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RELATIONSHIP BETWEEN ANOPHELISM OF FISH PONDS AND MALARIA TRANSMISSION AT LWIRO-KATANA, EASTERN ZAIRE

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ABSTRACT A study on anopheles larvae population in fish ponds was carried out in 1992 at Lwiro-Katana, South Kivu region, Zaire. The fish ponds serve as the habitat of immature stages of local the malaria vector species, *Anopheles gambiae* and *Anopheles funestus*. The larvae of these two species together comprise 98.33 percent of all the mosquitoes found in the ponds in contagious distribution and were abundant from February to May. A significant correlation was found between the relative density of malaria vector species in the fish ponds and the number of malaria patients registered at the health centers of Lwiro-Katana.

Key Words: Anophelism; Fish ponds; Malaria; Lwiro-Katana; Zaire.

INTRODUCTION

Entomological investigations of anophelism have been undertaken at Lwiro-Katana in the South Kivu region, Zaire, by Rahm & Vermylen (1967) on systematic inventory, by Muhinda (1988) on anophelism evolution in the dynamics of malaria transmission, and recently by Basabose & Kilosho (in press) on anopheles larvae breeding sites.

However, there has been no study on anopheles breeding in fish ponds. In particular, there is no study concerning the epidemiological role of the pond ecosystems in malaria transmission at Lwiro-Katana. This lack of study is important because the local people link the recent increase in malaria infection with fish ponds which have been rapidly increasing since 1987. The fish ponds comprise the favorite breeding sites of mosquito larvae.

This paper aims to assess the magnitude of anopheles species spawning in fish ponds, focusing on the local malaria vector species: *A. gambiae* and *A. funestus* (Rahm & Vermylen, 1966, 1967; Muhinda, 1988), to determine their seasonal changes in relative density, and, finally, to establish the relationship between fish ponds and malaria disease transmission. In order to analyse the relevant data, some ecological indices, such as relative density, constancy, spatial dispersion, biocenotic affinity and similarity quotient are employed.

STUDY AREA

Lwiro-Katana is situated in the surroundings of the Research Center for Natural Sciences on the western side of Lake Kivu, Eastern Zaire (alt. 1,460–1,760 m); (28°48'E, 2°14'S). This mountaneous area has a humid tropical climate characterized by heavy rain (1,500 mm annualy) with moderate temperature varying from 18 to 20°C (Chifundera, 1988). There are two main seasons: a long rainy season of 9 months, from September to May, and a short dry season of three months, from June to August. January is marked by little precipitation.

The vegetation is dominated by a cultivation-induced savanna which has replaced the original *Albizzia grandibracteata* forest vegetation (Baluku, 1987).

MATERIALS AND METHODS

1. Sampling Collection

Twenty-eight fish ponds were selected at random from among the 69 ponds inventoried in the study area and they were continuously investigated throughout the year of 1992. The larval sampling was made in shallow water near fish pond edges that the anopheles larvae favour (Pennak, 1953). Using an enameled soup plate (23 cm × 20 cm × 4 cm), water was drawn from 10 random chosen spots in each pond. The ponds were visited at approximately one-month interval. In Sub-Saharan Africa, the aquatic stage of anopheles species never exceed 25 days (Seketeli, 1986).

The collected larvae were counted and brought to the laboratory for identification. Some physico-chemical parameters of fish pond water were also recorded.

2. Data Treatment

The regression line $\log S = a. \log N + b$ (Murray & Spiegel, 1981) was used to verify if the anopheles larvae were efficiently sampled. This equation is explained in the "end note" of this paper.

The relative density (larvae/m^2) of the collected species is calculated from the upper surface area ($\pi R^2 = 415.47$ cm^2 or 1/24 m^2) of the sampling container and the number of water-drawings.

The Constancy degree (Cd) of anopheles species in the investigated ponds was calculated according to the relation given by Bodenheimer (1955).

The spatial dispersion (Elliott, 1983) was calculated by comparing the variance (S^2) to the arithmetic mean ($\bar{X}$) of larvae sample size.

The biocenotic affinity factor (Af) and the similarity quotient (Qs) were calculated according to the mathematical relations given by Bachelier (1963).

To establish the relationship between fish ponds and malaria transmission, the Student's t-test was used to compare the monthly data on malaria vector larvae from the fish ponds with the number of malaria patients registered at the health centers of the study area. The Chi-square test was also used. All the statistical

analyses were two-tailed.

RESULTS AND DISCUSSION

1. The Collected Species

Five species were identified: *A. gambiae* (49.70%), *A. funestus* (48.63%), *A. marshalli* (1.29%), *A. demeilloni* (0.30%) and *A. coustani* (0.08%). The majority (98.33%) of the mosquitoes found in the ponds were the malaria vector species, *A. gambiae* and *A. funestus*; see, Table 1.

The sampling efficiency was confirmed by the regression line log S=0.29 log N +0.06 (Fig. 1). From this line, an investigation on 120 further ponds (antilog 2.45−antilog 2.21) should reveal a contigency sixth species. Thus, the five species which have been collected are the most common.

Table 1. Seasonal changes in the number of sampled anopheles species and monthly mean of precipitation and temperature.

Monthly value	J	F	M	A	M	J	J	A	S	O	N	D
*A. gambiae**	1	103	140	98	104	37	17	41	20	17	30	47
*A. funestus**	21	125	92	104	78	63	40	49	18	16	22	13
A. marshalli	1	0	0	3	0	1	0	0	0	5	7	0
A. demeilloni	0	0	0	0	0	0	2	0	0	2	0	0
A. coustani	0	0	0	0	0	0	0	0	1	0	0	0
Precipitation 1981–1992	140	150	168	216	129	34	24	44	132	203	188	174
Temperature 1981–1992	19.8	19.9	19.9	19.9	19.8	19.0	18.8	19.7	20.1	19.7	19.6	19.6

*: Malaria vector species.

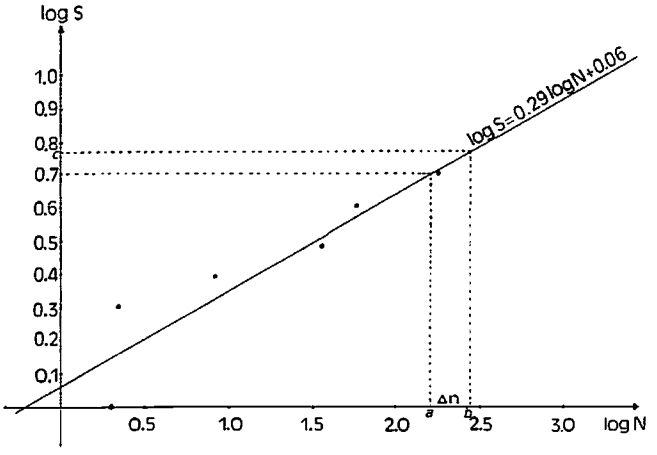

Fig. 1. Sampling efficiency estimation by the regression line log S=0.29 log N+0.06. a=2.21, b=2.45, c=0.78, n=antilog a−antilog b=120 fish ponds.

2. Ecological Indices

Figure 2 shows the seasonal changes in the relative density of the two malaria vector species, *A. gambiae* and *A. funestus*. The relative density of each species varies significantly from month to month ($N=12$, $df=10$, $p<0.05$). This depends neither on the precipitation nor on the ambiant temperature ($N=12$, $df=10$, $p>0.50$) (Table 1).

While the relative density of malaria vector species was higher from February to May, *A. gambiae* as well as *A. funestus* maintain their presence throughout the year. Eco-biological studies spanning several years are necessary to identify the causes to the increase in the number of each species at a particular time (For example, refer comparisons with other aquatic communities, environmental factors including adverse climate conditions, and limited food supply may be necessary).

The spatial dispersion of the collected species has been calculated for March,

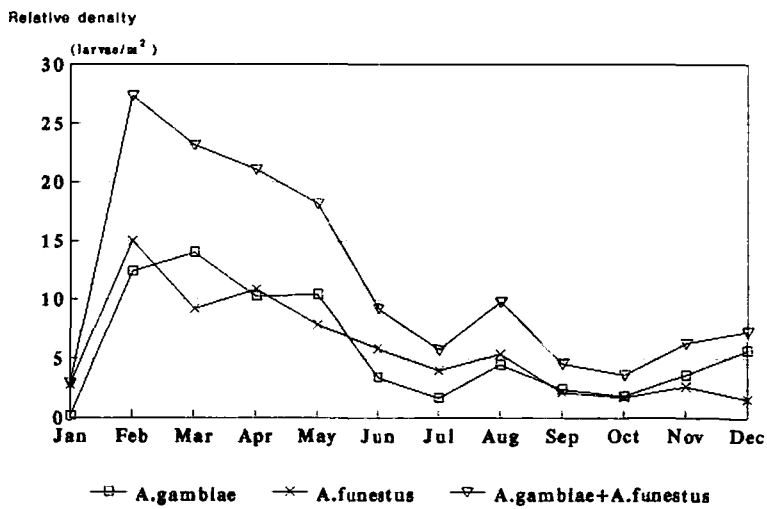

Fig. 2. Seasonal changes of the relative density of *Anopheles gambiae* and *Anopheles funestus*.

Table 2. Estimated distribution pattern of anopheles species collected in March, April, September and October, 1992.

Anopheles species	March			April			September			October		
	$\bar{X}$	S^2	D	$\bar{X}$	S^2	D	$\bar{X}$	S^2	D	$\bar{X}$	S^2	D
A. gambiae	1.22	6.97	C	1.02	7.91	C	1.02	2.20	C	0.25	0.70	C
A. funestus	1.83	2.31	C	0.91	1.84	C	1.35	5.23	C	0.40	0.59	C
A. marshalli	—	—	—	0.30	0.45	C	—	—	—	0.50	1.61	C
A. demeilloni	—	—	—	—	—	—	—	—	—	0.20	0.20	R
A. coustani	—	—	—	—	—	—	0.10	0.10	R	—	—	—

$\bar{X}$: Mean of collected larvae per drawing; S^2: variance; D: type of distribution; C: contagious distribution; R: random distribution; —: no collected species.

Table 3. Constancy degree of anopheles species collected in the fish ponds.

Anopheles species	Visited fish ponds	Infested fish ponds	Constancy degree	Type of constancy
A. gambiae	28	26	92.86%	Constant species
A. funestus	28	20	71.43%	Constant species
A. marshalli	28	5	17.86%	Accidental species
A. demeilloni	28	3	10.71%	Accidental species
A. coustani	28	1	3.57%	Accidental species

Table 4. Biocenotic affinity (%) among different anopheles species.

	A. gambiae	*A. funestus*	*A. marshalli*	*A. demeilloni*	*A. coustani*
A. gambiae	—				
A. funestus	22.06	—			
A. marshalli	1.75	9.09	—		
A. demeilloni	3.45	5.66	100.00	—	
A. coustani	0.00	0.00	0.00	0.00	—

April, September and October (Table 2). The anopheles larvae showed two types of distribution: contagious ($S^2 > \bar{X}$) and random ($S^2 = \bar{X}$). Contagious distribution was seen for the frequent species, *A. gambiae* and *A. funestus*, due to the tendency of the larvae to bunch together without traveling away from their birth place, as pointed out by Sergent & Sergent (1947). According to Dajoz (1982), contagious distribution is observed among the species which are most adapted to the biotope they inhabit. Therefore, the two malaria vector species favor the fish pond as their natural environment, and are observed fairly constantly: $Cd > 50\%$ (Table 3).

A. marshalli, although low in number, also showed a contagious distribution ($S^2 > \bar{X}$). Thus, this species also finds the fish ponds to be a favorable breeding place and it may comprise one of the major vectors in the future, if antilarval measures are not taken now.

Random distribution ($S^2 = \bar{X}$) was observed among less abundant species, *A. demeilloni* and *A. coustani*, for which the inventoried fish ponds were not a favorable breeding place. They have been found as accidental species ($Cd < 25\%$) in these ecosystems (Table 3).

Different anopheles species were found with low biocenotic affinity (Table 4). This situation can be explained by interspecific feeding competition in the fish ponds. Studies on dietary and population dynamic of anopheles larvae are needed to verify this assumption. However, *A. marshalli* and *A. demeilloni* were both specialized in the same habitats. The two species showed a maximum biocenotic affinity ($Af = 100\%$).

A high similarity in the pattern of infestation by anopheles larvae was noticed among the fish ponds (Table 5). This is explained by the low variation in water physico-chemical features observed (Table 6) among the different fish ponds.

3. Impact of Fish Ponds on Malaria Transmission at Lwiro-Katana

The introduction of a pisciculture program aiming at reducing endemic mal-

Table 5. Similarity (%) among investigated fish ponds infested by anopheles species.

E1																										
100	E2																									
67	67	E3																								
67	67	100	E4																							
67	67	100	100	E5																						
67	67	100	100	100	E6																					
50	50	80	80	80	80	E7																				
40	40	67	67	67	67	86	E8																			
67	67	100	100	100	100	80	67	E9																		
67	67	100	100	100	100	80	67	100	E10																	
67	67	100	100	100	100	80	67	100	100	E11																
50	50	80	80	80	80	67	86	80	80	80	E12															
40	40	67	67	67	67	86	100	67	67	67	86	E13														
67	67	100	100	100	100	80	67	100	100	100	80	67	E14													
67	67	100	100	100	100	80	67	100	100	100	80	67	100	E15												
50	50	80	80	80	80	100	86	80	80	80	67	86	80	80	E16											
67	67	100	100	100	100	80	67	100	100	100	80	67	100	100	80	E17										
50	50	80	80	80	80	67	57	80	80	80	67	57	80	80	67	80	E18									
0	0	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	E19								
100	100	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	0	E20							
100	100	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	0	100	E21						
67	67	100	100	100	100	80	67	100	100	100	80	67	100	100	80	100	80	67	67	67	E22					
100	100	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	0	100	100	67	E23				
0	0	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	100	0	0	67	0	E24			
100	100	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	0	100	100	67	100	0	E25		
50	50	80	80	80	80	100	86	80	80	80	67	86	80	80	100	80	67	50	50	50	80	50	50	50	E26	
100	100	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	0	100	100	67	100	0	100	67	E27
100	100	67	67	67	67	50	40	67	67	67	50	40	67	67	50	67	50	0	100	100	67	100	0	100	67	100	E28

E: Fish ponds.

Table 6. Physico-chemical features of fish pond water.

Features	Unit	Mean	Standard deviation
pH	—	6.55	0.35
Water density	—	0.98	0.02
Chlorure	mg/l	25.51	5.09
Calcium	mg/l	12.02	2.80
Magnesium	mg/l	13.61	2.77
Iron	+	+	+
Aluminum	+	+	+
Water Temperature	°C	19.60	1.47

+: Traces.

Table 7. Correlation between the density of malaria vector species (relative density; larvae/m²) and malaria patients (number of cases registered at Lwiro-Katana health centers).

Parameters	Months												r	t*	df
	J	F	M	A	M	J	J	A	S	O	N	D			
RD	2.9	27.4	23.2	21.1	18.0	9.2	5.7	9.8	4.6	3.6	6.2	7.2	0.81	4.37	10
MP	1,476	769	864	786	495	463	545	514	550	493	659	695			

RD: Relative density; MP: number of malaria patients (monthly mean) registered in 1992; r: correlation coefficient; t*: statistic t with a significant correlation ($p<0.05$) between relative density of malaria vector species collected in the following month "month+1" and the number of malaria patients registered in the current month "month+0"; df: degree of freedom.

nutrition at Lwiro-Katana (Hennart, 1983), has increased the population of malaria vectors in the fish ponds. Malaria infection actually increased, if we compare the data for 1987 to 1989, the period of fish pond expansion, with that for 1990 to 1992 after the program had been completed (Fig. 3).

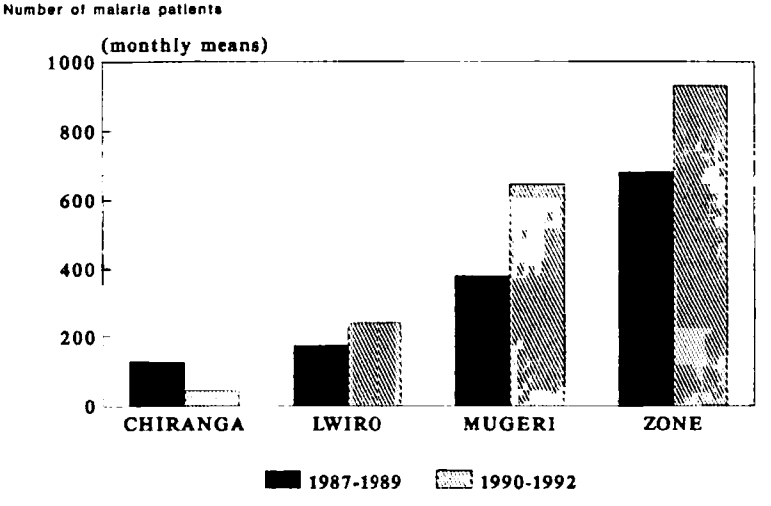

Fig. 3. Monthly means of malaria patients registered at the health centers of Lwiro-Katana from 1987 to 1989 and from 1990 to 1992.

The established correlation between the relative density of malaria vector species in the fish ponds and the number of malaria patients registered at the health centers in the Lwiro-Katana area shows how these ecosystems have a profound impact on the epidemiology of malaria. The correlation is significant when the density of larvae collected in the following month, "month+1," is compared with the malaria patients registered in the current month "month+0" (Table 7). This one-month interval is justified by the fact that it is not the larvae but adult mosquitoes, which transmit malaria infection. It takes about one month from the time an egg laid by an adult female, which has fed on an infected human, to grow into an adult insect to sting and transmit malaria (Seketeli, 1986).

CONCLUSION AND RECOMMANDATION

This paper investigated the relation between the fish ponds and malaria transmission at Lwiro-Katana, Eastern Zaire. The following observations are important:

(1) Fish ponds provide the major malaria vector species, *A. gambiae* and *A. funestus*, with permanent and favorable breeding sites for spawning and the aquatic stage development.

(2) The larvae of the two major malaria vectors are not randomly distributed in the fish ponds, but are found clumped in shallow water in a contagious distribution.

(3) *A. gambiae* and *A. funestus* are particularly abundant in the fish ponds from February to May, although they are observed throughout the year.

(4) There is a significant correlation between relative density of malaria vectors and the number of malaria patients registered in the previous month. Malaria is currently the main cause of consultation at the health centers of Lwiro-Katana (Repport of Central Office of Katana Health Zone, 1992).

The local community needs to be encouraged to make efforts in antilarval actions, while the pisciculture program is promoted to improve the local nutritional and socio-economic conditions.

The introduction of larvivorous fishes to the ponds. This would economically and simultaneously solve the problems of malaria and malnutrition, both endemic in Lwiro-Katana area. Environmental management that involves engineering physical modification of mosquito breeding sites must be steadily undertaken. Further studies focused on selection and evaluation of potential larvivorous fishes are called for to use them the above biological control against mosquito larvae.

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Appendix 1. Estimation of Sampling Efficiency by Regression Line.

Murray & Spiegel (1981) provided the following regression line for estimating the sampling efficiency:

$\Sigma \log S = nb + a \Sigma \log N$

$\Sigma (\log S. \log N) = b \Sigma \log N + a \Sigma (\log N)^2$,

where n represents the number of species collected; S. the rank of sampled species in the fish ponds; and N, total number of investigated ponds divided by the number of infested ponds.

The raw data for calculating the constants (a and b) in the above equations are as follows:

Appendix 1. Data of sampled fish ponds according to their infestation by Anopheles species.

Anopheles species	Z*	S	N	log S	log N	$(\log N)^2$	log S × log N
A. gambiae	80	2	2.14	0.30	0.33	0.11	0.10
A. funestus	82	1	2.08	0.00	0.32	0.10	0.00
A. marshalli	4	3.5	42.75	0.54	1.63	2.66	0.88
A. demeilloni	4	3.5	42.75	0.54	1.63	2.66	0.88
A. coustani	1	5	171.00	0.70	2.23	4.97	1.56
Total	171	15	260.72	2.08	6.14	10.50	3.42

Note: Z = the number of fish ponds where each species was collected.
From the above table, a is calculated at 0.29 and b at 0.06. Thus, the regression line is:
$\log S = 0.29 \log N + 0.06$, as shown in Figure 1.