested urban areas create a biotope no longer comparable with conditions in the rural parts. However, there are no ecological barriers that could prevent reinfestation of the mosquito-controlled areas from the uncontrolled parts. The distribution of species in collections of adult mosquitos and larvae differs only slightly between the treated and untreated zones, except for a higher proportion of *C. p. fatigans* in the collections of larvae from the controlled zones (Tables 1–3).

Table 1. Numbers of mosquito larvae (all species) in breeding sites in controlled and uncontrolled areas [a]

| Type of breeding site | Controlled areas | | Uncontrolled areas | | Both areas | |
|---|---|---|---|---|---|---|
| | no. of larvae | % | no. of larvae | % | no. of larvae | % |
| husk pits | 6 429 | 9.8 | 969 | 9.6 | 7 398 | 9.8 |
| discarded receptacles | 27 017 | 41.3 | 3 723 | 36.7 | 30 740 | 40.5 |
| trenches | 3 472 | 5.3 | 850 | 8.3 | 4 322 | 5.7 |
| tanks | 1 777 | 2.7 | 144 | 1.4 | 1 921 | 2.5 |
| catch pits | 7 384 | 11.2 | 403 | 4.0 | 7 787 | 10.2 |
| drains | 3 312 | 5.0 | 225 | 2.2 | 3 537 | 4.6 |
| boats | 228 | .3 | 0 | 0 | 228 | .3 |
| arecanut pots | 7 401 | 11.3 | 1 859 | 18.3 | 9 260 | 12.2 |
| wells in use | 339 | .5 | 41 | .4 | 380 | .5 |
| unused wells | 108 | .2 | 1 | .01 | 109 | .2 |
| tree holes [b] | 1 199 | 1.8 | 145 | 1.3 | 1 344 | 1.7 |
| spent nuts [b] | 4 151 | 6.3 | 1 160 | 11.5 | 5 311 | 7.0 |
| swamps [b] | 2 454 | 3.7 | 203 | 2.0 | 2 657 | 3.5 |
| crab holes [b] | 74 | .1 | 0 | 0 | 74 | .1 |
| others [b] | 413 | .6 | 443 | 4.3 | 856 | 1.2 |
| total | 65 758 | | 10 166 | | 75 924 | |

[a] Breeding in water plants is not represented in the list, because these plants were not examined.
[b] These were not made by man.

Table 2. Numbers of mosquito larvae of different species collected from breeding sites in controlled areas in the period 1962–68

| Breeding site | *C. p. fatigans* | | *C. gelidus* | | *C. tritaenio rhynchus* | | *Ae. aegypti* | | *Ae. albopictus* | | *Armigeres* | | Others | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % |
| husk pits | 3 484 | 21.3 | 782 | 45.7 | 107 | 5.6 | 9 | .4 | 73 | .6 | 1 889 | 6.3 | 85 | 5.4 | 6 429 | 9.8 |
| discarded receptacles | 4 666 | 28.4 | 113 | 6.7 | 416 | 22.0 | 1 653 | 75.3 | 9 419 | 77.8 | 10 342 | 35.0 | 408 | 25.9 | 27 017 | 41.3 |
| trenches, burrow pits | 1 677 | 10.0 | 380 | 22.3 | 546 | 29.0 | 15 | .7 | 148 | 1.6 | 344 | 1.1 | 312 | 19.8 | 3 472 | 5.3 |
| tanks | 692 | 4.2 | 14 | .8 | 75 | 4.0 | 158 | 7.2 | 442 | 3.6 | 327 | 1.0 | 69 | 4.4 | 1 777 | 2.7 |
| catch pits | 1 603 | 9.7 | 20 | 1.1 | 42 | 2.2 | 29 | 1.3 | 175 | 1.4 | 5 420 | 18.1 | 95 | 6.0 | 7 384 | 11.2 |
| drains | 2 052 | 12.4 | 90 | 5.3 | 223 | 11.8 | 41 | 1.8 | 189 | 1.5 | 653 | 2.2 | 64 | 4.0 | 3 312 | 5.0 |
| boats | 164 | 1.0 | 0 | 0 | 0 | 0 | 7 | .3 | 49 | .4 | 3 | .01 | 5 | .3 | 228 | .3 |
| arecanut pots | 780 | 4.8 | 39 | 2.3 | 105 | 5.4 | 107 | 4.8 | 498 | 4.3 | 5 816 | 19.4 | 56 | 3.5 | 7 401 | 11.3 |
| wells | 222 | 1.3 | 13 | .8 | 37 | 1.9 | 7 | .3 | 16 | .1 | 16 | .08 | 28 | 1.8 | 339 | .5 |
| unused wells | 58 | .3 | 5 | .03 | 11 | .6 | 4 | .2 | 18 | .1 | 12 | .04 | 0 | | 108 | .2 |
| spent nuts | 161 | 1.0 | 0 | 0 | 28 | 1.5 | 26 | 1.2 | 508 | 4.2 | 3 417 | 11.4 | 11 | .7 | 4 151 | 6.3 |
| tree holes, plants | 161 | 1.0 | 36 | 2.1 | 21 | 1.1 | 88 | 4.0 | 292 | 2.5 | 559 | 1.8 | 42 | 2.7 | 1 199 | 1.8 |
| swamps | 567 | 3.5 | 205 | 12.0 | 236 | 12.5 | 32 | 1.4 | 163 | 1.3 | 1 068 | 3.5 | 183 | 11.6 | 2 454 | 3.7 |
| crab holes | 6 | .03 | 0 | 0 | 37 | 1.9 | 16 | .7 | 6 | .05 | 0 | | 9 | .5 | 74 | .1 |
| others | 19 | .1 | 14 | .8 | 6 | .3 | 9 | .4 | 82 | .7 | 73 | .2 | 210 | 13.4 | 413 | .6 |
| total | 16 312 | | 1 711 | | 1 890 | | 2 201 | | 12 128 | | 29 939 | | 1 577 | | 65 758 | |
| % of total larvae | 24.8 | | 2.6 | | 2.9 | | 3.2 | | 18.4 | | 45.5 | | 2.4 | | | |

Table 3. Numbers of mosquito larvae of different species collected from breeding sites in uncontrolled areas in the period 1962–68

| Breeding site | *C. p. fatigans* | | *C. gelidus* | | *C. tritaenio rhynchus* | | *Ae. aegypti* | | *Ae. albopictus* | | *Armigeres* | | Others | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % |
| husk pits | 69 | 4.7 | 148 | 41.6 | 55 | 8.2 | 0 | | 236 | 11.6 | 252 | 5.7 | 209 | 27.5 | 969 | 9.5 |
| discarded receptacles | 531 | 36.4 | 56 | 15.9 | 70 | 10.5 | 84 | 74.4 | 1 251 | 61.5 | 1 680 | 35.1 | 51 | 6.7 | 3 723 | 36.7 |
| trenches, burrow pits | 166 | 11.3 | 81 | 22.9 | 324 | 48.4 | 0 | | 106 | 5.2 | 104 | 2.8 | 69 | 9.0 | 850 | 8.3 |
| tanks | 0 | | 0 | | 9 | 1.3 | 6 | 5.3 | 109 | 5.3 | 16 | .3 | 4 | .5 | 144 | 1.4 |
| catch pits | 113 | 7.7 | 17 | 4.9 | 9 | 1.3 | 0 | | 60 | 2.9 | 196 | 4.0 | 8 | 1.1 | 403 | 4.0 |
| drains | 87 | 5.9 | 13 | 3.7 | 54 | 8.0 | 18 | 15.9 | 10 | .5 | 35 | .7 | 8 | 1.1 | 225 | 2.2 |
| boats | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | |
| arecanut pots | 314 | 21.5 | 7 | 2.0 | 41 | 6.0 | 0 | | 52 | 2.5 | 1 441 | 30.1 | 4 | .5 | 1 859 | 18.3 |
| wells | 16 | 1.1 | 0 | | 25 | 3.7 | 0 | | 0 | | 0 | | 0 | | 41 | .4 |
| unused wells | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 1 | .1 | 1 | .01 |
| spent nuts | 75 | 5.1 | 0 | | 36 | 5.4 | 0 | | 92 | 4.5 | 957 | 20.0 | 0 | | 1 160 | 11.5 |
| tree holes, plants | 0 | | 2 | .5 | 0 | | 5 | 4.4 | 65 | 3.2 | 69 | 1.2 | 4 | .5 | 145 | 1.4 |
| swamps | 49 | 3.3 | 33 | 8.4 | 32 | 4.8 | 0 | | 28 | 1.3 | 2 | .004 | 59 | 7.2 | 203 | 2.0 |
| crab holes | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | |
| others | 43 | 2.9 | 0 | | 16 | 2.4 | 0 | | 31 | 1.5 | 2 | .004 | 351 | 45.6 | 443 | 4.3 |
| total | 1 463 | | 357 | | 671 | | 113 | | 2 040 | | 4 754 | | 768 | | 10 166 | |
| % of total larvae | 14.4 | | 3.5 | | 6.6 | | 1.0 | | 20.0 | | 46.8 | | 7.6 | | | |

Heavy breeding is found in both areas in discarded receptacles, e.g., spent coconuts and other types of small water-containers.

*Adult stages*

Of the 10 216 dwellings examined in the filariasis belt in 1971, 61.5% harboured mosquitos; 22 758 mosquitos were collected, giving an overall average of 2.2 mosquitos per house and an average of 3.6 per mosquito-positive house (figures based on a 5-minutes search per house). A total of 824 hours were spent in collecting resting mosquitos, yielding an average of 27.8 mosquitos per man per hour. The catching rates were 3 times higher in the urban areas than in the rural parts in spite of the control measures in the former.

The dwellings examined in 29 settlements and towns outside the filariasis belt numbered 3 899, of which 45% were found to harbour mosquitos; 7 585 mosquitos were collected, giving averages of 2 mosquitos per house and 4.3 per mosquito-positive house. A total of 340 hours of collecting yielded an average of 22.4 mosquitos per man per hour. Densities, however, varied in these " outstations " from an occupation rate of 9% to 88% of the dwellings, from 0.1 to 5.3 mosquitos per house, and 1.1 to 8.7 per mosquito-positive house; the catch rate per man per hour varied from 1.3 to 59.1. As might be expected, all the high figures related to the larger towns, such as Kandy, Kataragama, Puttalam, Jaffna, Horana, Polonnaruwa, Kegalle, and Polgahawela, and to communities living close to these places.

From past records on the prevalence of the most common species of mosquitos collected from houses in the filariasis belt (Table 4), it is seen that the filarial vector, *C. p. fatigans*, largely dominates the mosquito fauna in the houses; about 7 of every 10 mosquitos were of that species despite a slight decrease since the 1949–62 period. *Ae. aegypti*, on the other hand, made a relatively substantial gain in both the controlled and uncontrolled areas.

The average total infection rate for all stages of *W. bancrofti* larvae has oscillated around the 1.5% mark—from 2.0% in 1967 to 1.2% in 1970 and 1.6% in 1972. The average infectivity rate since 1967 remained stationary at 0.6%, but went down in 1972 to 0.3%. As indicated earlier, it would seem that an equilibrium has been reached between transmission potentials and control measures, so that the infection and infectivity rates should stay the same for as long as this equilibrium is maintained.

*Larval stages*

Data concerning the collections of larvae are summarized in Tables 1–3. Tables 2 and 3 list the species most commonly found and their proportions in 15 of the most common types of breeding sites. The predominant species in both controlled and uncontrolled zones was *Armigeres subalbatus*,

Table 4. Data from past records on the prevalence of different species of mosquitos in houses in the filariasis belt during the periods 1949–62 and 1969–70 [a]

| | Period: 1949–62 | | Period: 1969–70 | |
|---|---|---|---|---|
| | controlled areas | uncontrolled areas | controlled areas | uncontrolled areas |
| *C. p. fatigans* | 77.5 | 86.1 | 68.5 | 66.5 |
| *C. gelidus* | 3.3 | 2.1 | 3.6 | 4.5 |
| *C. tritaeniorhynchus* | 3.6 | 1.9 | 3.0 | 3.3 |
| *Ae. aegypti* | 2.3 | .05 | 5.3 | 3.2 |
| *M. uniformis* | 8.6 | 6.4 | 6.8 | 8.2 |
| *M. annulifera* | 1.0 | 1.3 | .6 | .4 |
| *Ar. subalbatus* | .9 | .3 | 5.4 | 6.1 |
| *A. subpictus* | .8 | .6 | .7 | .9 |
| other species | 2.0 | 1.25 | 6.1 | 6.9 |

[a] Figures are expressed as percentages.

followed by *C. p. fatigans* and *Ae. albopictus* (the last-named is a vicious biter during the 2 hours after sunset and would not normally be sampled in our routine adult collections, which were carried out mainly in the early mornings). It is seen from Table 1 that only a small proportion of breeding sites were not man-made, i.e., 12.5% in the controlled zones and 19.1% in the uncontrolled zones. From data on the larvae collected in the uncontrolled zones, it is possible to calculate the extent of suppression of larval development if the present control method (based on weekly applications of larvicides to " permanent breeding pools ") were to be extended to the following breeding sites:

A. Breeding sites that could be treated: trenches (with 8.3% of all larvae collected), catch pits (4.0%), drains (2.2%), and others (4.3%). Thus, a total of 18.8% of all larvae could be suppressed.

B. Breeding sites that cannot be treated: husk pits (with 9.6% of all larvae; cannot be treated because of danger of poisoning to labourers), discarded receptacles (with 36.7% of all larvae; impracticable to spray), tanks (with 1.4% of all larvae; danger of poisoning), arecanut pots (with 18.3% of all larvae; danger of poisoning), wells in use (with 0.4% of all larvae; danger of poisoning), tree holes and plants (with 1.3% of all larvae; impracticable to spray), spent nuts (with 11.5% of all larvae; impracticable to spray), and swamps (with 2.0% of all larvae; only partially treatable). Thus, a total of 81.2% of all larvae cannot be suppressed.

The above figures indicate that the control methods at present applied by the Anti-Filariasis Campaign could only be partially effective since they leave a very large proportion of breeding sites undisturbed. In all fairness, it should be pointed out that the above calculations are based on the numbers of positive breeding pools without consideration of the fact that the larvae produced in one catch pit or trench, for instance, might be higher than the numbers of larvae found in one discarded tin.

Table 5 shows how mosquito breeding would be affected and how control measures would be improved by specific or combined control methods. The action of destroying only discarded household receptacles in the uncontrolled areas would result in the inhibition of almost twice the number of breeding pools than could be achieved by the present spraying programme: 36.7% (not including spent coconuts) against 20.2%. If, in addition to the removal of the discarded receptacles, breeding in spent coconuts and in arecanut pots could be prevented, the breeding of all species could be

Table 5. Expected percentage reduction of mosquito species as a result of treatment or elimination of specific groups of breeding sites in uncontrolled zones [a]

| | *C. p. fatigans* | *C. gelidus* | *C. tritaeniorhynchus* | *Ae. aegypti* | *Ae. albopictus* | *Ar. obturbans* | All species |
|---|---|---|---|---|---|---|---|
| larvicidal spraying in catch pits, drains, tanks, boats, trenches, etc. | 27.8 | 31.5 | 67.0 | 21.2 | 15.4 | 7.8 | 20.2 |
| elimination of discarded household receptacles and spent nuts | 41.5 | 15.9 | 18.3 | 74.4 | 66.0 | 55.1 | 48.2 |
| | 69.3 | 47.4 | 85.3 | 95.6 | 81.4 | 62.9 | 68.4 |
| avoidance of breeding in arecanut pots | 21.5 | 2.0 | 6.0 | 0 | 2.5 | 30.1 | 18.3 |
| | 90.8 | 49.4 | 91.3 | 95.6 | 83.9 | 93.0 | 86.7 |
| prevention of breeding in husk pits | 4.7 | 41.6 | 8.2 | 0 | 11.6 | 5.7 | 9.5 |
| | 95.5 | 91.0 | 99.5 | 95.6 | 95.5 | 98.7 | 96.2 |

[a] The figures in the bottom rows are cumulative percentages.

brought down by more than half: 48.2 + 20.2 + 18.3, or 86.7%; this would reduce breeding of the filarial vector, *C. p. fatigans*, by 90.8%. The elimination of these breeding sites in the controlled areas would increase the efficiency of control against *C. p. fatigans* by 34.2%. In regard to other mosquito species, especially *Ae. aegypti* and *Ae. albopictus*, which are potential virus carriers, the elimination of discarded receptacles alone would reduce the breeding potential of these species by respectively 76.5% and 80.2% in the controlled zones, and 74.4% and 66.0% in the untreated areas.

The breeding of mosquitos in husk pits in certain parts of Sri Lanka presents a particular problem (Lambrecht & Kulasingam, unpublished report to WHO, 1973). Husk pits are excavations of variable size, usually not more than 1 m deep, filled with water from a nearby stream, lagoon, or tidal pool, and are used during the making of " coir ", a fibre obtained from the husk of the coconut. After the removal of the nut, the husks are left in the pits to soak for a variable length of time, on an average from 2 to 4 months. After " maturation ", the husks are pounded, often by hand, and the fibres are removed and left to dry. The coir is used for rope-making, as a filling for mattresses or under upholstery, for doormats, and so on. During the period of soakage, the pits become active breeding sites for a number of mosquito species, especially *C. gelidus* and *C. p. fatigans*. Although larvicides, such as fenthion, may be used in routine mosquito abatement programmes in the filarial areas of Sri Lanka, these compounds cannot be used in the husk pits, because people have to enter and stay in the water of the pits for prolonged periods of time when stocking or removing the husks.

A study of husk pits in the Ambalangoda–Balapitiya area, about 88 km south of Colombo, for 3 months showed that the culicine fauna in these pits was quite different from that in other breeding places. *C. gelidus* was predominant and accounted for 76.2% of the 3 246 larvae examined; next was *C. p. fatigans* with only 7.2%. Larvae collected in a variety of pools other than husk pits, but in an environment similar to that of husk pits, were of the following species: *C. p. fatigans* (37.2%), *Ar. subalbatus* (25.4%), *Ae. albopictus* (11.8%), *C. gelidus* (10.6%), and *C. tritaeniorhynchus* (7.2%). In a densely built-up area south of Colombo, the following 5 species: *Ar. subalbatus* (42.2%), *Ae. albopictus* (18.8%), *Ae. aegypti* (12.8%), *C. p. fatigans* (10.3%), and *C. gelidus* (7.0%), were identified in a variety of breeding sites.

Clearly, mosquitos proliferate in the husk pits where the alkalinity of the water seems particularly to favour the larvae of *C. gelidus*; the latter are found in their highest numbers above pH 7, reaching a peak at pH 10. In other breeding sites, however, the highest densities of *C. gelidus* are found at pH 6. It would thus seem that the correlation between the hydrogen-ion concentration and the development of *C. gelidus* is only secondary, because the favourable conditions in the husk pits for this species are probably due to certain organic or inorganic compounds formed during maturation of the husks or as a result of bacterial growth. These compounds are perhaps also detrimental to the normal development of other mosquito species.

Larvae of *Ar. subalbatus* predominate in a variety of pools, especially in arecanut pots, but are completely absent from the husk pits. In the arecanut pots, the only other species commonly found in association with *Ar. subalbatus* is *C. p. fatigans*. Some observations suggest that in these small breeding sites the 2 species may be in competition, leading to the elimination of *C. p. fatigans* at a certain stage, perhaps as a result of an excess of organic contents released during the fermentation of the arecanuts.

Although the proportion of *C. p. fatigans* in the husk pits is relatively small, the presence of large numbers of these pits in certain areas of the filariasis endemic belt makes them an important breeding site for the vectors of *W. bancrofti*. In addition, the spread of *C. gelidus* adds to the mosquito annoyance and there is a risk that it may be a possible vector of viruses.

*Ae. aegypti* larvae were collected from urban breeding sites and were especially numerous in collections from the harbour areas of Colombo. The predilection of *Ae. aegypti* for harbour areas and their sometimes restricted distribution in those areas were also noted in the Seychelles and may be related to their transport and introduction by sea-craft (Lambrecht, unpublished report to WHO, 1969).

In a survey carried out in the Colombo harbour area by the Municipal Public Health Service during 1966–67, the following data were obtained;

(*1*) Resting adult mosquitos: of 3 818 dwellings examined, 439 (11.5%) were found to harbour mosquitos; 1 380 mosquitos were collected (average

0.4 mosquito per house or 3.1 mosquitos per mosquito-positive house). Species distribution: *Ae. aegypti* (31.5%), *Ae. albopictus* (1.0%), *C. p. fatigans* (66.1%), and others (1.4%).

(*2*) Larvae collected from the same areas: of 3 289 breeding places examined, 5.1% proved to be positive and yielded 1 683 larvae. Species distribution: *Ae. aegypti* (32.4%), *Ae. albopictus* (12.6%), *C. p. fatigans* (53.5%), and others (1.5%).

(*3*) Larvae from floating harbour service craft: 273 were examined; 10.1% of them yielded a total of 320 larvae. Species distribution: *Ae. aegypti* (88.7%) and *C. p. fatigans* (11.3%).

(*4*) Larvae from floating local craft: 537 were examined; 4.4% of them yielded a total of 264 larvae. Species distribution: *Ae. aegypti* (47.3%), *Ae. albopictus* (10.3%), *C. p. fatigans* (29.9%), and others (12.5%).

The pH values of 680 breeding places from where larvae were collected were estimated by means of wide-range and narrow-range BDH indicator papers. The average pH range of the breeding pools tested was 6.2–8.6 and the mean overall average for all breeding pools was 7.1.

## MOSQUITO CONTROL PROGRAMME

At the moment of writing, mosquito control is carried out from 15 stations in the endemic belt. In addition, the city of Colombo with a population of around 650 000 has its own mosquito control unit within the city health services. Mosquito control work is also carried out by local bodies in 5 other stations, financed by the Anti-Filariasis Campaign.

Mosquito control is based essentially on the treatment of permanent breeding places with fenthion (BAYTEX EC), 28.5 ml diluted in 4.5 litres of water, at a target dose of 1 mg/litre, which is applied with the aid of pressurized HUDSON/X-PERT sprayers, equipped with a pressure gauge.

The number of breeding sites sprayed weekly totals about 85 000 in the 15 control areas. Drains and trenches account for about 55% of these sites, followed by burrow pits (15%) and catch pits (9%). Husk pits (6.5%) were only occasionally sprayed when they were not in use. When calculated in relation to the total number of breeding sites, the treated sites account for only 20%. Indeed, the control programme would be far more effective if it were possible to prevent breeding in discarded receptacles, arecanut soaking pots, and spent nuts in conjunction with the present spraying programme


# RÉSUMÉ

## ASPECTS ENTOMOLOGIQUES DE LA LUTTE CONTRE LA FILARIOSE EN SRI LANKA

L'éléphantiasis est connu en Sri Lanka depuis plusieurs siècles. Actuellement, la filariose à *Wuchereria bancrofti* est endémique dans la région côtière du sud-ouest de l'île où vivent quelque 2 millions de personnes. Le parasite est transmis par *Culex pipiens fatigans*.

Un programme de lutte contre la filariose a été lancé en 1952. Le taux d'infection humaine, qui atteignait à cette époque 15% dans certaines régions, a été ramené en 1972 à moins de 1% grâce au dépistage et au traitement des cas et à la lutte antivectorielle par larvicides. En 1970-1972, les taux d'infection et d'infectivité chez *C. p. fatigans* étaient respectivement de 1,6 et 0,6%. Au cours des cinq dernières années, les taux d'infection chez l'homme et chez le vecteur sont restés pratiquement identiques, indiquant un équilibre entre l'efficacité des mesures de lutte et le potentiel de transmission du parasite et du vecteur. Il ne faut pas s'attendre à une modification de ces taux aussi longtemps que les facteurs de l'équilibre resteront inchangés.

La présence de *C. p. fatigans* dans la plupart des régions de l'île et les analogies d'environnement rendent possible l'extension de la filariose à d'autres zones que la zone actuelle d'endémicité. On en a signalé un certain nombre de cas parmi les étudiants de l'Université de Peradeniya, à environ 100 km de la zone d'endémicité.

L'absence d'infections dans certaines régions très peuplées et apparemment propices, comme Jaffna dans le nord, laisse supposer que des différences de longévité du vecteur suivant les régions peuvent jouer un rôle.

De l'analyse des données entomologiques, il ressort que: *a*) la lutte antivectorielle menée dans des secteurs séparés faisant partie d'un territoire intégralement infesté ne donne que des résultats incomplets et doit être poursuivie sans relâche par suite de la réintroduction continuelle du vecteur; *b*) l'efficacité de la lutte antilarvaire est entravée par le risque pour la santé qu'implique parfois l'usage du fenthion et par l'impossibilité d'utiliser les larvicides dans certains gîtes larvaires; *c*) un grand nombre de petits gîtes, aux alentours des habitations, ne peuvent être éliminés efficacement que par des mesures d'assainissement, ce qui suppose la coopération active de la population.

## REFERENCES


1. Abdulcader, M. H. M. & Padley, R. Filariasis records in Ceylon. *Indian J. Malar.*, **14**: 521-543 (1960).
2. Abdulcader, M. H. M. Mosquito fauna of the *W. bancrofti* endemic belt in Ceylon and their role in the transmission of filariasis. *Bull. Indian Soc. Malar.*, **2**: 201-212 (1965).
3. Abdulcader, M. H. M. The significance of the *Culex pipiens fatigans* Wiedmann problem in Ceylon. *Bull. Wld Hlth Org.*, **37**: 245-249 (1967).
4. Abdulcader, M. H. M. et al. Vectorial capacity of *Culex pipiens fatigans* in Ceylon. *J. trop. Med. Hyg.*, **68**: 254-256 (1965).
5. Detinova, T. S. *Age-grouping methods in Diptera of medical importance.* Geneva, World Health Organization, 1962 (Monograph Series, No. 47).
6. Samarawickrema, W. A. A study of the age-composition of natural populations of *Culex pipiens fatigans* in relation to the transmission of filariasis due to *Wuchereria bancrofti* in Ceylon. *Bull. Wld Hlth Org.*, **37**: 117-137 (1967).
7. Wijetunge, H. P. A. Filariasis in a university campus in Ceylon. *J. trop. Med. Hyg.*, **70**: 25-28 (1967).