Study of Vector Aspects of Mosquito-Borne Diseases in Some Irrigation Schemes in Sri Lanka

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Water resource development in Sri Lanka dates back several centuries. In recent times the Government of Sri Lanka has undertaken a number of multipurpose water development projects primarily to increase agricultural production and hydroelectric power generation, and to generate additional employment. Environmental changes associated with development of irrigated agriculture and human settlements are known to have a great impact on vector-borne diseases. This paper presents preliminary findings from two projects investigating the relationship between water development systems and mosquito vectors.

Project 1

The primary objective of Project 1 was to determine the prevalence and abundance of the mosquito vectors and malaria, filariasis, and arboviral diseases in some water resources development project, in Sri Lanka.[2]

Originally recommended by the WHO/FAO/UNEP Panel of Expert, on Environmental Management for Vector Control (PEEM), the project was financed by the World Health Organization (WHO) and carried out under the joint coordination of the South Asia Cooperative Environment Program (SACEP) and the Sri Lankan Ministry of Health (MOH). Implementation was undertaken by the Anti-Malaria Campaign, Anti-Filariasis Campaign, and Medical Research Institute (Annex 1). The level of successful implementation of the study can serve, therefore, as an indicator of the efficacy and limitations of intersectoral/interinstitutional collaboration.

Study areas. Investigations were carried out in selected localities of the Mahaweli Development Project, System C, Zone 2 (Mahaweli C2), which is an area with a changing environment where irrigation water services and human settlements have been completed very recently (Map 1); and selected localities in Kirindi Oya/Lunugamwehera Project in southeastern Sri Lanka where settlements/ resettlements (Map 2) are in progress and irrigation water services have not yet started. The studies were conducted in each area in 2 phases of 21 days duration during the wet and dry periods.

Experimental procedure. Adult and larval mosquitoes were collected outdoors and inside "cadjan" (palm leaf) huts using human bait at night, hand collecting techniques, pyrethrum spray, cattle-hailed net traps, bird/pig baited-traps, exit window traps, and larval sampling in both natural and man-made potential breeding habitats.

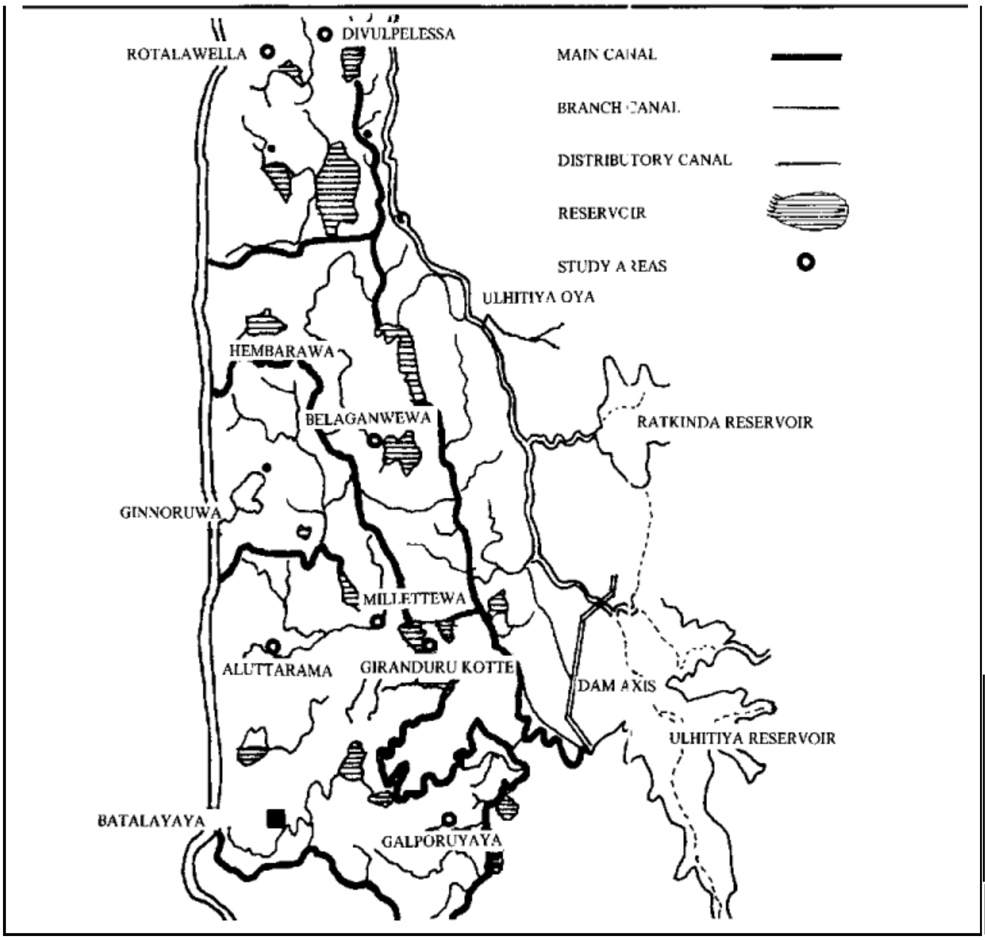
After species identification of all samples, the potential vectors of filariasis were dissected for microfilarial infections. Mosquitoes collected from pig-baited traps were used to isolate Japanese encephalitis (JE) virus.

Results and observations. This paper summarizes mainly the entomological findings in phase 1 (wet period). Laboratory processing of the material collected in phase 2 (dry period) is ongoing.

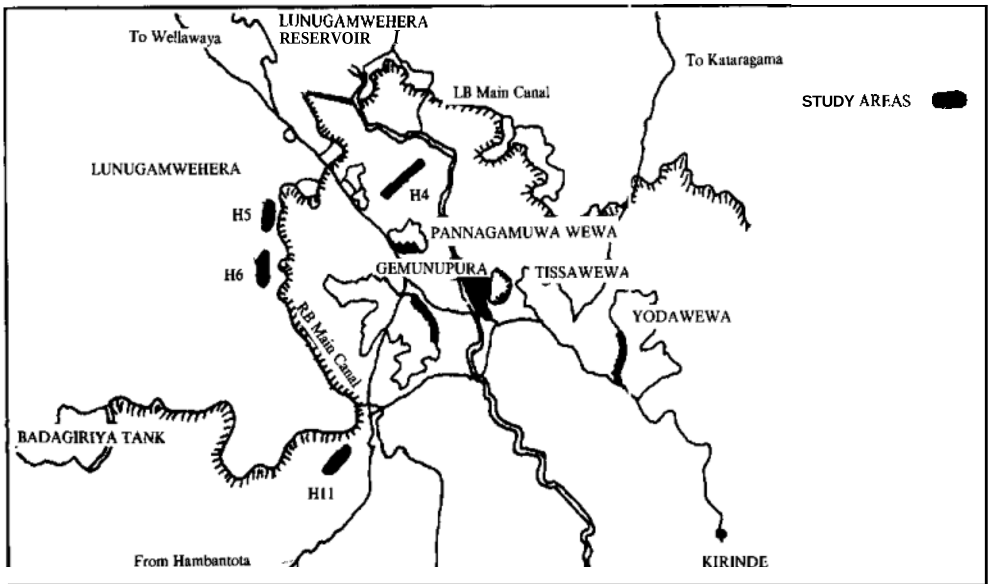
Forty-four species of mosquitoes, involving 13 species of anophelines and 31 of culicines were encountered in Mahaweli C2, and 11 anophelines and 27 culicines from the Lunugamwehera/Kirindi Oya sites. Most of the species were common to

[1]All the authors except W.M. Nanayakkara participated in Project 1, only P R.J Herath and W M Nanayakkara participated in Project 2.

[2]For detailed information on the arboviral component of this study, please refer to the article in these proceedings by T. Vitarana et al.



Map 1
Project 1 study areas in Mahaweli C2



Map 2
Project 1 Study areas in Kirindi Oya.

both areas. *Culex hutchinsoni,* which has not been recorded previously in Sri Lanka[3], was reported from Mahaweli C2. Tables 1a and 1b show the mosquito fauna encountered in the two areas.

Table 1a. Mosquito fauna (Culicines) encountered in some of the representative areas of Mahaweli C2 and Kirindi Oya, 1985.

Species (Culicines)	Mahaweli System C	Kirindi Oya
Mimomyia (Mimomyia) hybrids	+	
M. (Etorleptiomya) luzonensis	+	
Coquillettidia (Coquillettidia) crassipes	+	
Mansonia (Mansonoides) annulifera	+	+
M. (Mnd) indiana	+	
M. (Mnd) uniformis	+	
Aedes (Aedeomyia) catasticta	+	
A. (mucidus) scataphagoides	+	
A. (Finlaya) gubernatoris	+	+
A. (Christophersiomyia) thomsonii	+	
A. (Stegomyia) aegypti	+	+
A. (Stg) albopictus	+	+
A. (Adimorphus) alboscutellatus		+
A. (Adm) jamesii	+	+
A. (Adm) pallidostriatus	+	
A. (Adm) pipersalatus	+	+
A. (Adm) taeniorhynchoides	+	+
A. (Adm) vexans vexans	+	
A. (Adm) vittatus	+	+
A. (Verrallina) butleri	+	
A. (Neomelaniconion) lineatopennis	+	+
Armigeres (Armigeres) subalbatus	+	+
Culex (Lutzia) fuscanus		
C. (Eumelanomyia) minutissimus	+	+
C. (Culiciomyia) nigropunctatus		+
C. (Cui) pallidothorax		
C. (Culex) bitaeniorhynchus	+	+
C. (Cux) gelidus		+
C. (Cux) mimulus		+
C. (Cur) pseudo vishnui	+	+
C. (Cux) quinquefasciatus	+	+
C. (Cux) sitiens		+
C. (Cux) tritaeniorhynchus	+	+
C. (Cux) vishnui		
C. (Cux) whitmorei	+	+
C. (Cux) hutchinsoni	+	

Table Ib. Mosquito fauna encountered in some representative areas of the Mahaweli System and Kirindi Oya, 1985.

Species (Anopheline)	Mahaweli System C	B	H	Kirindi Oya
A. aconitus		-	+	
A. annularis	+	+	+	+
A. barbirostris	+	+	+	+
A. culicifacies	+	+	+	+
A. jamesii	+	+	+	+
A. maculatus	+	+	+	+
A. nigerrimus	+	+	+	+
A. pallidus	+	+	+	
A. peditaeniatus				
A. ramsayi				
A. subpictus	+	+	+	+
A. tesselatus	+	+	+	+
A. vagus	+	+	+	
A. varuna	+	'	+	+

Among these are a number of species known to be vectors or potential vectors of malaria, filariasis, and arboviral diseases. Figure 1 compares the relative proportions of the different vectors and potential vectors from these areas.

Most of the anopheline species recorded are those which are commonly encountered in malarious areas of Sri Lauka. ***A. culicifacies,*** **known** to be the most important vector of human malaria in the country, was present in very small numbers in both areas. In addition, 10 species of anopheline ***(A. annularis, A. barbirostria, A. jamesii, A. maculatus, A. nigerrimus, A.*** pallidus, ***A. subpictus, A. tessellatus, A. vagus*** and ***A. varuna)*** which are considered potential vectors of human malaria in Sri Lanka occurred in both regions[4] ***A. nigerrimus*** was the predominant anopheline species. Malaria is known to be endemic in both areas.

[3]Jayasekera, N. and R.V. Chelliah. 1981. An annotated checklist of mosquitoes of Sri Lanka" *MAB* (National Science Council) 8:1-16. Colombo, Sri Lanka.

[4]Herath, P.R.J., T. Abeywardena. and U.G.K. Padmalal 1983. A study of the role of different indigenous Anophelins species in the transmission of human malaria in Sri Lanka. *Proc Sri Lanka Assoc Adv Sci.* 6 (abstract).

Figure *1*. Relative proportions of different vectors and potential vectors in Mahaweli C (Jan/Feb) and Kirindi Oya (Feb/Mar), 1985.

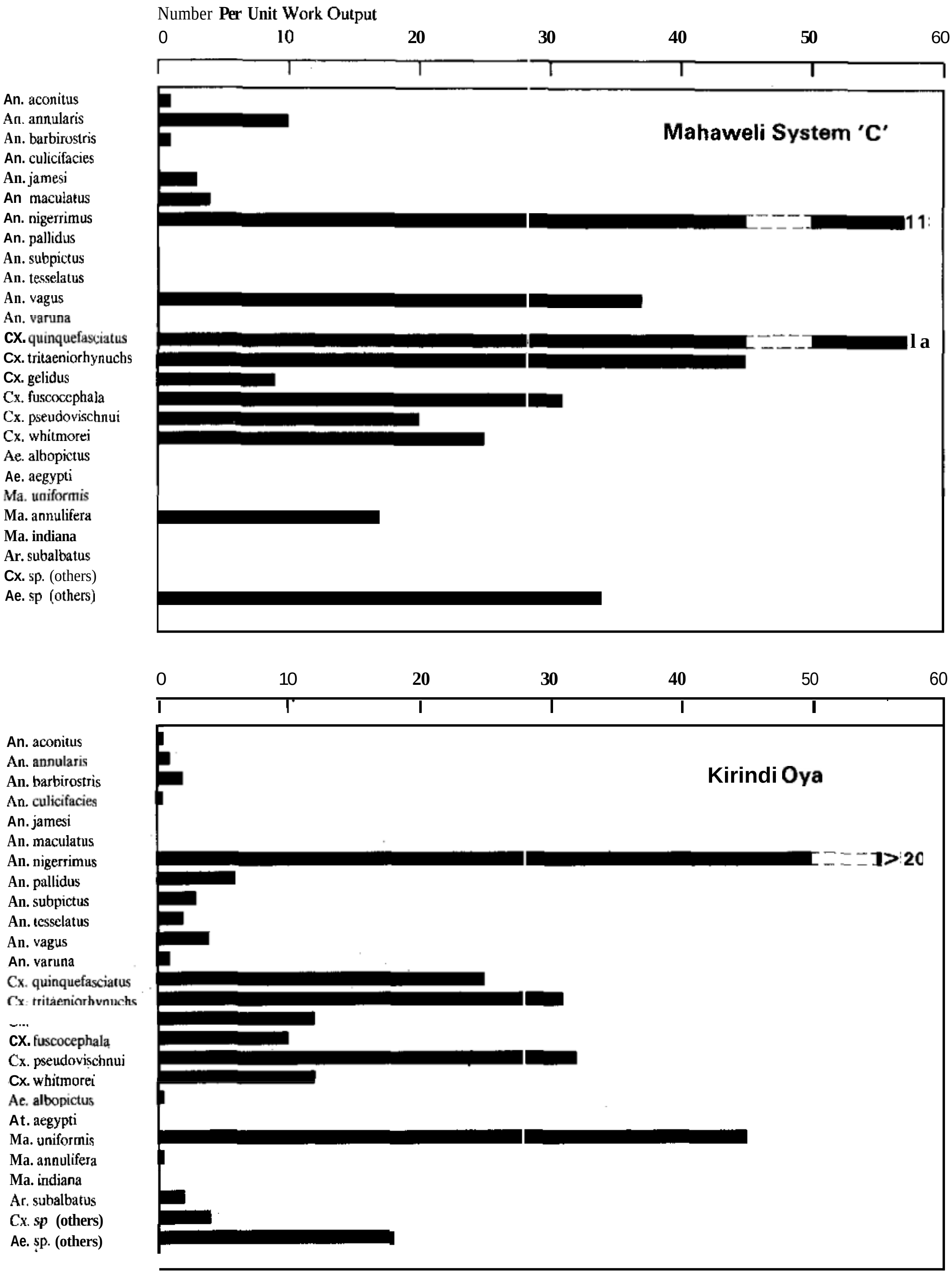


Table 2a. **Major Breeding Places of mosquito vectors (established and potential vectors) of disease encountered in Mahaweli System C/Zone 2 February/March 1985.**

Breeding places	Anopheline I-II Larvae	An (c) culicifacies	An (A) barbirostris	An (A) nigerrimus	An (A) peditaeniatus	An (c) aconitus	An (c) annularis	An (c) jamesi	An (c) kawari	An (c) maculatus	An (c) pallidus	An (c) subpictus	An (c) tesselatus	(c) varuna	An (c) vagus	Ae (Stg) aegypti	Ae (Stg) albopictus	Am (Arm) subalbatus	Cx (Cux) gelidus	Cu (Cux) fuscocephala	Cx (Cux quinquefasciatus	Cx (Cux) tritaeniorhynchus	Cx (Cux) pseudovishnui	Ma (Mnd) annulifera	Ma (Mnd) indiana	Ma (Mnd) uniformis
1. Rice fields	+			+										+					+	+		+				
2. Irrigation canal	+																									
3. Irrigation tank	+																									
4. Tank margin	+																									
5. Ground pool (rain water)	+	+		+				+											+	+		+	+			
6. Rock pals	+																									
7. Borrowpit	+																		+	+						
8. Catchpit																					+					
9. Damaged seal pit																					+					
10. Blocked drains																					+					
11. Earth drains																				+	+					
12. Marshy land	+			+																		+				
13. Cement tanks				+																						
14. Discarded recepticles																+	+	+			+					
15. Barrels																	+				+					
16. Tyres																	+				+					
17. Tree hales																	+	+								

Table 2b. **Major Breeding Places of mosquito vectors (atablished and potential vectors) of disease encountered in Kirindi Oya February/March 1985.**

Breeding Places	Anopheline I-II Larvae	An (c) culicifacies	An (A) barbirostris	An (A) nigerrimus	An (A) peditaeniatus	An (c) aconitus	An (c) annularis	An (c) jamesi	An (c) kawari	An (c) maculatus	An (c) pallidus	An (c) subpictus	An (c) tesselatus	An (c) varuna	An (c) vagus	Ae (Stg) aegypti	Ae (Stg) albopictus	Am (Arm) subalbatus	Cx (Cux) gelidus	Cx (Cux) fuscocephala	Cx (Cux) quinquefasciatus	Cx (Cux) Tritaeniorhynchus	Cx (Cux) pseudovishnui	Ma (Mnd) annulifera	Ma (Mnd) indiana	Ma (Mnd) uniformis
1. Borrow pit	*	+	+				+	+			+	+		+	+					+						
2. catch pit				+																						
3. Damaged seal pit																										
4. Blocked drains																	+			+	+	+				
5. Ground pol	+	+		+								+			+											
6. Rain water pools	+											+										+	+			
7. Rock pools	+	+	+	+	+							+														
8. Earth drains																					+					
9. Rice fields	+		+	+				+			+			+	+							+	+	+		
10. Marshy land	+			+																						
11. Cement tanks																	+				+					
12. Discarded recept																	+	+			+					
13. Barrels																	+									
14. Tyres																	+									
15. Irrigation canal	+			+										+	+							+	+			
16. Irrigation tank	+			+			+				+	+			+					+		+	+			
17. Tree holes																										
18. Sand pools	+			+										+		+										
19. Coconut shells	+																+	+								

The major breeding habitats of the non-anopheline species are shown in Tables 2a and 2h.

Culex quinquefasciatus, the established vector of bancroftian filariasis (due to *Wuchereria bancrofti)* in Sri Lanka, was the predominant mosquito species in the Mahaweli area and was also present in high numbers at Kirindi Oya. They were found to breed in a variety of man-made habitats which seem to be closely associated with rapid urbanzation. Although this type of filariasis is believed to he confined to a southwestern coastal endemic belt, it has been shown that the natural populations of *C. quinquefasciatus* in different parts of Sri Lanka are homogenous and are equally susceptible to *W. bancrofti* infections.[5] In Mahaweli C2, two microfilaria positive cases were found among the human population screened for *W. bancrofti* infections and an infection rate of 1.72% was detected in *C. quinquefasciatus* (Table 3).

in the area, the spread and stabilization of bancroftian filariasis in these situations can he expected. *Mansonia annulifera, M. uniformis,* and *M. indiana,* whith have been incriminated previously as vectors of Brugia malayi, causing *brugian filariasis* in Sri Lanka, were also found in both areas.

C. tritaeniorhynchus, C. **gelidus, C. jucocepkala,** and *C. pseudovishnui,* which are established vectors of Japanese encephalitis **(JE)** in Southeast Asia, were recorded in both areas. *C. tritaeniorhynchus* was more prevalent in Mahaweli C2 than at Kirindi Oya, however, all species were found to he breeding in rice fields and ground pools in both study areas. Recent findings suggested that *C. tritaeniorhynchus* breeds predominantly in rice fields while C. gelidus is more commonly associated with ground pools and coconut husk pits.

***Table* 3.** Filariasis: the status of the vector and disease in Mahaweli C2 and Kirindi Oya, 1985.

	Mahaweli System C2		Kirindi Oya
	Phase 1 Jan/Feb	Phase 2 Aug/Sep	Phase 1 Feb/Mar
No, of houses examined	261	232	86
Total *C. quinq.* collected	3507	4w	322
MH	38.3	5.1	14.9
No. dissected	1031	348	311
No. infected		6	
percentage		1.72	
Filarial larvae, range	0 - 0	1 - 10	0 - 0
Mean larvae/mosquito		6	
Filaria positive persons detected in the area	2		1

Results from phase 2 (Sep 1985) are being processed

In this area, this is the first record of *W. bancrofti* infections in human and vector populations. Therefore, because *W. bancrofti* infections are present along with a high prevalence of the vector species

Aedes aegypti and *A.* **albapictus,** vectors of dengue and dengue haemorrhagic fever **(DHF),** were prevalent in Mahaweli C2, while only ***A. albopictus*** was recorded in Kirindi Oya (Table **4).**

'Jayasekera, N.. W.A. Sarnarawickrema, C.G. Jansen, and R.V. Chelliah. 1981. Filariasis in Sri Lanka: Crossing relations of natural populations of *Culex* quinquefasciatus. *J Nat* Sci Coun *Sri* Lanka 9(2):177-182. Samarawickrema, W.A., N. Jayasekera, R.V. Chelliah, and C.G. Jansen. 1981. Filariasis in Sri Lanka: Susceptibility of Culex quinquefasciatus to *W. bancrofti* (Cobbold) in Sri Lanka, *J Nat Sci Coun Sri Lanka* 9(2):171-176.

Table 4. Data on larval surveys for *Aedes aegypti* (A) *A. albopictus* (B) in Mahaweli C2 (Jan-Feb—and Kirindi Oya (Feb-Mar), 1985.

		Mahaweli C2	Kirindi Oya
Total no. of premises examined		850	600
Premises positive for breeding of	A		
Continer index	A	0.21	
	B	11.22	17.19
Premises index	A	0.35	
	B	14.35	15.50
Breteau index	A	0.35	
	B	18.82	21.85

Three out of the 850 premises where water-holding containers were surveyed for Aedes breeding were positive for A. *aegypti* larvae in Mahaaeli C2. Many of these containers were rubber tyres which had, collected rain water. A. albopictus showed a Breteau index of 18.8% and 21.8% For Mahaweli and Kirindi Oya areas, respectively.

These observations, which show a relatively high level of species diversity, including many confirmed and potential vectors of several diseases of public health importance, could predict health hazards to settlers in these areas.

Annex 2 shows the intersectoral participation in the project by the different organizations. Collaboration in the project implementation was most effective among three institutions of the Ministry of Health (MOH).

Project 2

Project 2 is a bionomic study of indigenous anopheline species in the transmission of human malaria in Sri Lanka and, in particular, the factors related to vectorial capacities in different ecological, epidemiological, and geographical and seasonal situations in Sri Lanka.

Environmental changes which occur in major irrigation development projects appear to alter and possibly favor the transmission potential of disease vectors. This paper compares observations of vectorial capacities in malaria vectors from an area in the Mahaweli System which has undergone more than 10 years of environmental changes with two other areas which have been untouched by recent irrigation developments. All three areas possess the same climatic and geophysical characteristics, and historically have shown similar malaria transmission patterns. In addition, some preliminary data are presented on anopheline breeding in the Mahaweli Development Project area where the irrigation management practices are somewhat stabilized.

Financial support was received from the World Health Organization (WHO)/Tropical Diseases Research Programme (TDR) of the Scientific Working Group on FIELD/MAL and supplemented by the Anti-Madaria Campaign, Sri Lanka Ministry of Health. The study was conducted by the entomological field staff of the Anti-Malaria Campaign and a Graduate Research Assistant (Annex 3).

Study *Areas.* This report includes findings from three different environments within the north-central malaria endemic dry zone of Sri Lanka (Map 2). In all these areas tanks from the ancient irrigation system are still in use. These areas include:

1. Mahaweli System H, the Madatugama section of the Kekirawa Health Area, where major environmental changes have occurred following more than 10 years of settlements/resettlements, deforestation, and irrigation activities.

2. Wewala in the Dambulla Health Area with old settled villages and some environmental changes hut not influenced by the recent irrigation activity of the Mahaweli Development Scheme.

3. A number of localities in Puttlam Health Area, also with settled villages hut not affected by the Mahaweli irrigation network.

Experimental procedure. The anopheline species were studied and monitored for prevalence/abundance, indoor/outdoor human biting, resting behavior, animal (cattle) biting densities, longevity (parous rates), determination of human blood index (HBI), and exodus from houses. Standard collecting techniques were used, including the use of indoor/outdoor human-bait at night, outdoor hand techniques, pyrethrum spraying, window traps, cattle-baited "cadjan"/net traps, and blood meal for precipition testing, etc. The laboratory processing involved species identification, classification into blood digestion stages, dissection for parous rates, 24-hour mortality/ survival observations in window traps and insecticide susceptibility testing.

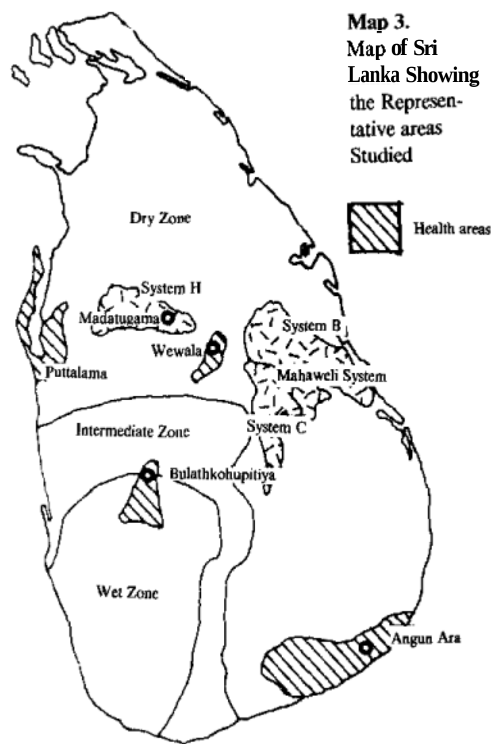
Owing to various constraints, particularly trained manpower, the duration and periods of work varied in the different areas. Madatugama was investigated for **21** days each month for **13** months in 1984-85, Wewala daily for **4** months in 1985, and localities in Puttlam Health Area for 7-14 days per month for 19 months during 1984-85.

Results and observations. The anopheline species **(A.** aconitus, **A.** annularis, **A.** barbirostris, **A.** culicifacies, A. jamesii, A. maculatus, **A.** nigerrimus, **A.** pallidus, **A.** subpictus, **A.** tesselatus, **A.** vagus, and ***A. varuna)*** generally found in malarious areas of Sri **Lanka** were recorded in all three sites. However, ***A. culicifacies,*** the predominant vector of human malaria, **was** recorded in very low numbers at Madatugama and Wewala. The overall prevalence of the different species from the three sites has not been compared.

Man-vector contact and longevity are two of the factors related to vectorial capacities and are generally considered important indicators following enviionmental changes due to irrigation development activities. Figure *2* compares these for the different anopheles species in relation to their overall prevalence in the respective areas.

Although all the anopheline species are **known to** he highly zoophilic, a degree of human biting was recorded similar to that in the rest of the country. There was no general increase in man-vector contact (human bait densities) following jungle clearing in development areas. It is possible that any imbalance in the man-animal ratio created in Mahaweli areas by deforestation and human settlements is counteracted by the high cattle population introduced to the areas, and to which mosquitoes are highly attracted.

Indoor resting sampling noted a somewhat greater population increase in the Madatugama area of the usually exophilic ***A. vagus.*** This could be expected to favor man-mosquito contact and needs to be monitored further. ***A. culicifacies*** and ***A. subpictus*** continued to he highly endophilic, as they are throughout Sri Lanka. Species longevity (expressed



Map 3. Map of Sri Lanka Showing the Representative areas Studied

Figure 2. Anopheline Prevalence, Human Biting Densities, Parous Rates and indoor Resting Densities from the (3) Representative Areas.

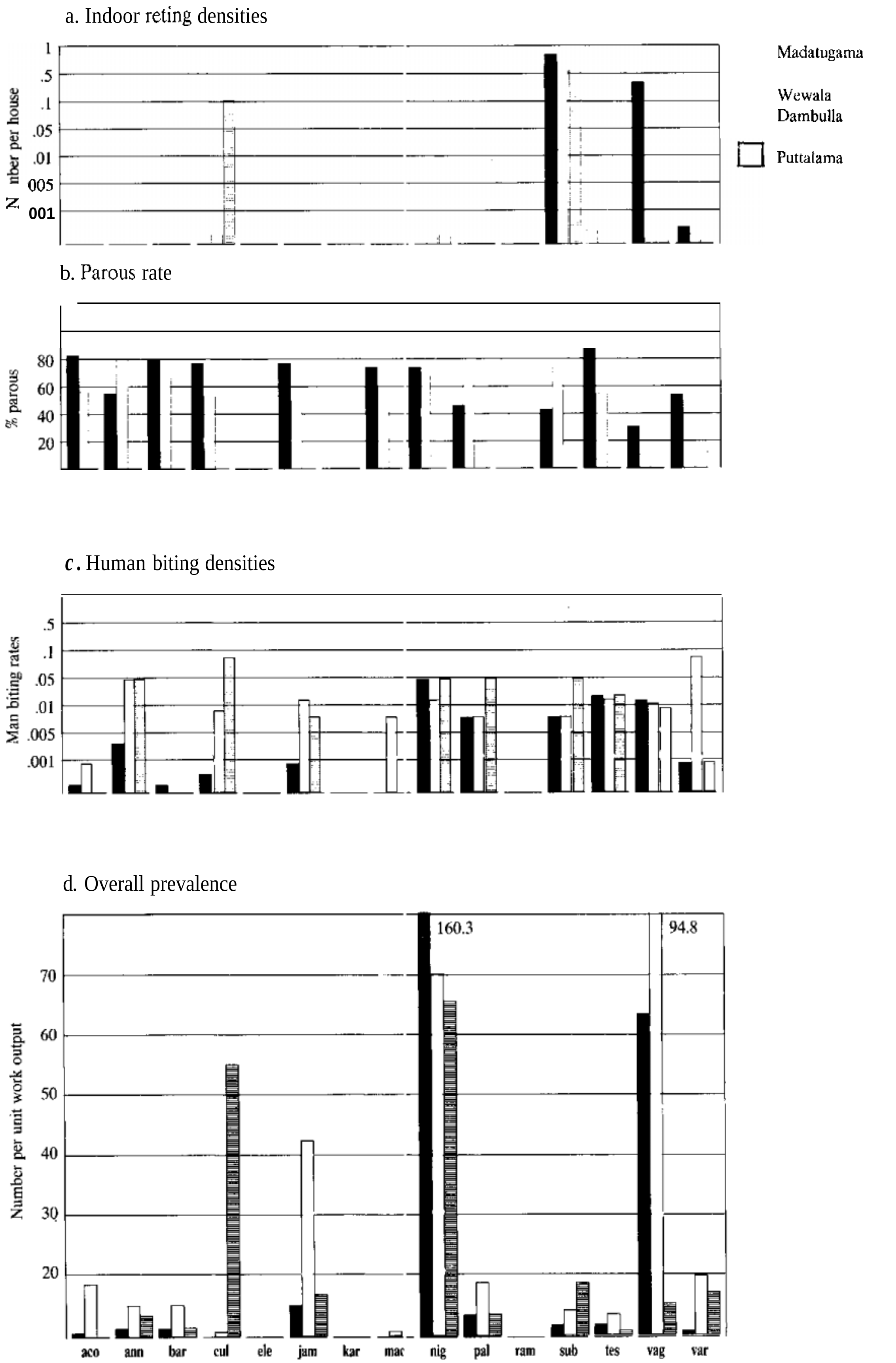


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Table 5a. Data on larval sampling at Mahaweli H, May 1984-May 1985

Breeding Places	No. of Spots Examined	No. of Spots Positives	No. of Dips Done	No. of Dips Positive	No. of Larvae Stages I-II	No. of Larvae Stages III-IV	An. aconitus	An. annularis	An. barbirostris	An. jamesi	An. nigerrimus	An. pallidus	An. subpictus	An. tessellatus	An. vagus	An. varuna
							ANOPHELINE SPECIES									
Paddy field	7852	1373	76704	1327	1591	1506	22	05	71	29	1190	82	15	37	488	22
Dambulu Oya -margin	232	06	2576	06	08	08	-			.	05	-		-	03	
Dambulu Oya - sand pool	333	13	3231	40	43	47	-			-	27	03	-		10	01
Irrigation channel	1121	13	7682	01	22	56	.			.	22	-	-	-	34	-
Main canal	1220	16	18575	50	24	34		.	05	-	30	01	.	02	07	01
Distributing canal	1132	76	18354 +1591	138 +03	126	99	.	.	01	02	66	06	.	01	30	41
Distributing canal pool	107	14	1429	66	35	49	.	.	14	.	37	03	.	.	23	.
Field canal	1432	37	16438	90	70	110	12	01	01	04	68	01	-	02	on	28
Field canal pool	27		276													
Rock pool	236	35	2484	215	60	220	02	.	37	12	147	-	04	-	45	02
Earth well	59		1766													
Stream	25	01	630	30	37	17	-	01	.	-	11	01	04	-	06	05
Rain water pool	1128	57	11092	127	209	173	09	.	01	05	103	25	.	.	76	02
Tyre track	51	03	409	18	03	21	-			.	01	-	03	-	19	-

Table 5b. Data on anopheline breeding **in** Madatngama (Mahaweli H), May 1984-May 1985.

	No. of spots	(% positive)	No. of dips	No. of larvae	(% of total)
Paddy field	7852	(17.5)	76704	3097	(67.8)
Dambulu Oya - margin	232	(2.6)	2576	14	(0.31)
-sand pool	333	(3.9)	3231	90	(2.0)
Sub-total	*565*	(3.4)	5807	*104*	(2.3)
Irrigation canal	1121	(1.2)	7682	78	(1.7)
Branch canal	1220	(1.3)	18575	58	(1.3)
Distributing canal	1132	(6.7)	19945	225	(4.9)
Dist canal pool	107	(13.0)	1429	**84**	**(1.8)**
Field canal	1432	(2.6)	16438	180	(3.9)
Field canal pool	27	**(0)**	276	0	**(0)**
Total canal system	5039	(3.1)	64345	625	(13.7)
Rock pool	236	(14.8)	2484	280	**(6.1)**
Earth well	59	(0)	1776	0	**(0)**
Stream	25	**(4.0)**	630	54	(1.2)
Rain water pool	1125	(5.1)	11092	382	(8.4)
Tyre track	51	(5.9)	409	**24**	(0.5)
TOTAL	**14952**	**(11.0)**	**163247**	**4566**	**(100)**

as parous rates) in Madatugama compared to areas not influenced by irrigation was higher for all species, except A. annularis, *A. pallidus,* and *A. subpictus.*

Preliminary data on larval breeding in Madatugama (Tables 5a and b) show the paddy fields to be a major breeding place for anopheline mosquitoes, and responsible for 67.8% of the total larvae sampled. By comparison, the irrigation canals recorded only **13.7%**. This seems to suggest that the intermittent flushing resulting from the 7-day rotation for water releases in the area may to some extent control larval breeding in the irrigation canals. Dambulu Oya, the naturally occurring river in the area studied, recorded only **2.3% of** the larvae, with no *A. culicifacies* recorded during the sampling period despite the fact that the river-and stream-beds are known to be highly preferred breeding habitats for this species. It appeared that the excess water channeled periodically through this river to a reservoir limited the pool formation and *A. culicifacies* breeding in the river beds, which is an advantage for malaria control efforts.

These observations suggest the need to investigate further the interaction of irrigation/agricultural practices, agricultural pesticide applications, and rainfall on mosquito reproduction in irrigation systems in order to identify environmental management approaches for vector control. Such studies Seem most appropriate in irrigation systems where the environmental changes, settlements, irrigation water management, and agricultural practices are stabilized. This is now under consideration.

Annex 1. Staff who participated in the WHO/PEEM study.

Dr M B Wickremasinghe	Entomologist, AMC
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Mn N Jayasekera	Entomologist, MRI
Dr U T Vitarana	Virologist, Director/MRI
Dr P R J Herath	Entomologist, AMC/MOH (Principal Investigator)
Mn V Gunatilake	SACEP representative to WHO/PEEM study
F R Karandawela	Entomological Assistant (EA)
D R W Pathiranact	
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R M Bandara	
N De Soyza	
N W G Premaratne	
G H Gamini	
Sheik Shermath	
G. Chandratillake	
D.A.T. Bopearachchi	
R.V. Chelliah	Technician
C.G. Jansen	
K. Manoranjitham	
S.K. Saranapala and field assistants, microscopists, mosquito collectors	

Annex 2. Intersectoral participation for the study on mosquito-borne disese in small scale water resources in Sri Lanka.

	Mini of Health	SACEP[b]	Mahaweli Authority	WHO[c]
Personnel				
professional	5	-		
support	35	-		
mgmt of funds, procurements	-	1		
mgmt of transport	2	1		
Equipment/Supplies	29%	-	-	71%
Transport/Vehicles	69.6	-	0.3	30.1
Staff salaries	96.5	3.5		

[a] Anti-Malaria Campaign. Anti-Filariasis Campaign and Medical Research Institute; [b] South Asia Cooperative Environment Program; [c] World Health Organization.

Annex 3. Staff who participated in the study.

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