CHARACTERISTICS OF MALARIA VECTOR BREEDING HABITATS IN SRI LANKA: RELEVANCE FOR ENVIRONMENTAL MANAGEMENT

Wim van der Hoek[1], Felix P Amerasinghe[2], Flemming Konradsen[1] and Priyanie H Amerasinghe[2]

[1]International Irrigation Management Institute, PO Box 2075, Colombo, Sri Lanka; [2]Department of Zoology, Faculty of Science, University of Peradeniya, Sri Lanka

Abstract. In and around a village in the Anuradhapura District of Sri Lanka anopheline larvae were sampled from July 1994 to April 1996 in all surface water bodies. Samples positive for *Anopheles culicifacies*, the established vector of malaria in Sri Lanka, and for *An. barbirostris, An. vagus,* and *An. varuna*, potential secondary vectors, were characterized by site, exposure to sunlight, substratum, turbidity of the water, presence of vegetation, and presence of fauna. Availability of pools of stagnant water in the stream near the village and along the edge of the village tank was highly predictive for presence of *An. culicifacies* larvae, independent from the other characteristics that were included in the study. The biological and physical characteristics could not very well explain the preference for certain habitats, but it was of interest that *An. culicifacies*, generally considered to bread in sun exposed clear water pools, was able to exploit habitats that were shaded and contained turbid water. Environmental management interventions to control *An. culicifacies* breeding have to take into account that the secondary vectors of malaria exploit other habitats and would not be affected by the interventions.

INTRODUCTION

To design the best environmental management interventions for the control of malaria there is a need to know the breeding preferences of the most important vectors. In addition to the identification of vector breeding sites in space and time, vector breeding habitats should be described with respect to bio-physical and water quality parameters. Also, good knowledge of breeding preferences and habitat characteristics of the major vectors will make it easier to predict the possible implication of development initiatives with an impact on the ecology of a particular area. In Sri Lanka a number of studies have been carried out describing the ecology of malaria vectors (Worth, 1937; Amerasinghe and Munashingha, 1988; Wijesundera, 1988; Amerasinghe and Ariyasena, 1990). These studies have established that *Anopheles culicifacies*, the principal vector of malaria in Sri Lanka, mainly breeds in small stagnant pools of water. Seasonal transmission as well as epidemics of malaria are dependent upon the availability of these temporary pools of water in river and stream beds.

An ongoing research project in the Anuradhapura District of Sri Lanka aims at identifying environmental management measures for malaria vector control in an agro-ecological region dominated by small scale reservoir (tank) based irrigation. A number of interventions to control vector breeding have been considered as part of a watershed management project being implemented in the same area. These include the maintenance of a constant flow in the natural streams to prevent pooling, improved drainage from the paddy fields and a reduction in the seepage area below the irrigation tanks. Other activities taking place in this area want to achieve more environmentally sustainable use of resources. While these are not aimed at malaria control, some interventions might have an impact on vector breeding. One of them is reforestation, including the planting of trees along rivers and streams. This could reduce sun exposure of stream bed pools making them less conducive for *An. culicifacies* breeding. Monitoring of entomological parameters is taking place in the research area since 1994. This also includes adult mosquito collections and preliminary results show that several species in addition to *An. culicifacies*, notably *An. barbirostris*, *An. vagus* and *An. varuna* can be positive for circumsporozoite proteins of *Plasmodium vivax* or *P. falciparum* with ELISA (Amerasinghe *et al*, unpublished data). These species would therefore have to be considered potential secondary vectors of malaria. A detailed study of anopheline breeding during the first 13 months of the project showed a great diversity in the types of

Tel:+94-1-867404; Fax:+94-1-866854; Email: w.van-der-hoek@cgnet.com

habitats utilized for breeding by different anopheline species (Amerasinghe *et al*, 1997). *An. culicifacies* was almost exclusively found in stream bed pools, tank bed pools and pools formed by rainwater in the drainage area. *An. varuna* was more or less restricted to the flowing stream and stream bed pools, *An. vagus* was the only potential vector with a preference for rice fields, and *An. barbirostris* made use of a rather wide range of habitats but not of stream and stream bed pools. The occurrence of potential secondary vectors of malaria with different breeding habits raises the question whether control interventions directed at *An. culicifacies* would create ecological changes that increases the breeding potential of the secondary vectors. Secondly, there is the question whether *An. culicifacies* will be able to explore alternative breeding sites that are not affected by a control intervention. In the present report breeding sites of the four potential vectors of malaria in the study area are described with respect to biological and physical characteristics to try to answer these questions.

MATERIALS AND METHODS

The study was performed near the village of Mahameegaswewa in the Anuradhapura District of Sri Lanka (Fig 1). The village is situated close to the Yan Oya stream which forms the main waterway in the greater watershed of Huruluwewa. This natural stream does not provide irrigation water for the village, but it is incorporated into the large scale Mahaweli Developmental Project. Fields are irrigated with water from an ancient tank. Sampling methods for immature mosquitos have been described before (Amerasinghe *et al*, 1997). The present study refers to samples obtained from the start of the research project in July 1994 to April 1996. All surface water bodies in and around the village were sampled fortnightly and with an equal sampling effort. Samples were characterized by site, exposure to sunlight, substratum, turbidity of the water, presence of vegetation, and presence of fauna.

In the analysis, first the characteristics of samples positive for *An. culicifacies* larvae or pupae were compared with samples positive for other anopheline mosquitos. This ensured that only samples were included from habitats that were suitable for anopheline breeding. In addition, to collect information on variables that could explain preference of *An. culicifacies* for certain breeding sites, positive samples were compared with *An. culicifacies* negative samples, excluding those months when no *An. culicifacies* were found. Results are reported as odds ratios (OR), defined in this context as the odds of a certain factor being present in breeding sites positive for *An. culicifacies* divided by the odds of the factor being present in breeding sites negative for *An. culicifacies*. Odds ratios were adjusted for confounding by other variables using logistic regression.

RESULTS

Table 1 shows the diversity of types of habitats utilized for breeding by the four potential vectors of malaria in Huruluwewa. Table 2 gives the physical and biological characteristics of the anopheline breeding sites. Most of the anopheline larvae were found in clear water with the exception of *An. culicifacies*. While 73.2% of the *An. culicifacies* positive samples in stream bed pools were from clear water, only 10.0% of positive samples from tank bed pools were from clear water. It shows some flexibility in physical water quality requirements of *An. culicifacies*. Generally anophelines were found in sun exposed or partially shaded habitats, with the exception of *An. varuna*. Positive samples for *An. culicifacies* and *An. varuna* were often from habitats with a sandy or mixed sand-mud bottom. Most samples positive for anopheline

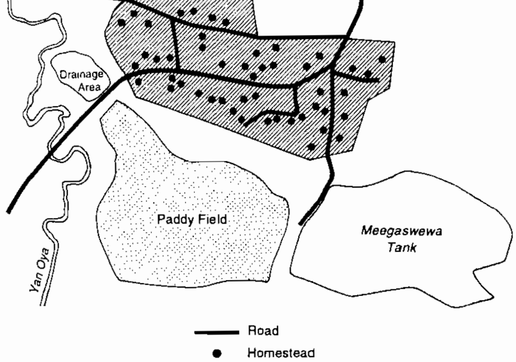

Fig 1–Map of Mahameegaswewa village with surface water bodies sampled for immature mosquitos.

Table 1

Breeding habitats of potential malaria vectors in Huruluwewa, July 1994 to April 1996. Columns give the percentage distribution of positive samples for each species by habitat.

Habitat	ANCU[1](%)	ANBR[2](%)	ANVG[3](%)	ANVR[4](%)	Total(%)
Stream	9.9	3.3	0.0	57.4	26.5
Stream bed pools	42.7	2.9	1.0	24.3	15.7
Tank	3.1	19.1	2.0	4.3	10.0
Tank bed pools	30.5	5.5	18.2	1.1	7.0
Tank seepage area	3.8	34.3	8.1	4.6	16.9
Rainwater pools[5]	9.2	13.0	11.1	1.4	7.6
Rice fields	0.8	12.5	51.5	1.2	9.5
Irrigation canals[6]	0.0	9.4	8.1	5.7	6.8
Total	100 n = 131	100 n = 545	100 n = 99	100 n = 564	100 n = 1,339

[1] ANCU: *An. culicifacies*
[2] ANBR: *An. barbirostris*
[3] ANVG: *An. vagus*
[4] ANVR: *An. varuna*
[5] including rain water pools in the paddy field drainage area
[6] small field canals leading from the tank outlet through the paddy fields

Table 2

Physical and biological characteristics of anopheline breeding sites in Huruluwewa.

Characteristics of breeding sites	Species				
	An. culicifacies	*An. varuna*	*An. vagus*	*An. barbirostris*	Other anophelines
No. of positive samples	131	564	99	545	697
Water quality (%)					
Clear	47.3	79.6	63.6	65.1	70.2
Turbid	52.7	20.4	36.4	34.9	29.8
Sunlight (%)					
Exposed	48.1	19.5	89.9	49.2	66.0
Partial shade	40.5	64.0	10.1	42.9	28.8
Shaded	11.5	16.5	0.0	7.9	5.2
Substratum (%)					
Mud	56.5	52.0	99.0	85.5	92.1
Other	43.5	48.0	1.0	14.5	7.9
Vegetation (%)					
Present	67.2	89.7	81.8	91.7	88.5
Absent	32.8	10.3	18.2	8.3	11.5
Fauna (%)					
Present	45.0	34.4	17.2	31.9	20.9
Absent	55.0	65.6	82.8	68.1	79.1

mosquitos were from habitats that contained vegetation, but this was less pronounced for *An. culicifacies*. Main vegetation types found in connection with anopheline mosquitos were grass (42.4% of all samples positive for anopheline mosquitos), rice plants (11.7%), other live vegetation such as water plants, roots, and algae (30.3%), and dead leaves (40.2%). *An. culicifacies* positive samples more often had fauna present than samples that were positive for the other anophelines. Most important fauna encountered in the habitats were frogs, fish, shrimps, and water bugs. Of these most species of fish and water bugs can be considered predators of mosquito larvae. The multivariate analysis showed significant but weak negative associations for *An. culicifacies* with clear water (OR 0.62, 95% CI 0.40-0.99) and with muddy substratum (OR 0.57, CI 0.33-0.98). Regression coefficients for exposure to sunlight, presence of vegetation, fauna and culicine mosquitos were not statistically significant. The variables did not explain *An. culicifacies* breeding very well. When including habitat in the model, with the flowing stream as reference, strong associations remained with stream bed pools (OR 6.07, CI 3.12-11.82) and tank bed pools (OR 6.12, CI 2.73-13.74). This indicates that there are other characteristics that made stream bed pools and tank bed pools suitable for *An. culicifacies* breeding and that were not included in the present study.

Presence of stream bed pools, tank bed pools and rain water pools changed greatly during the study period. From July to October 1994 there was significant pooling, with *An. culicifacies* breeding. In the same months in 1995 very little pooling was observed with no *An. culicifacies* breeding at all. With the sampling effort remaining the same throughout the study period, there was a decline in number of samples from stream bed pools from 268 (37% of total number of samples from July to October 1994) to 23 (2% of total number of samples from July to October 1995). Compared with July to October 1994 there were also reductions in availability of rainwater pools (12.3% to 0.1%) and to a lesser extent for tank bed pools (15.8% to 11.4%) for the same months in 1995. While absence of rain water pools can be explained by the low annual rainfall in 1995 (960 mm against 1,510 mm in 1994) (Department of Meteorology, unpublished data), pooling in the stream did not occur because of more water releases into the Yan Oya stream from the Mahaweli irrigation system (Irrigation Department, unpublished data).

DISCUSSION

Species specific control interventions aimed at reducing the breeding of malaria vectors run the risk that other vectors not affected by the interventions will maintain transmission or that the target vector explores alternative breeding sites. The present study confirms that in this part of Sri Lanka *An. culicifacies* is able to explore other habitats, especially tank bed pools and rainwater pools, with different biological and physical characteristics. The presence of *An. culicifacies* in tank bed pools with turbid water could indicate that the physical quality of water may not play such an important role as previously assumed. However, in the period of 1995 and 1996 covered in this study, when only a very limited number of stream bed pools were generated, very little larval breeding occurred despite the availability of tank bed pools. It was shown before that tank bed pools are available for only a short period and that they are exploited for breeding only when large populations of adult mosquitos have built up and are deprived of their favorite breeding sites in stream bed pools (Amerasinghe *et al*, 1997). Interventions directed at the prevention of stream bed pooling could therefore be effective even when *An. culicifacies* has the capacity to breed in other habitats. Such interventions will have no effect on *An. barbirostris* and *An. vagus* as these species make use of other breeding habitats. *An. varuna* was mainly found in slow flowing stream water and in stream bed pools and for the control of this potential vector it might be necessary to maintain a certain minimum flow velocity in the stream. While all potential vectors preferred sun exposed habitats, a considerable number of positive samples was found in partially shaded stream bed pools. It is therefore doubtful whether shading of the stream would have much effect. However, early studies on anopheline breeding in Sri Lanka found a strong preference of *An. culicifacies* for sun exposed habitats (Carter, 1929). The removal of vegetation from potential breeding sites will according to this study also not be an effective way to control *An. culicifacies* populations.

Availability of stream bed pools and tank bed pools was highly predictive for presence of *An.*

culicifacies larvae, independent from the limited number of biological and physical characteristics used in this study. This means that some other factors play a role such as chemical parameters, presence of nutrients, or level of dissolved oxygen (Amerasinghe *et al*, 1995). A study has been started on these water quality parameters in the same study area. Despite the uncertainties, the presence of a single important vector which is restricted to specific breeding habitats over a short period of time makes a strong case for the further development and testing of environmental or engineering interventions to control malaria.

ACKNOWLEDGEMENTS

Financial support for this work was provided by the Danish International Development Agency (DANIDA), the Norwegian Agency for Development Co-operation (NORAD) and the Government of Japan.

REFERENCES

Amerasinghe FP, Munasingha NB. A predevelopment mosquito survey in the Mahaweli Development Project area, Sri Lanka: Immatures. *J Med Entomol* 1988; 25 : 286-94.

Amerasinghe FP, Ariyasena TG. Larval survey of surface water-breeding mosquitoes during irrigation development in the Mahaweli Project, Sri Lanka. *J Med Entomol* 1990; 27 : 789-802.

Amerasinghe FP, Konradsen F, Fonseka KT, Amerasinghe PH. Anopheline (Diptera: Culicidae) breeding in a traditional tank-based village ecosystem in north-central Sri Lanka. *J Med Entomol* 1997; 34 : 290-7.

Amerasinghe FP, Indrajith NG, Ariyasena TG. Physico-chemical characteristics of mosquito breeding habitats in an irrigation development in Sri Lanka. *Ceylon J Sci* 1995; 24 : 13-29.

Carter HF. Further observations on the transmission of malaria by anopheline mosquitoes in Ceylon. *Ceylon J Sci* 1930; 2 : 159-76.

Cowper LT. Malaria Vectors Associated with Rice Culture in Southeast Asia and the Western Pacific. In: Vector-borne Disease Control in Humans through Rice Agroecosystem Management. International Rice Research Institute, Philippines, 1988.

WHO. Vector Control for Malaria and Other Mosquito-borne Diseases. *WHO Tech Rep Ser* 1995; 857.

Wijesundera M, de S. Malaria outbreaks in new foci in Sri Lanka. *Parasitol Today* 1988; 4 : 147-50.

Worth HN. The control of anopheline breeding in river beds. *Trans R Soc Trop Med Hyg* 1937; 30 : 521-30.