assessing the options for control of malaria vectors through different water management practices in a natural stream that formed part of such a tank cascade system. The studies established conclusively that *An. culicifacies* was the major vector of epidemiological importance and that a small river, the Yan Oya, was the primary vector-breeding habitat in the watershed, which posed a significant risk factor for malaria early during the transmission season. Villages further away from the stream had lower densities of the main vector, and concomitantly lower malaria than the villages closest to the stream. Detailed analyses of water dynamics of the entire watershed area have been used to model different water management practices that could reduce vector breeding in this key habitat and thereby have a system-wide impact on malaria in the watershed. The most viable management option was a redistribution of existing water flows in order to maintain a water depth sufficient to discourage the breeding of the vector (Matsuno et al. 1999). Costs analyses of the potential water management measures and other vector control interventions such as the spraying of houses with insecticides and the use of bed nets have shown that flushing the streams through seasonal water releases from upstream reservoirs would be the cheapest vector control measure (Konradsen et al. 1999). These studies were implemented by a multidisciplinary research team with expertise in the diverse disciplines of vector ecology, parasitology, epidemiology, social science, economics and irrigation engineering (representing IWMI, the University of Peradeniya and the Anti-Malaria Campaign). In the second phase of this project the water management methods will be implemented on a routine basis in consultation with the health workers, irrigation managers and farmers and the impact on vector mosquitoes and malaria incidence monitored.

Water management and other environmental management methods deserve a place in malaria control activities. Key issues in determining the success of environmental methods are (1) knowledge of the local vector ecology and malaria epidemiology; and (2) close interactions and real collaboration between health specialists and engineers.

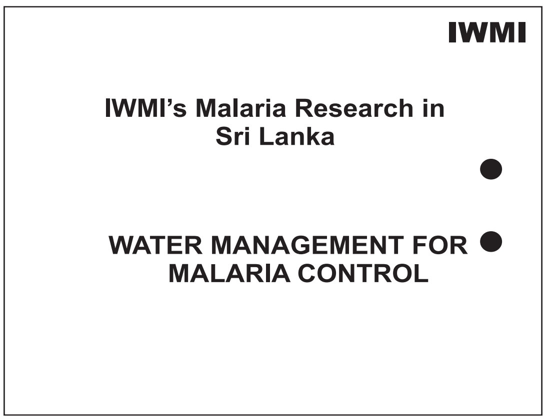
Towards a risk map of malaria for Sri Lanka

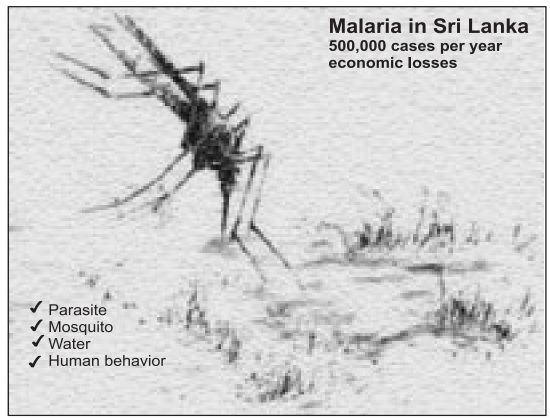
It is a logical step from detailed studies on vector ecology, risk factors for malaria, and socioeconomic aspects of the disease to the development of a risk map for malaria. Such a risk map would primarily be based on the availability of surface water that has the potential for pooling and generation of vector mosquitoes. It is expected that people living close to the breeding sites are at higher risk for malaria than people living further away. In a geographic information system (GIS), the malaria incidence and population distribution could be superimposed on a map of all potential breeding sites. This makes it possible to derive a function showing the relationship between distance to breeding site and malaria. In a GIS other variables that play a role in malaria transmission can also be included. Some information, such as land use patterns can now easily be obtained from satellite remote sensed imagery and imported into GIS.

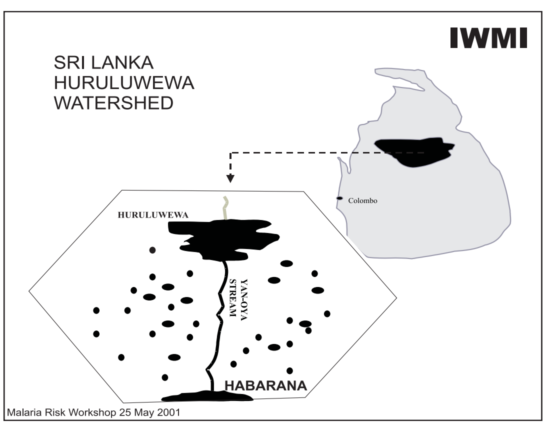
A malaria risk map will make it possible to target priority areas with control activities, such as insecticide house spraying, larviciding, and bed net programs. Including temporal changes in the malaria risk map will make it possible to use it as an early warning system for impending epidemics.

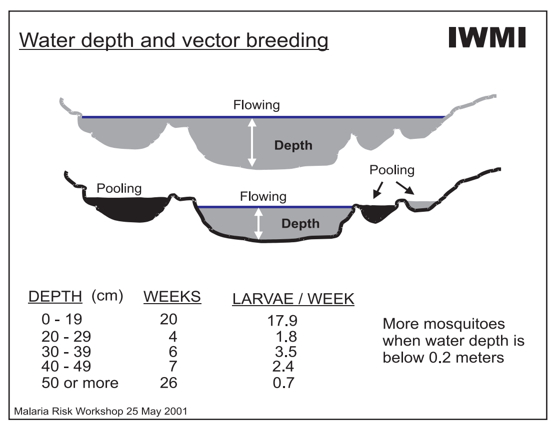
The first phase of the IWMI project was implemented in the Uda Walawe area where malaria incidence was mapped and related to environmental variables at the lowest administrative (GN) level. Larval, adult and human malaria surveys will be needed to validate predictive models. These models will then be modified if necessary. An extension of the risk map project is proposed in a more participatory way. Regional workshops would be held where staff from AMC and the Ministry of Health are encouraged to collect the necessary data from their own areas. Training will be provided to enable participants to process the data and make the resulting maps available for routine management. This exercise could then be expanded to other divisions and districts in a stepwise fashion and eventually cover the entire island. For this approach to be successful, a partnership is needed between the Ministry of Health (including AMC), research organizations (universities, IWMI), international organizations (WHO), and NGOs working in poorly accessible areas.

PowerPoint slides presentation





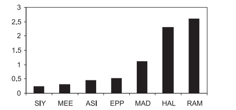




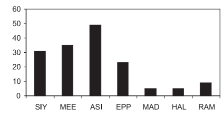
Huruluwewa watershed

IWMI

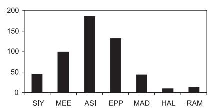
Average distance from Yan Oya (km)



Number of *An. culicifacies* per house (km)



Number of malaria cases per 1000



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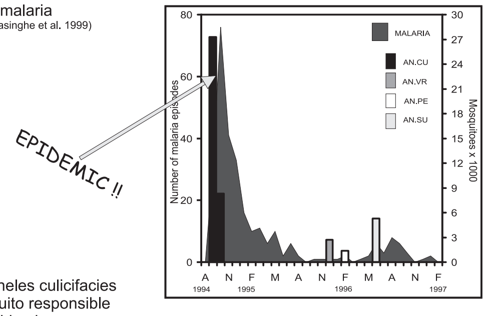
Mahameegaswewa

infective vectors and malaria

(Amerasinghe et al. 1999)

IWMI



Anopheles culicifacies mosquito responsible for epidemic

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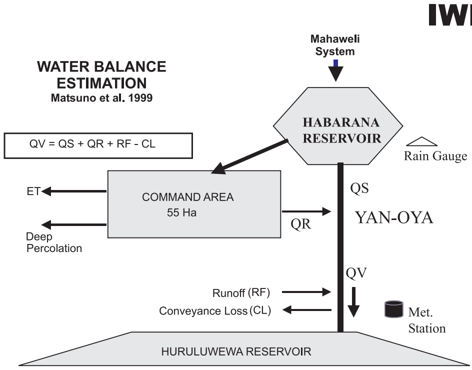
WATER BALANCE ESTIMATION

Matsuno et al. 1999



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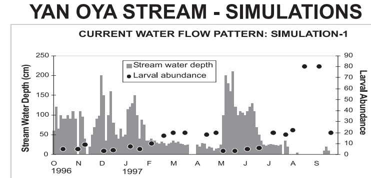
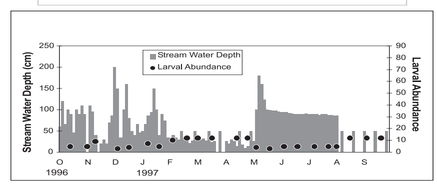
YAN OYA STREAM - SIMULATIONS





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Cost of malaria control

	US$
Insecticide spraying	2.75
Impregnated bed nets	1.02
Larviciding	0.53
Water management	0.26

Total annual cost per individual protected

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Huruluwewa: 7 villages

n = 210 cases, 1100 controls

Distance house - stream	Relative Risk for malaria
< 250 m	13.6
250 – 499	6.8
500 – 749	9.2
750 – 999	1.3
1000 – 1249	1.7
>= 1250	1.0

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Clearing of dead trees blocking the stream

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Straightening stream bed

IWMI

- ✓ Excavate shallow inner bends
- ✓ Use government excavator and personnel
- ✓ Excavator crawls along stream straightening, pushing live trees, removing dead logs
- ✓ Removed ground to be deposited in sand mining pits

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Laundry and bathing sites

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Rapids (continued)

IWMI

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CGIAR sima SYSTEMWIDE INITIATIVE ON MALARIA AND AGRICULTURE

IWMI

ACTION PLAN

for a

Systemwide Initiative
on
Malaria and Agriculture

PROPOSAL OUTLINE 1
May 16, 2001

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CGIAR sima SYSTEMWIDE INITIATIVE ON MALARIA AND AGRICULTURE

IWMI

Better agro-ecosystem management can contribute to malaria control, leading to increased agricultural productivity and poverty alleviation

- Scientific documentation of interactions between agriculture and malaria
- Agricultural practices, development strategies and policies tested and developed
- Partnerships between the health and agricultural sectors
- Capacity enhanced for inter-sectoral research on health and agriculture

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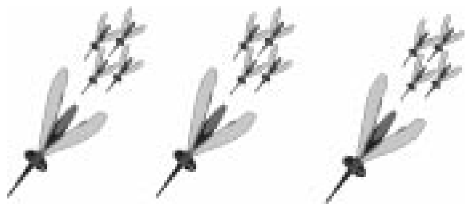
Malaria Vectors in Sri Lanka

Dr. Felix P. Amerasinghe, Principal Researcher,
Water, Health and Environment Theme, IWMI

Anopheles culicifacies was originally incriminated (between 1913 and 1930) as the vector of malaria in Sri Lanka based on the evidence of dissections. More recent Enzyme Linked Immunosorbent Assay (ELISA)-based evidence (sometimes supplemented by dissection) has shown a large number of anopheline species to be infected in addition to *An. culicifacies*. These species are *An. aconitus, An. annularis, An. barbirostris, An. nigerrimus, An. pallidus, An. peditaeniatus, An. subpictus, An. tessellatus, An. vagus* and *An. varuna*. This does not automatically mean that all these species are effective field vectors. Species that have consistently been incriminated are *An. annularis, An. subpictus, An. vagus, An. varuna* and (to a lesser extent) *An. tessellatus*. These species have differing biting and resting behaviours that place humans at differential risk, depending on the vector. *An. culicifacies* and *An. subpictus* bite indoors and outdoors, but the other species are primarily outdoor biters. Biting periodicity too, varies from species to species. Malaria control entomology in Sri Lanka is based around *An. culicifacies*, and so the major strategy is of indoor residual insecticide spraying that targets indoor resting and feeding adults. Vector control of immature stages, too, is directed at the primary vector alone, in the form of larviciding the major breeding habitats such as stream and riverbed pools. There is presently no effective strategy against the subsidiary vectors—those that bite primarily outdoors and breed in a multitude of other habitats. Ecological research over the past two decades has resulted in good information on the ecology of these species that could be used to advantage in devising control options where such species are locally important in transmission. Another aspect that deserves more attention is that of sibling species: recent research shows that siblings B and E of *An. culicifacies* occur in the country, and based on Indian studies, the latter appears to be the efficient vector. We know little of the differential ecologies of these two siblings in Sri Lanka. Four siblings (A,B,C,D) of *An. subpictus* are present, with the salt-water breeding sibling-B prevalent in coastal areas, and the freshwater breeding sibling-C prevalent in inland areas. Whilst *An. subpictus* s.l. has been regularly incriminated in malaria transmission, we have little information on which sibling is involved—a very limited study has implicated sibling-C, but this study is certainly of inadequate size and duration for firm conclusions to be drawn. Two sibling species are presently known for *An. annularis*, but their status in Sri Lanka is unknown. Investigating this is a matter of some importance because *An. annularis*, too, is a species that has been involved in malaria transmission in several instances in the recent past. Research on these subsidiary vectors of malaria is very relevant because it is likely that they will assume greater importance in transmission as human populations increase and more and more natural resource areas are opened up for human settlement.

IWMI

MALARIA VECTORS IN SRI LANKA



Felix P. Amerasinghe

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IWMI

Several anopheline mosquitoes implicated in malaria transmission in Sri Lanka

Anopheles aconitus — *Anopheles annularis*

Anopheles barbirostris — *Anopheles culicifacies*

Anopheles pallidus — *Anopheles peditaeniatus*

Anopheles nigerrimus — *Anopheles subpictus*

Anopheles tessellatus — *Anopheles vagus*

Anopheles varuna

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IWMI

Sri Lanka

All evidence points to major vector being *An. Culicifacies*

Evidence also indicates that *An. Subpictus* is a secondary vector.

Other species that could be locally important in transmission are: *An. Annularis, An. Tessellatus, An. Vagus and An. varuna.*

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Documented instances of other vector involvement in malaria transmission

Anopheles annularis - Mahaweli System-C; System B; Southern Sri Lanka? (PF/PV)

Anopheles subpictus – *Kataragama Mahaweli System-C (PF/PV)*

An. Varuna - Elahera, Huruluwewa (PV-VK247*)*

Other instances in grey Literature?
E.g., Among recent AMC records*?*

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BITING & RESTING HABITS

An. Culicifacies, An. subpictus: Indoor & outdoors

Main control strategy: indoor residual spraying, bednets

No control strategy

An. Annularis, An. tessellatus — *An. Vagus, An. Varuna:*

Primarily outdoors

No control strategy

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IWMI

BREEDING - major habitats

An. culicifacies: stream/riverbed pools

Main control strategy: larviciding

No control strategy

An. Subpictus, An. vagus: turbid pools, rice fields
An. Tessellatus: rainwater pools
marshes, tank, canals
pools

An. Annularis:
An. Varuna: streams,

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Sibling species:

- Morphologically identical (or almost identical) in all life stages (larva, pupa, adult).
- Genetically distinct, reproductively isolated.
- Behaviourally distinct: breeding/biting/resting
- Different vectorial capacities
- Different insecticide resistance capabilities

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Sibling species can be detected on the basis of:

- Inversions on polytene chromosomes
- Structural variations in metaphase Y-chromosomes
- Electrophoretic variations in LDH-enzymes
- Species-specific cuticular hydrocarbon profiles
- DNA-probes
- Polymerase Chain Reaction (PCR) assays

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Anopheles culicifacies consists of a complex of 5 sibling species (A, B, C, D, E,)

INDIA

	A	B	C	D	E
% Human biting	0-4	0-1	0-3	0-1	?
Biting Activity	All Night	All Night	All Night	Upto Midnight	?
Peak biting	22-23	22-23	18-24	18-24	?
PV/PF	vector	non/poor vector	vector	vector	vector
Sporozoite Rate	0.51	0.04	0.30	0.40	0.46

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In Sri Lanka: *An.culicifacies*

Hitherto: only B occurred, and was the major vector.

Now: B and E have been identified (Surendran et al. 2000).

The both siblings occurred in:

- Moneragala District (Pelawatta)
- Puttalam District (Elivitiya)
- Trincomalee District (Puliyankulam)

Only sibling E occurred in Badulla District (Aluthwela)

Based on the limited study done, E seems to be more common than B.

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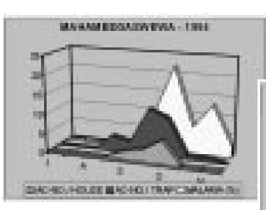
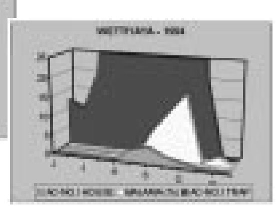
IWMI

Two riverine villages - different transmission patterns





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An. culicifacies B and E

We have no precise information on

- distribution
- breeding ecology
- biting habits
- resting habits
- vectorial capacity
- insecticide resistance status

of these two sibling species in Sri Lanka.

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