Malaria Transmission and Control in Huruluwewa, Sri Lanka

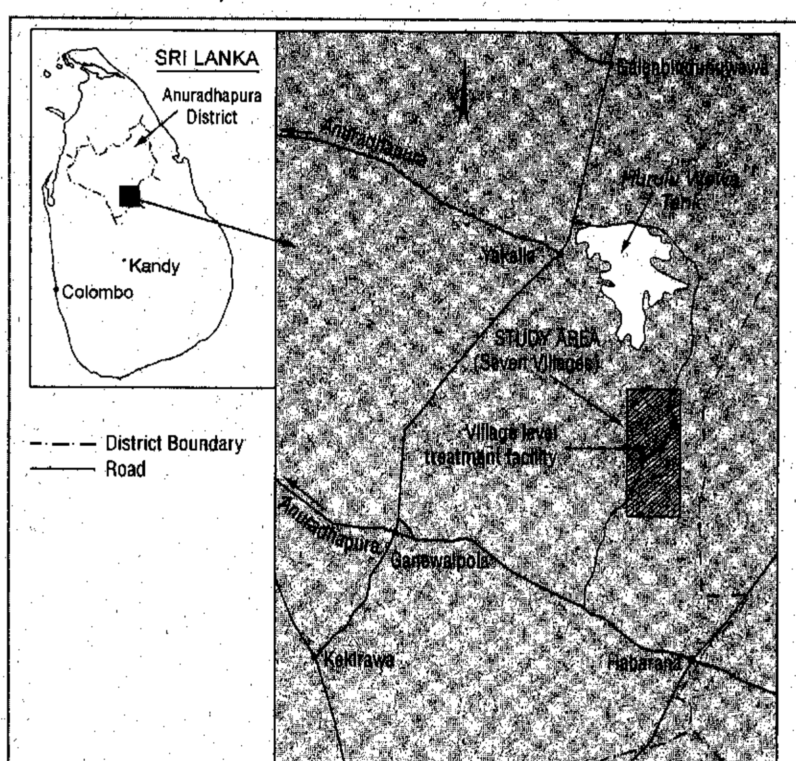
A collaborative research program between the International Water Management Institute, the University of Peradeniya, and the Anti-Malaria Campaign

Summary of Research Findings

A series of studies was conducted between July 1994 and March 1998 to increase the knowledge of malariology in the context of a traditional Sri Lankan dry zone environment with extensive irrigated agriculture, and to identify and assess the feasibility of new control interventions that could supplement the ongoing control efforts by the government. The main focus of the new interventions was related to water management for vector control and community-based initiatives for diagnosis and treatment of malaria.

Initially the studies focused on one village but were later expanded to include the communities living in seven neighboring villages with approximately 2,500 individuals (see figure 1). For two of the studies, the sub-basin of the river was used as the basis for analysis. The land in the study area comprises homesteads, land under small-scale reservoir-based irrigation, and areas under slash and burn cultivation (*chena*). One stream crosses the study area and serves as the main drainage point of the Huruluwewa watershed. In addition, this stream conveys irrigation water from upstream irrigation systems to a large irrigation reservoir downstream of the study area.

FIGURE 1. The study area.



ANOPHELINE LARVAL ECOLOGY

Intensive larval sampling was conducted in a village ecosystem to describe the breeding habitats of the potential malaria vectors and to document the temporal relation between environmental factors and larval abundance. During the dry season, the species considered to be the major vector of malaria in Sri Lanka, *Anopheles (An.) culicifacies*, was found exclusively in small pools when the water level in the stream was low. However, later in the year, the large number of pools created by the pre-monsoonal rains within the bed of the irrigation reservoirs and in the paddy drainage area created opportunities for *An. culicifacies* breeding at a time when the breeding potential in the stream had been reduced by the inflow of rainwater. Clearly, flow dynamics of the stream and the timing of the pre-monsoonal rains were important determinants of *An. culicifacies* larval abundance. Secondary vectors were found to have distinct breeding preferences and the overall abundance was associated with the availability of habitats that were created by agricultural activities. Seepage areas below the reservoir walls were important breeding habitats for *An. jamesii* and *An. nigerrimus*. Irrigation canals produced *An. barbirostris, An. peditaeniatus* and *An. varuna*, and rice fields and temporary pools in chena and home gardens produced *An. peditaeniatus* and *An. vagus*. *An. varuna* coexisted with *An. culicifacies* in the stream but it could maintain breeding potential at higher water levels as well. Breeding in the rice fields and irrigation channels was limited to some extent by the water rotations practiced in the area to conserve water.

When looking at the characteristics of the breeding sites of four of the likely malaria vectors in the area, it was found that *An. culicifacies*, in contradiction of the general belief, was able to exploit habitats that were shaded and contained turbid water. However, it was found that the availability of pools in the stream and in the reservoir bed was highly predictive of the presence of *An. culicifacies* irrespective of overall habitat characteristics such as exposure to sunlight, type of substratum, turbidity of the water, and the presence of vegetation and fauna.

TRANSMISSION DYNAMICS

To describe the transmission dynamics of malaria in a study village and to determine the importance of the various potential vectors, adult mosquitoes were sampled and the number of human malaria cases were recorded. An approximation of the entomological inoculation rate was obtained by using species-specific values of abundance, circumsporozoite rates, and the human blood index. A total of 14 different anophelines was collected. Of these, 7 different species were infected with either *Plasmodium (P.) falciparum* (76%) or *P. vivax* (24%). The highest sporozoite rate was found in *An. barbirostris* (0.015) followed by *An. culicifacies* (0.011) and *An. annularis* (0.010). Serotype PV247 was recorded from a vector (*An. varuna*) for the first time in Sri Lanka. Human blood was found in 10 different species. The highest human blood index was seen in *An. culicifacies* (0.095) followed by *An. nigerrimus* (0.052) and *An. tessellatus* (0.050). Although *An. culicifacies* was only the fifth most abundant species, it had the highest mean number of infective vectors (MIV) per collection night—more than three times that of the next two on the list, *An. vagus* and *An. peditaeniatus*.

The unstable nature of malaria was clearly demonstrated during the study period. During late 1994 to early 1995, an outbreak of malaria occurred with 46 percent of the village population experiencing at least one episode of malaria. Following this outbreak, incidence of malaria remained at a low level. High monthly MIV was associated with *An. culicifacies* during the onset of the 1994 malaria outbreak. Lower MIVs associated with low incidence of human malaria were seen when *An. peditaeniatus*, *An. subpictus*, *An. vagus*, and *An. varuna* were involved in transmission. During this malaria outbreak, close to 75 percent of all human cases was reported to be due to *P. falciparum*. During this period, only *P. falciparum* was detected in the mosquito population. For the rest of the study period, the balance between *P. vivax* and *P. falciparum* remained approximately equal in both humans and mosquitoes.

The study leaves no doubt that *An. culicifacies* was the species mainly responsible for the outbreak of malaria experienced in the village. The adult population dynamics of *An. culicifacies* was linked to the breeding opportunities made available in the slow flowing stream and in the reservoir bed, and was not correlated with the main monsoonal rains. The build-up in adult *An. culicifacies* supported the increase in human malaria cases. Seasonally highly abundant, outdoor, dusk-biting species such as *An. vagus* and *An. peditaeniatus* could have an impact on the maintenance of malaria transmission. Based on the available information, it seems likely that if the consistent low level of *An. culicifacies* breeding in the stream during the dry season could be controlled, the adult abundance of this species would be very low at the time when the pre-monsoonal rains set in. A very low abundance of *An. culicifacies* would make it difficult to fully exploit the habitats generated by the pre-monsoonal rains, especially since these habitats will only be available for a relatively short period. By the time the full monsoon floods the reservoir and the drainage areas, breeding possibilities for *An. culicifacies* are greatly reduced.

RAINFALL AND MALARIA

Information on mean monthly rainfall and mean monthly relative humidity was correlated with the monthly malaria incidence from 1979 to 1995 for the area covered by a district hospital, which included the villages in the smaller study area. The analysis was done to provide more information on the seasonality and annual changes in incidence levels of malaria linked to meteorological parameters and to see if a possible predictive formula could be derived. Aggregated data from 1979 to 1995 showed an increase of rainfall in October with a peak in November, and an increase in malaria incidence in December followed by a peak in January. However, with the same two-month time lag, the correlation between monthly rainfall and monthly malaria incidence was not very strong. A better correlation was obtained when the distribution of rainfall over a month was taken into account. Despite the statistical significance, the practical relevance of the relationship between higher than average seasonal rainfall and higher than average seasonal malaria incidence is probably limited. Rainfall and relative humidity alone were not sufficient to predict increases in malaria incidence. The entomological findings in the study area indicate that the occasional inter-monsoonal showers occurring during the dry season and the distribution of the pre-monsoonal rains will be more important for the build-up of *An. culicifacies* than the rainfall during the main monsoon season. However, a range of the secondary vectors breeding in groundwater pools is likely to be more directly affected by the amount and extent of the main monsoonal rains. This may also mean that transmission will be initiated earlier in a riparian village than in villages further away from waterways and, in this way, the main monsoonal rains may have an impact on the district-wide correlation between rainfall and incidence of malaria.

KNOWLEDGE, ATTITUDES, AND PRACTICES

Studies were conducted to answer a range of questions related to the knowledge of malaria among the communities in the study area, their use of preventive measures, and strategy for coping with malaria illness. Information on the treatment-seeking behavior of the population was collected and a qualitative assessment was made of the rationale behind their preference for certain types of facilities. Methodologies were derived to estimate the economic impact of malaria on households in a selected village.

The surveyed community of five villages had a high knowledge of malaria with 98 percent of them being aware that two different types of malaria were present in the area and with one of the two (*P. falciparum*) having the potential to develop what was locally described as "brain malaria." The correct treatment for malaria was indicated by 98 percent of the respondents although side effects of antimalarials were often confused with symptoms of the disease. Almost all the respondents knew that mosquitoes were involved in transmission. Several studies in the area indicated that the community gave a very high priority to the confirmation of infection by blood-film test before taking treatment. A survey conducted just after the main transmission season showed that overall malaria was ranked as the third most important community problem, after lack of water for cultivation and poverty.

Several surveys conducted during the study period have shown that the community made exclusive use of western-type facilities for diagnosis and treatment. Approximately 85 percent of the community made use of some form of government facility before the introduction of a malaria treatment center in one of the study villages. Home treatment with paracetamol was the first medication taken in 85 percent of the households. In addition to the drug-based treatment, special diets were often prepared for the patients to re-establish the "hot/cold" balance of the body and to regain energy.

More than 90 percent of the households had their houses sprayed with residual insecticide under a government-funded spraying program. In 23 percent of the households, one or more of the members made use of mosquito nets. The use of mosquito nets was significantly more prevalent among the well-off families. During the rainy season, a common preventive measure was the burning of commercial anti-mosquito coils (54% of households) or the roasting of traditional herbal remedies known for their repellent effects (69%). Environmental based control interventions were not carried out in the area and no community involvement in vector control took place outside the government-funded spraying program.

ECONOMIC BURDEN TO HOUSEHOLDS

The total direct expenditure on a single malaria episode was approximately US$3.00, which should be compared with a median annual household income of approximately US$260.00 for the surveyed community. The money spent on special diets for malaria patients was the highest item of expenditure. The opportunity cost to the households related to labor days lost due to illness was estimated on the basis of daily activity records and confirmed malaria cases, and the application of actual wage rates for men, women, and children. In a year with an average malaria incidence the economically active age group (14 to 60 years) lost 1.8

percent of working days due to malaria and 5.2 percent due to all other illnesses. This resulted in an average annual economic loss per household of US$15.50 for malaria and US$47.50 for all other illnesses, corresponding to 6 percent and 18 percent of annual household net income, respectively. A few families were greatly affected by malaria with eight families losing more than 10 percent of labor days during the most important agricultural season. Children not part of the economically active age group lost on average 2.7 percent of school days over a one-year period due to malaria and 3.2 percent due to other illnesses. The methodology developed to assess the economic impact of malaria could easily be applied elsewhere and is especially relevant under conditions of unstable malaria where the adult population is directly affected by the disease.

The very high knowledge of malaria, the perceived seriousness of the disease, and the relatively high economic cost of the disease to the households should make the community receptive to increased involvement in control activities. However, the traditional reliance on free services from the government for the control of malaria is likely to make the community less interested in participation in disease control. Also, the low income of the community makes it difficult to introduce control measures that increase the financial pressure on families, such as privately purchased bed nets or user fees to cover improved services. In monetary terms, the absolute cost of malaria to the households is relatively low, although high as a percentage of income, making it more difficult to identify new interventions with a favorable cost-benefit ratio.

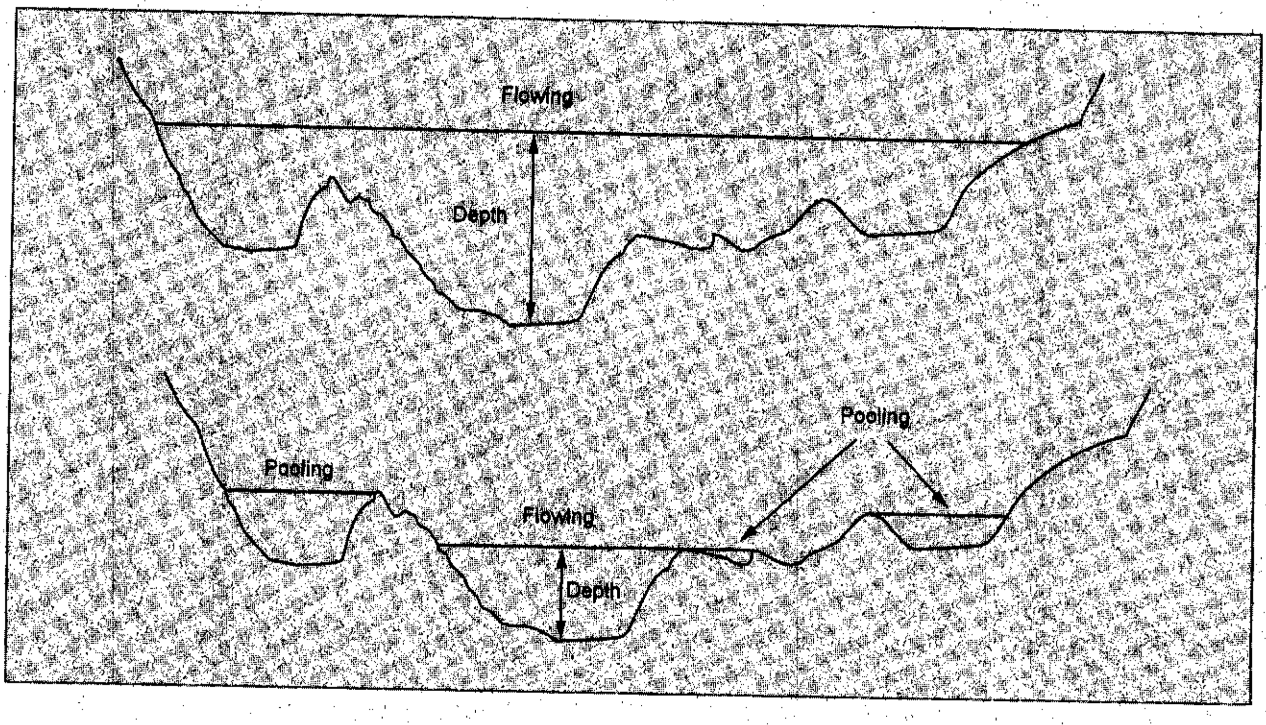
RISK FACTORS FOR MALARIA

To identify the risk factors for malaria and possible preventive measures, an epidemiological study was done in a village over a one-year period. Both environmental and socioeconomic risk factors were studied. Individuals living in houses where bed nets were used had a significantly reduced risk of getting malaria compared with families not using mosquito nets (relative risk of 0.16, 95% CI 0.05–0.45). Usage of traditional fumigants was also associated with a reduced risk of malaria. Interestingly, families using commercial anti-mosquito pyrethrum coils had a significantly higher risk of malaria infection than individuals living in houses where they were not used. Living close to the stream was a risk factor for malaria early in the transmission season but this did not reach statistical significance. It was not possible to assess the risk-related differences in educational status and quality of house constructions due to lack of variation in these factors between households.

WATER MANAGEMENT AS A CONTROL MEASURE

The association between water levels in the stream and the breeding of *An. culicifacies* was studied in great detail. The feasibility of using water management measures to reduce the larval abundance was also assessed. Entomological sampling took place in the stream on a fortnightly basis over a period of almost three and a half years. The highest number of immature *An. culicifacies* was found in August and September when there was virtually no flow in the stream. The second highest peak was observed in the period from February to April, when the water level was relatively low. It was found that the maximum stream water depth in the 14-day interval before sampling took place best explained the number of larvae. The larval abundance was reduced by 84 percent when the water level in

FIGURE 2. Breeding sites created in the stream when the water level drops.



the stream was increased from pooling level (close to 0 cm) to 50 cm (see figure 2).

A series of reservoirs was built early this century across the waterway upstream of the study area and the water levels were controlled by water releases from these reservoirs. The impact of different water management scenarios was tested using a water balance model and the established relationship between larval abundance and stream water depth. A range of water management options was tested for their impact on larval abundance using mathematical models. These included changes in the temporal upstream water allocations, agricultural practices, and physical maintenance of the reservoirs, all having the aim of making water available for fortnightly releases into the stream during the dry season. The results demonstrated potential for very effective vector control by feasible changes in irrigation management.

VILLAGE-LEVEL DIAGNOSIS AND TREATMENT

A village-level malaria treatment center was established as an experiment to test new approaches facilitating early diagnosis and prompt treatment of malaria in rural areas. The center was set up as a collaborative effort between the government malaria control staff, the researchers involved, and representatives of the community. It was housed in a single room in a village centrally located in the study area and it was able to provide services to all seven villages. The diagnosis and treatment of patients followed the standard government procedures. The assistants working at the center were selected from the community and were, after a two-week training period, entrusted with increased responsibility. After about 7 months, the center was fully managed by the assistants although supervisory visits were made by outside staff on a monthly basis.

The findings show that the village treatment center quickly took over the role as the main malaria facility serving the community. However, mothers with sick young children often preferred the government hospital since they felt that they received a more qualified opinion from the medical staff at the hospital. In addition, a small number of patients continued to make use of private facilities in the larger towns. Overall the village treatment center did not improve the response time in seeking treatment for young children but the delay for adults was reduced by 1–2 days. The group that benefited the most was the elderly and the handicapped in the community. The center significantly reduced the stress and discomfort normally experienced by them when seeking treatment for malaria. After the introduction of the center, people no longer delayed seeking treatment due to financial or time constraints, or because no person was available to accompany the patient to the hospital. The elimination of this small group of people that would normally delay seeking treatment for a considerable time is likely to have reduced the parasite reservoir in the community and may have influenced a reduction in the rate of transmission. The study indicated that the effectiveness of a village treatment center is influenced by the degree of initial support from key individuals in the community, the selection procedure and training of the staff of the treatment center, and the history of the relationship between the villages to be served by the center.

The wide fluctuations in the level of malaria incidence will make it more difficult to maintain a community interest in the treatment center, ensure a high quality of diagnosis, and financially sustain the center. To ensure the long-term sustainability of village treatment centers, it is therefore necessary to assess the feasibility of charging a user fee and the establishment of multi-purpose clinics. Government policies and administrative procedures will also need to be adjusted to facilitate the establishment of village treatment centers.

COST OF MALARIA CONTROL

An analysis of the cost-effectiveness of a range of different preventive and curative interventions was also conducted. Seen from the government perspective, a centrally located hospital capable of serving a relatively large area is the most cost-effective way of treating malaria patients. Wide use of mobile clinics and village-level facilities is an expensive control strategy for the government as the cost per case treated by them is approximately twice that of a centrally located hospital. However, when the expenses incurred by both government in providing treatment and households in seeking treatment are considered, the cost is almost the same for the three curative options, government hospital, village facility, and mobile clinics.

The government can implement a program of impregnating privately purchased mosquito nets providing protection to the households at approximately half the cost of the ongoing residual insecticide-spraying program. However, for this to be effective, there is a need to test new approaches to increase the usage of bed nets, especially by the rural poor. For larval control, the use of designated water management strategies should be explored, as this option is far cheaper than the use of chemically based larvicides.

THIS SUMMARY IS BASED ON THE FOLLOWING PAPERS:

1. Amerasinghe, F.P., F. Konradsen, K.T. Fonseka, P.H. Amerasinghe. 1997. Anopheline (Diptera: culicidae) breeding in a traditional tank-based village ecosystem in northcentral Sri Lanka. *Journal of Medical Entomology*, 34: 290-297.

2. Amerasinghe, P.H., F.P. Amerasinghe, F. Konradsen, and K.T. Fonseka. Forthcoming. *Malaria vectors in a traditional dry zone village in Sri Lanka.*

3. Konradsen, F., P. Steele, W. van der Hoek, P.H. Amerasinghe, and F.P. Amerasinghe. Forthcoming. *The cost of malaria control to government and households in Sri Lanka.*

4. Konradsen, F., W. van der Hoek, P.H. Amerasinghe, and F.P. Amerasinghe. 1997. Measuring the economic cost of malaria to households in Sri Lanka. *American Journal of Tropical Medicine and Hygiene*, 56: 656-660.

5. Konradsen, F., W. van der Hoek, P.H. Amerasinghe, F.P. Amerasinghe, and K.T. Fonseka. 1997. Household responses to malaria and their costs: A study from rural Sri Lanka. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 91: 127-130.

6. Konradsen, F., W. van der Hoek, P.H. Amerasinghe, F.P. Amerasinghe, and D. Perera. Forthcoming. *A village treatment centre for malaria: Community response.*

7. Konradsen, F., Y. Matsuno, F.P. Amerasinghe, P.H. Amerasinghe, W. van der Hoek. Forthcoming in *Acta Tropica*. *Anopheles culicifacies* breeding in Sri Lanka and options for control through water management.

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9. van der Hoek, W., F. Konradsen, D. Perera, P.H. Amerasinghe, and F.P. Amerasinghe. 1997. Correlation between rainfall and malaria in the dry zone of Sri Lanka. *Annals of Tropical Medicine and Parasitology*, 91: 945-949.

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11. van der Hoek, W., F.P. Amerasinghe, F. Konradsen, and P.H. Amerasinghe. 1998.Characteristics of malaria vector breeding habitats in Sri Lanka: Relevance for environmental management. *Southeast Asian Journal of Tropical Medicine and Public Health*, 29, 168-172.

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