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SPATIAL AND TEMPORAL DISTRIBUTION OF ANOPHELINE LARVAE IN TWO MALARIOUS AREAS IN SUCRE STATE, VENEZUELA

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The spatial and temporal distribution of anopheline larvae was studied in two coastal malarious areas of Sucre, State, Venezuela. Seven habitat types were sampled in the village of Guayana and eight species of Anopheles *were collected.* Anopheles aquasalis *was the predominant species collected and was most abundant in the brackish marsh habitat (71 larvae per 100 samples). It was most abundant during the rainy season. At the second location, Santa Fé, six habitat types were sampled and four anopheline species were collected. Habitats where* An. aquasalis *was most abundant were temporary freshwater ponds (34 larvae per 100 samples) and mangroves (10.5 larvae per 100 samples). At this location it was also most abundant in the rainy season. During the dry season it was collected in small numbers in river pools (1.3 larvae per 100 samples) along with large numbers of* An. pseudopunctipennis *(479 larvae per 100 samples). Larval control could be an important component of the malaria control program because major habitats could be defined and presence and abundance of larvae was limited to specific times of year.*

Key words: *Anopheles* – larvae – Venezuela

Anopheles aquasalis is the principal coastal vector of malaria from eastern Venezuela to southern Brazil and is considered the vector responsible for the recent reappearance of vivax malaria in Sucre State, Venezuela. The number of annual cases increased from two in 1982 to over 6,000 in 1990 (DER, 1990). Recent research on its biology showed that it is exophilic and exophagic (Berti et al., 1993). This behavior contributed to the ineffectiveness of indoor house sprays. By itself indoor house spraying did not lower the number of cases of malaria transmitted by *An. aquasalis* to an acceptable level (Berti et al., 1993).

An integrated program for the control of malaria and *An. aquasalis* was determined to be the best approach. To determine if larval control could be a major component of this program we studied the spatial and temporal distribution of *An. aquasalis* larvae in two malarious areas of Sucre State. Results on habitat preference and seasonal occurrence of larvae are presented in this study.

MATERIALS AND METHODS

Two locations were selected for study, one along the northern coast of Sucre State in the village of Santa Fé (Lat 10° 17'N, Long 64° 24'W) and the other on the peninsula of Paria in the village of Guayana (Lat 10° 35'N, Long 63° 57'W). A complete description of the two locations was given in Berti et al. (1993). Santa Fé is located in a coastal valley along the Cordillera de la Costa Oriental mountain range. Two ecological life zones occur in Santa Fé: a very dry tropical forest and a dry tropical forest. The area is dominated by littoral vegetation consisting of coastal mangrove, xerophytic and halophytic vegetation, and coconut plantations. Two rivers come down a pair of valleys and empty into the ocean at Santa Fé. Average yearly rainfall in this area is 760 mm and is seasonal, beginning in late May and

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abruptly ending in late November or early December. The eastern end of the study site was part of Parque National Mochima.

Guayana is located in a dry tropical forest, but due to the large number of streams running off the Cordillera the area is abundant in riparian vegetation. The littoral zone is approximately 10 km from Guayana and is similar to Santa Fé, but is much more extensive. Average yearly rainfall in Guayana is 1040 mm and is seasonal beginning in late May and ending in December.

Monthly larval surveys were conducted at each location using a liter-sized ladle. Breeding sites sampled were identified in preliminary studies but we continuously identifed new breeding sites and noted their importance in relation to the production of anophelines. At least 20 samples were taken from each site, but the number of samples taken varied from 20 to 110, depending on size of site, presence of larvae and time allowed for the survey. Larvae and pupae were taken to the laboratory for identification. Third and fourth instar larvae were identified using the key of Cova Garcia & Sutil (1977). First and second instar larvae were reared to third instar for identification, if possible. If not, we assumed that they were part of the same population of third and fourth instars and proportioned them according to number of each species collected. Pupae were reared to adults and identifed using the same key.

Breeding sites were classified according to the method of Galbadon (1941). A chemical analysis of each breeding site was made monthly using a standard LaMotte® Chemical kit, LaMotte Chemical Products Company, Chestertown, Maryland, USA. We measured alkalinity, salinity (total chloride), dissolved oxygen and pH. General characteristics such as size, depth, current, shade, clarity, and type of bottom surface were also noted. Rainfall data were taken from the nearest meteorological station; for Santa Fé, 40 km away in Barcelona, and for Guayana, 30 km away in Irapa.

RESULTS

Guayana

Spatial distribution – We sampled monthly eight potential breeding sites in Guayana from July 1988 to April 1990 (Fig. 1). These sites were classified into seven habitat types (Table I). The brackish marsh habitat was a semi-permanent site. Water levels depended on rainfall, underground seepage and tidal fluctuations. Eighteen emergent vegetation types were identified at this site dominated by the families Cyperaceae, Gramineae, and Thyphaceae. Larvae were collected along the edge of the marsh in areas of direct sunlight or partial shade. Chemically it differed from the other habitats in having higher salinity, and lower pH.

The spring habitat was heavily shaded (90%) by plants of the families Araceae, Gramineae, and Musaceae with dominant shade trees being Bignoniaceae, Lauraceae, Sterculiaceae, and Rubiaceae. Larvae were found in fallen debris that collected around the spring. The headwater streams were also heavily shaded (90%) and larvae were collected from calm pools formed in backwater areas of the streams. The dominant vegetation was the same as the spring. The small canal was partially shaded (30%) by Plamae, Leguminosae and Gramineae. Larvae were found in debris along the edges where the water was flowing slowly. The spring, headwater streams and small canal had continuous water flow, reflected by the higher amount of dissolved oxygen recorded at these sites compared to the other sites which did not have any current.

The lagoon habitat was partially shaded (20%) and larvae were found along the edges within plants of the families Gramineae, Leguminosae, as well as the aquatic plant genera *Utricularia* and *Eichornia.* Larvae were found in the aquatic plants and grasses along the edge of the lagoon. Partial shade was provided in addition by several Palmae, Araceae, Malvaceae and Rubiaceae. The stream overflow habitat had less than 10% shade and was dominated by plants of the families Cyperaceae and Gramineae. Larvae were found in this vegetation.

The flooded forest was heavily shaded (>95%) and had no noticeable water flow except where small streams passed through it. The dominant plant families providing shade were Araceae, Bignoniaceae, and Leguminosae. No larvae were found at in this habitat. Water clarity was low and a thin surface film covered the water. No chemical analysis of the water from this site was made.

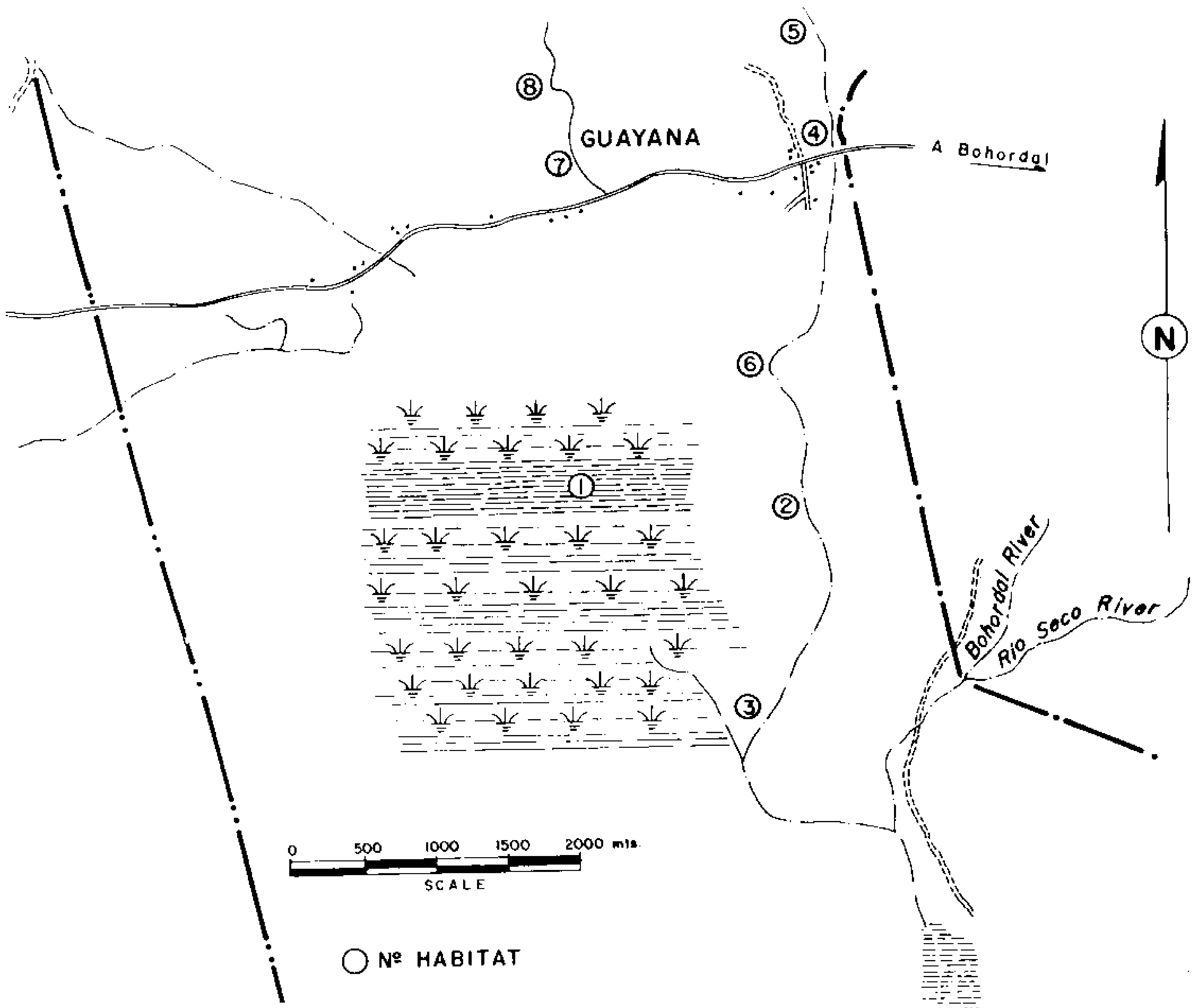

Fig. 1: map of sites sampled for larvae in Guayana. Habitat types are classified as small canal (6), headwater streams (5, 8), spring (7), flooded forest (2), freshwater lagoon (4), stream overflow (3), and brackish marsh (1).

TABLE I

General characteristics of breeding sites sampled in Guayana, Sucre State

Habitat type	Brackish marsh	Stream overflow	Small canal	Lagoon	Spring	Headwater stream	Flooded forest
Site No.	1	3	6	4	7	5,8	2
Size[a]	>> 500 m	10-100 m	1 m	100 m	< 10 m	< 10 m	>> 100 m
Depth	< 1.5 m	< 0.3 m	< 1.0 m	< 5.0 m	< 0.4 m	< 0.2 m	< 1.0 m
Current	none	none	slow	none	moderate	moderate	none
Shade	< 10%	< 10%	30%	20%	90%	90%	95%
Clarity	turbid	turbid	turbid	clear	clear	clear	turbid
Bottom	mud	mud	mud	mud	sand	sand	mud
pH	4.5-5.5	6.0-7.0	7.0-8.0	6.0-6.5	7.5	7.5	–
Alkalinity (ppm)	5-30	45-200	130-250	45-50	230-370	240-350	–
Salinity (g/l)	3.2-8.0	0.8-2.0	0.4-2.0	0.8-1.6	0.8-1.2	0.4-1.6	–
Oxygen (ppm)	0.2-0.4	0.2-6.0	3.0-4.8	0.8-1.6	3.8-4 2	2.6-3.0	–

a: width or depth in meters, estimated size of habitat sampled.

TABLE II

Anopheline larvae collected from breeding sites in Guayana, Sucre State from July 1988 to April 1990

Habitat type	Small canal	Headwater stream	Spring	Flooded forest	Lagoon	Stream overflow	Brackish marsh
Site No.	6	5,8	7	2	4	3	1
No. of samples	1058	1980	795	808	1707	1160	1172
Species							
An albitarsis	0	0	0	0	685 (40)[a]	0	0
An. apicimacula	0	7 (0.4)	9 (1.1)	0	0	0	0
An aquasalis	122 (12)	0	0	0	20 (1.1)	395 (34)	830 (71)
An. argyritarsis	0	5 (0.3)	14 (1.8)	0	0	0	0
An. eiseni	0	1 (0.1)	20 (2.5)	0	0	0	0
An. pseudopunctipennis	0	0	0	0	3 (0.2)	0	4 (0.3)
An. oswaldoi	5 (0.5)	0	2 (0.3)	0	16 (0.9)	18 (1.6)	38 (3.2)
An. triannulatus	1 (0.1)	0	2 (0.3)	0	74 (4.3)	0	0

a: total number of larvae collected (mean number of larvae per 100 samples).

Eight species of anophelines were collected in Guyana (Table II). *Anopheles aquasalis* was collected in four of the eight breeding sites. The brackish marsh was the site of greatest abundance (71 larvae/100 samples), followed by the stream overflow (34 larvae/100 samples), the small canal (12 larvae/100 samples) and the freshwater lagoon (1.1 larvae/100 samples). No *An. aquasalis* larvae were collected in the flooded forest, the spring nor the headwater streams.

Anopheles albitarsis was only collected from the freshwater lagoon. It was collected in high densities compared to other species at this site (Table II). Contrary to this, *An. oswaldoi* was collected in six of the seven habitat types, but in low numbers. *Anopheles triannulatus* was most abundant in the freshwater lagoon (4.3 larvae/100 samples), and *An. pseudopunctipennis* was collected in low numbers from just the freshwater lagoon (0.2 larvae/100 samples) and the brackish marsh (0.3 larvae/100 samples).

Three species, *An. apicimacula, An. argyritarsis,* and *An. eiseni* were collected in low numbers from the spring and headwater habitats (Table II).

Temporal distribution – The seasonal abundance of *An. aquasalis* larvae collected from the brackish marsh is presented in Fig. 2. This semi-permanent habitat was dry from April to June 1989 and in March and April 1990. *An. aquasalis* was most abundant in the rainy season and numbers collected gradually declined in the dry season. An exception to this occurred in February 1990 when the water level was low and larvae were highly concentrated. At this time we collect a large number of larvae (293 larvae/100 samples). The same trend of a greater number of larvae in the wet season than in the dry season was observed for the small canal and stream overflow areas (Fig. 3). These habitat types did not show the same regularity in numbers collected as did the brackish marsh. The overflow area, in 1988, had greater numbers of larvae at the beginning of the rainy season, but numbers declined sharply in September, in the middle of the rainy season. In 1989, were collected larvae from the stream overflow area at the beginning of the wet season in the month of May and not again until the dry season of 1990. In the small canal, *An. aquasalis* larvae were collected in low numbers, except in July 1989 when we collected 143 larvae/100 samples. Larvae of *An. aquasalis* were also present in low numbers in the freshwater lagoon during the wet season, but were not present in the dry season (Fig. 4).

Anopheles oswaldoi was collected in low numbers in the brackish marsh at the end of the rainy season and at the beginning of the dry season (Fig. 2). This bimodal trend was seen in the habitat types populated by this species.

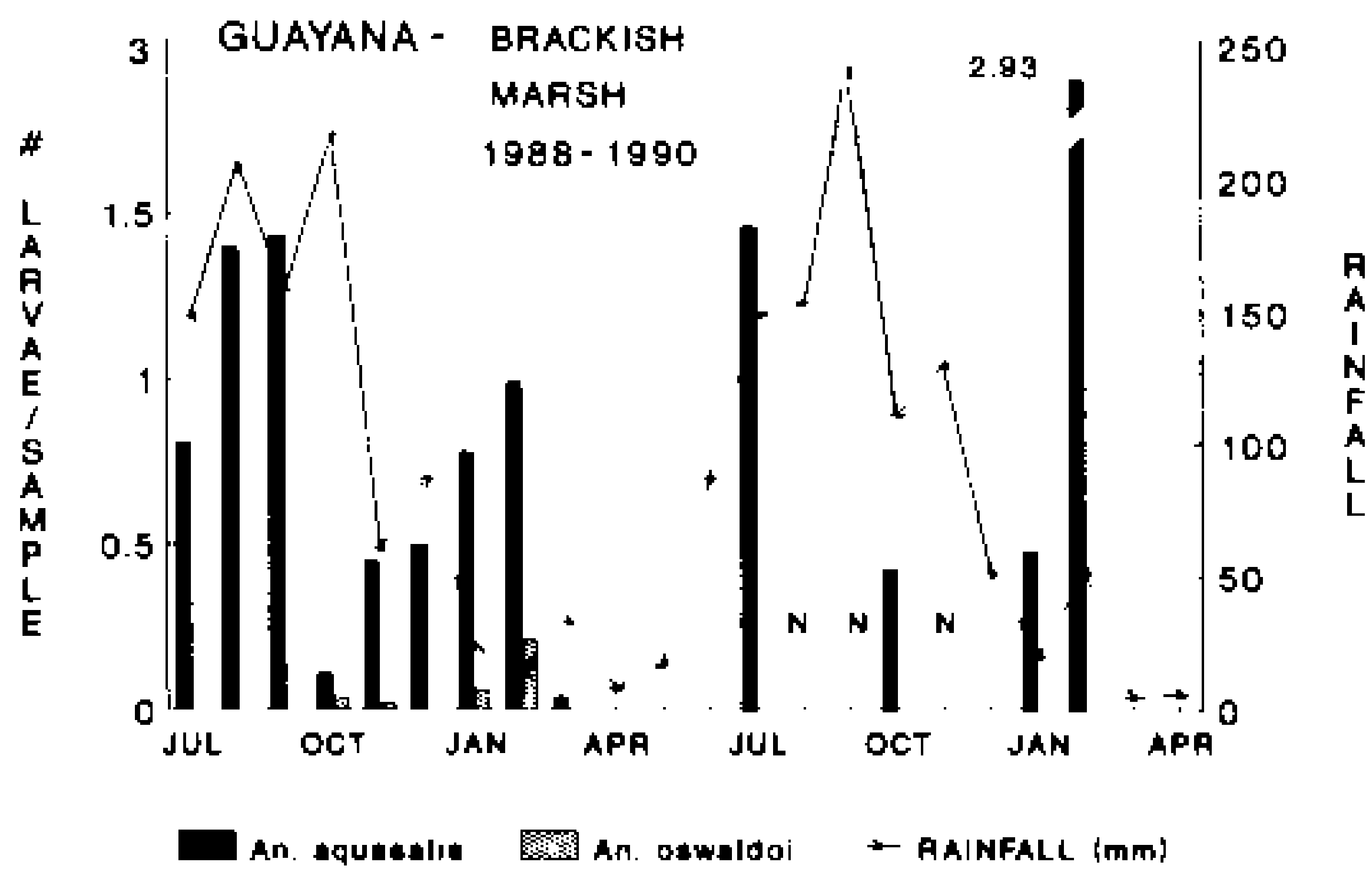

Fig. 2: number of *Anopheles aquasalis* and *An. oswaldoi* larvae collected per sample from the brackish marsh habitat in Guayana from July 1988 to April 1990. N = month when no collection was made.

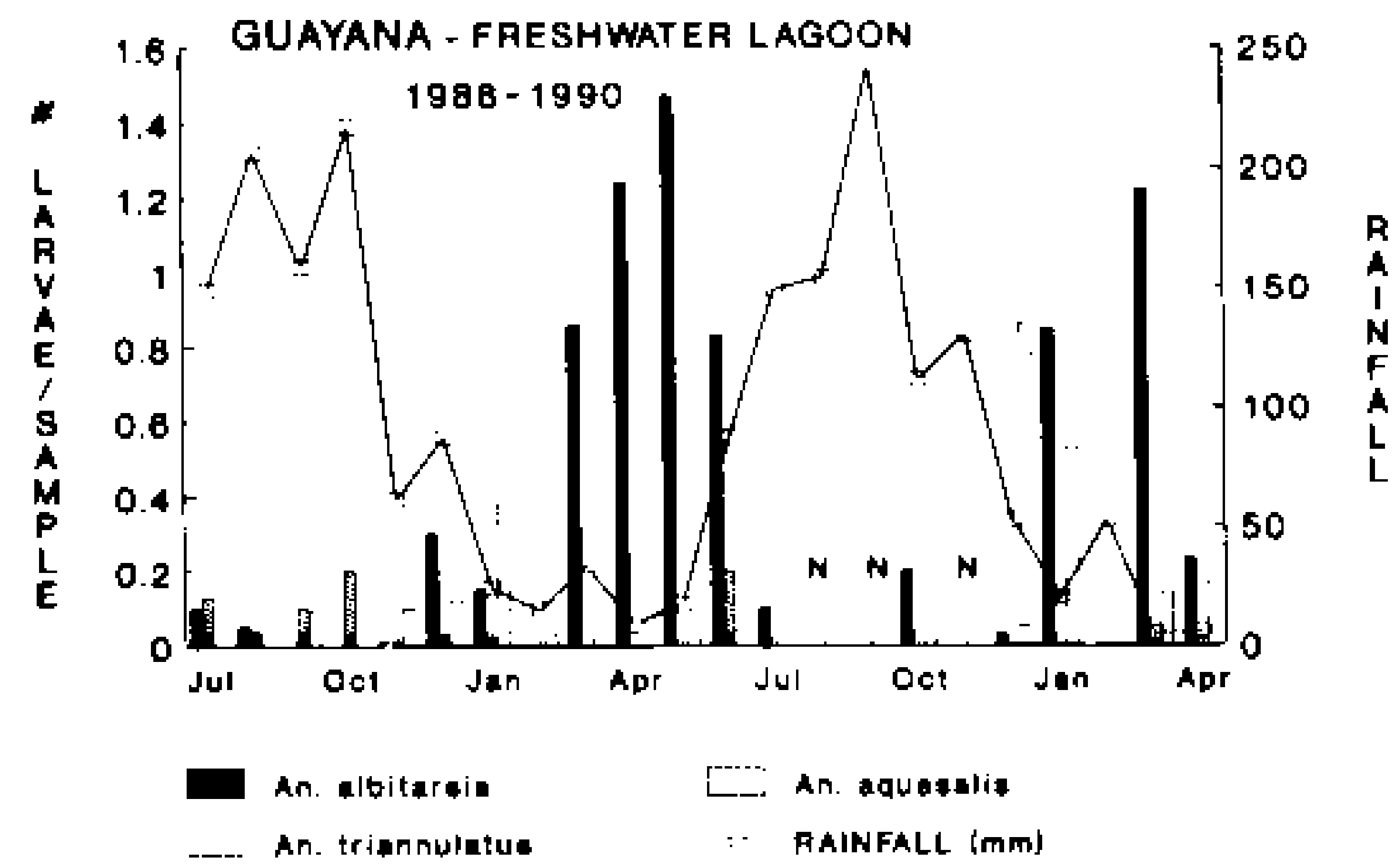

Fig. 4: species and number of anopheline larvae collected per sample from the freshwater lagoon habitat in Guayana from July 1988 to April 1990. N = month when no collection was made.

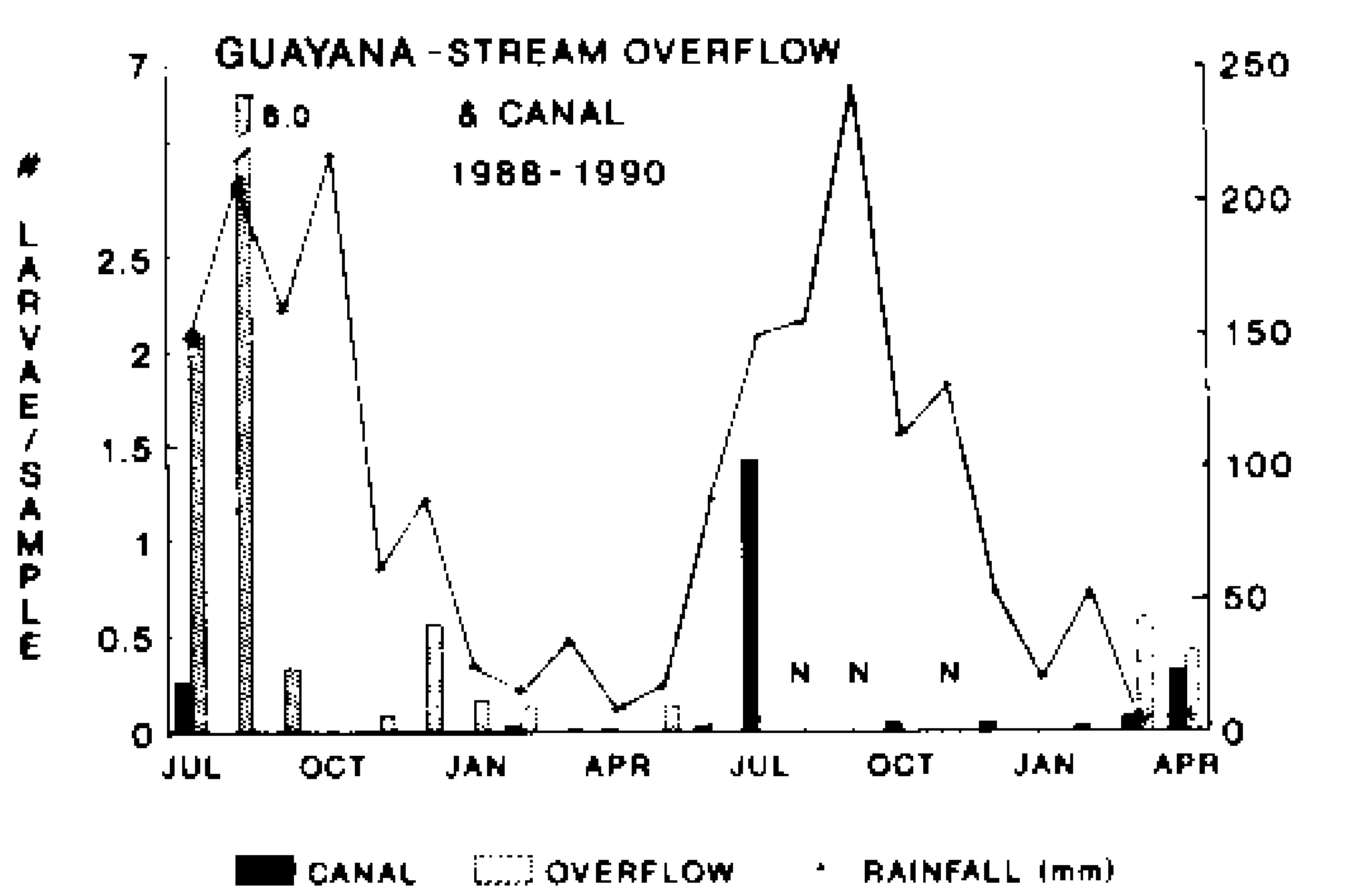

Fig. 3: number of *Anopheles aquasalis* larvae collected per sample from the stream overflow and small canal habitats in Guayana from July 1988 to April 1990. N = month when no collection was made.

The freshwater lagoon was dominated by *An. albitarsis* and this species was found in greater numbers in the dry season compared to the wet season (Fig. 4). Low numbers of *An. triannulatus* larvae were collected in the lagoon throughout the study with a slight peak in abundance at the beginning of the dry season. It was collected from other habitats in the dry season, but not in the wet season.

Santa Fé

Spatial distribution – In Santa Fé we sampled 24 potential breeding sites from July 1988 to October 1989 (Fig. 5). Sites were classified into six habitat types (Table III). The

TABLE III

General characteristics of breeding sites sampled in Santa Fé, Sucre State

Habitat type	Temporary pond	Small canal	River pool	Spring	Mangrove
Site No.	15, 21, 22 18, 19	1, 5, 17	7, 8, 9 10-12	2-4, 6 13, 14	16,24
Size[a]	10-100 m	1 m	< 0.5 m	< 10 m	> 100 m
Depth	< 0.4 m	< 0.5 m	> 0.1-2 m	< 0.4 m	< 1.0-2.0 m
Current	none	slow	fast	slow	slow[b]
Shade	10%	30%	0%	95%	10%
Clarity	turbid	turbid	clear	clear	turbid
Bottom	mud	mud	stones	sand	sand
pH	7.0-8.0	6.0-7.5	7.0-8.0	5.0-6.0	7.5-8.0
Alkalinity (ppm)	145-665	60-110	70-180	20-45	145-665
Salinity (g/l)	0.8-2.8	0.4-1.8	0.8-2.0	0.4-1.6	5.2-38.4
Oxygen (ppm)	0.2-4.4	4.6-7.0	1.8-7.4	0.4-4.4	0.2-6.4

a: width or depth in meters, estimated size of habitat sampled.
b: influenced by tides and seasonal rains.

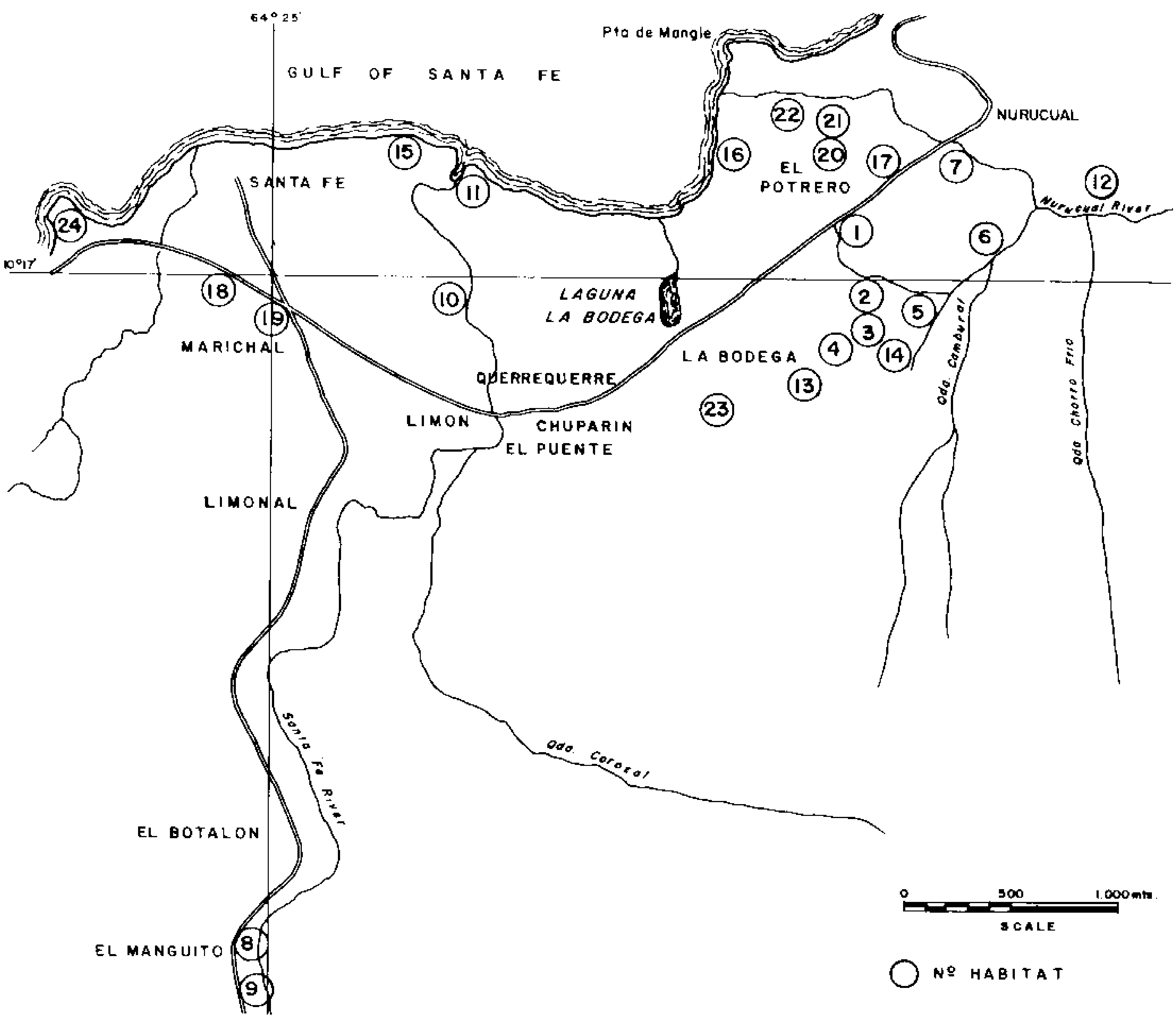

Fig. 5: map of sites sampled for larvae in Santa Fé. Habitat types sampled are classified as small canals (1, 5, 17), headwater streams (23), springs (2-4, 6, 13, 14), mangroves (16, 24), temporary ponds (15, 18, 19, 21, 22), and river pools (7, 8, 9, 10-12).

mixed species (Rhizophoracae) mangrove habitat was heavily shaded, but we collected most of the larvae in areas of partial shade (10%) along the edge of the mangrove where the family Gramineae was abundant. The mangrove was the only saline habitat sampled (5.2 g/l to 38.4 g/l of chloride). The temoprary pools were partially shaded (10%) by the families Cyperaceae, Leguminosae, Thyphaceae, and Gramineae. Several floating aquatic plant genera were identifed. They were *Lemna, Azolla, Salvinia, Chara, Nitella, Spirogyra,* and *Utricularia.* Larvae were found in this vegetation.

The small slow moving canals were partially shaded (30%) by Anacardiaceae, Araceae, Bignoniaceae, Mirtaceae, Musaceae, and Leguminosae. Two aquatic plant genera were identifed as *Chara* and *Nitella.* Larvae were found along the edges of the canals in this aquatic vegetation and fallen debris. The heavily shaded (95%) springs from which the small canals arose were shaded by plants of the families Gramineae, Araceae, Musaceae, Leguminosae. No aquatic vegetation was found in the springs. Larvae were found in debris along the edges of the springs.

The river pools were unique in character because they appeared during the dry season not the wet season. At this time the aquatic plant genera *Chara, Nitella* and *Spirogyra* were abundant. Larvae were found in pools with this vegetation. There was no shade at this habitat type.

The presence of flowing water was reflected by the higher dissolved oxygen in the small canals and river margins compared to other habitats (Table III). The mangrove habitat had the largest range of dissolved oxygen (0.4-6.4 ppm) and was most likely caused by the clos-

TABLE IV

Anopheline larvae collected from breeding sites in Santa Fé, Sucre State from July 1988 to October 1989

Habitat type	Small canal	Headwater stream	Spring	Mangrove	Temporary pond	River pool
Site No.	1, 5, 17	23	2-4, 6 13, 14	16, 24	15, 21, 22 18, 19	7, 8, 9 10-12
No. of samples	2040	445	2410	1440	1486	1172
Species						
An. aquasalis	17 (0.8)[a]	0	0	151 (10.5)	508 (34)	15 (1.3)
An. argyritarsis	11 (0.5)	8 (1.8)	14 (0.6)	0	4 (0.3)	358 (31)
An. pseudopunctipennis	0	0	9 (0.4)	0	9 (0.6)	5618 (479)
An. oswaldoi	0	0	0	0	7 (0.5)	0

a: total number of larvae collected (mean number of larvae per 100 samples).

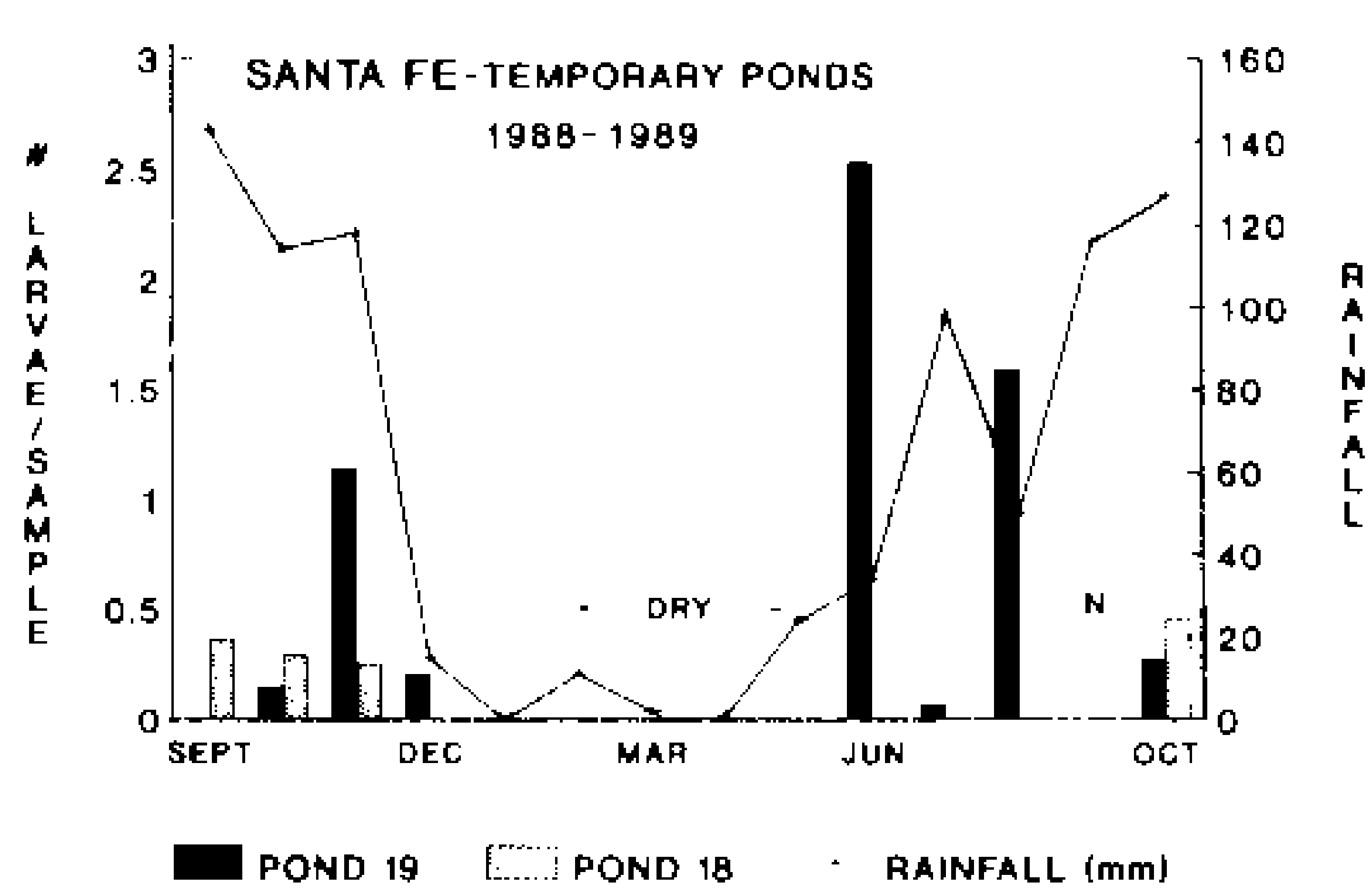

Fig. 6: number of *Anopheles aquasalis* larvae collected per sample from temporary pond habitats 18 and 19, in Santa Fé from September 1988 to October 1989. N = month when no collection was made.

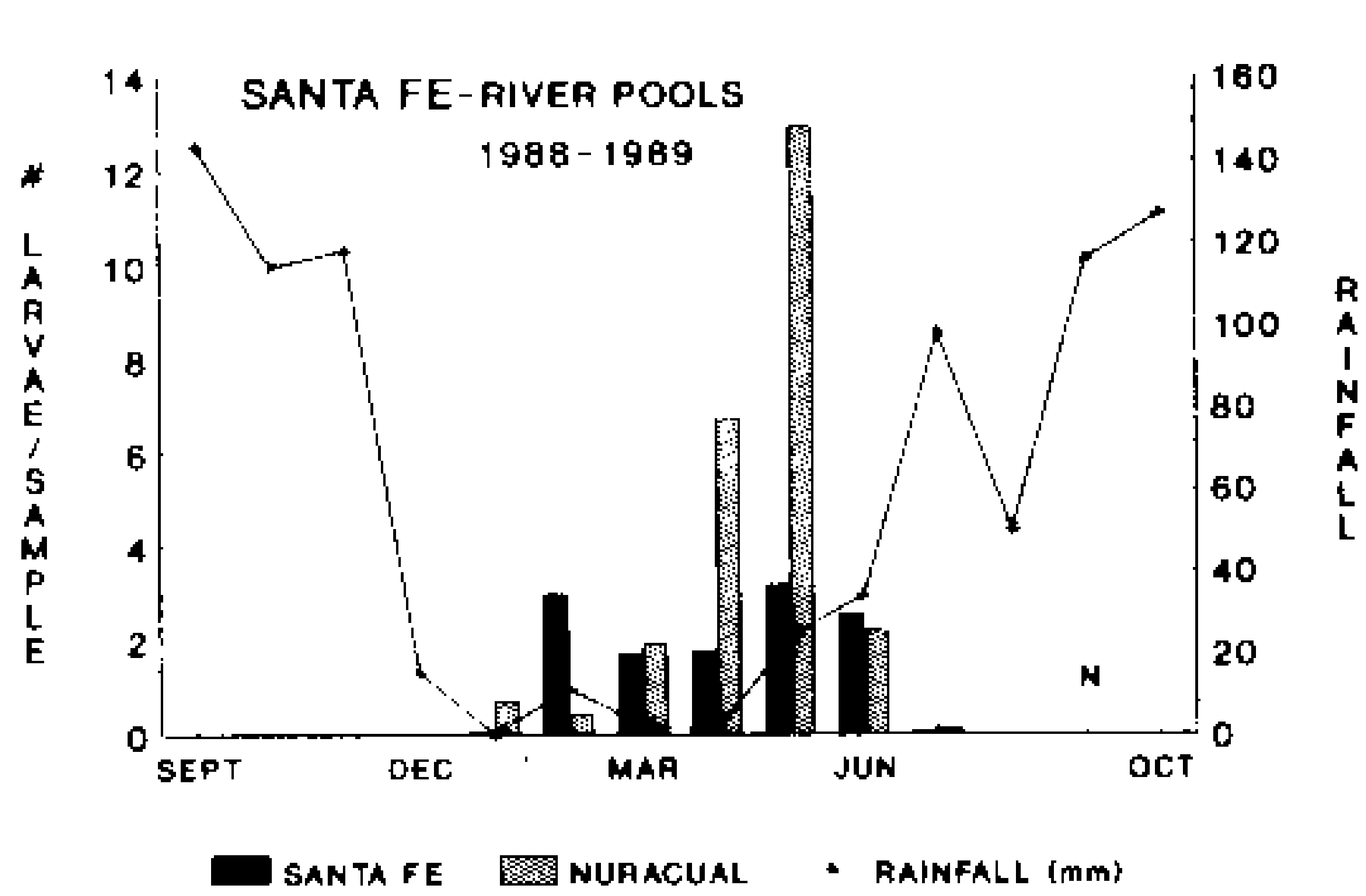

Fig. 7: number of *Anopheles pseudopunctipennis* larvae collected per sample from river pool habitats in Santa Fé. Habitats sampled were along rivers Santa Fé (sites 7, 12) and Nurucual (sites 8, 9): N = month when no collection was made.

ing and opening of the beach channel by tides and wet season rains. No major difference in pH, or alkalinity was observed among habitats.

Four species of *Anopheles* were collected in Santa Fé (Table IV). *An. aquasalis* was found in greatest numbers in the temporary ponds (34/100 samples), followed by mangroves (10.5/100 samples). Larvae were collected in low numbers in small canals (0.8 larvae/100 samples) and in pools along the margins of the two rivers (1.3 larvae/100 samples). Larvae of *An. aquasalis* were not collected in springs or in the headwater stream.

Anopheles argyritarsis larvae were collected in five of the six habitats sampled. It was much more abundant in pools along the two rivers (31 larvae/100 samples) as compared to other positive breeding sites (0.3-1.8 larvae/100 samples).

The predominant species found in pools along the river margins was *An. pseudopunctipennis* (479 larvae/100 samples). It was only collected in one other habitat type, temporary ponds (0.6 larvae/100 samples). The fourth species collected was *An. oswaldoi* which was collected in very low numbers in the temporary ponds (0.5 larvae/100 samples).

Temporal distribution – The seasonal abundance of *An. aquasalis* is shown in Fig. 6 for the two most important temporary freshwater ponds, (Nos 18, 19). Both ponds had larvae present during the rainy season but they were dry during the first five months of 1989. Pond 19 was positive for larvae on seven visits while Pond 18 was positive on four visits. Pond 18 did not become positive in 1989 until October. The other temporary ponds in this study (15, 21, 22) were always negative for anopheline larvae. The larval survey of the mangrove began in September 1989 at site No. 16. Larvae were surveyed over an area >40 hectares with no success. In July 1989, we began to survey a mangrove lagoon (site 24) in Cochiama (Fig. 5). This lagoon was connected to the sea through a channel which was blocked during certain periods of the dry season. It was found positive for *An. aquasalis* on all four occasions sampled (59 larvae/100 samples). Otherwise, *An. aquasalis* was collected only twice in pools along the river margins during the dry season and not at all during the wet season.

Anopheles pseudopunctipennis larvae were collected along the river margins in quiet pools with green filamentous algae. They were only collected during the dry season when the current was low (Fig. 7). In Fig. 7 we show the mean number of larvae collected by river, where sites 7 and 8 correspond to river Santa Fé and sites 9 and 12 correspond to river Nurucual. River site 10 was near the mouth of river Santa Fé where few larvae were collected and pools were more similar to backwater areas than to pools. The other species found along the margin of the two rivers in the dry season was *An. argyritarsis*. It was found in low numbers except in March 1989 when 248 larvae were collected in 60 samples.

DISCUSSION

Spatial distribution – Previous research on the biology of *An. aquasalis* larvae demonstrated that larvae are more abundant in brackish water than in freshwater habitats (Lucena, 1946; Senior White, 1951; Milward de Andrade, 1953a, 1958). Milward de Andrade (1958) however concluded after studying 506 biotypes along the coast of Brazil, that the chloride content of water is not the only factor that determines the distribution of *An. aquasalis*. Larvae have been found in habitats of low cloride concentrations (Ayroza Galvão et al., 1942; Lucena, 1946). We found larvae in habitats with salinities ranging from 0.4 g/l to 38.4 g/l of chloride. If found in freshwater habitats they are located along the coast or in inland habitats which have high concentrations of salt ions (Lucena, 1946; Deane et al., 1948; pers. obs.). This raises the important question of coastal freshwater habitats as *An. aquasalis* breeding sites. Are they secondary, or spill over sites which are only occupied because they are near saltwater habitats or are there other unknown factors which these freshwater habitats have in common with saltwater habitats which makes them favorable larval habitats for this species.

Milward de Andrade (1958) considered that *An. aquasalis* was an acidophilic species with higher densities at lower pH. In our study, the brackish marsh in Guayana was the only site sampled with low pH (4.5-5.5) and it had the highest number of larvae collected per sample (71 larvae/100 samples); other studies do not confirm this trend (Ayroza Galvão et al., 1942; Senior-White, 1951; Cova Garcia et al., 1977; Silvain & Pajot, 1981). Over the pH range studied, differences in pH may be related more to the area of study and the number of different habitats sampled than to pH alone.

Although *An. aquasalis* is found at times in shaded areas (Faran, 1980) we found it restricted to sites that were only partially shaded. Therefore we consider at our study locations as well as other sites collected from in Venezuela to be a "sun loving" species.

All other anophelines collected are freshwater species; although *An. albitarsis* and *An. argyritarsis* have been collected in breeding sites of 7.7g/l of chloride (Lucena, 1946). We found *An. argyritarsis* mainly in side pools of streams, rivers and canals. In other studies it was found in a diverse number of habitats including ponds and swamps (Linthicum, 1988). *An. albitarsis* was only found in the permanent freshwater lagoon located in Guayana which is unusual considering it has been previously collected in a wide range of habitat types (Linthicum, 1988). Also, *An. triannulatus* and *An. oswaldoi* have been found in diverse freshwater, permanent and semi-permanent habitats (Faran, 1980). We also found *An. oswaldoi* in the brackish marsh, but only when the salinity was low. We collected *An. apicimacula* and *An. eiseni* from habitats typical for these species, clear shaded areas of streams and pools (Forattini, 1962).

Anopheles pseudopunctipennis larvae were collected in its typical dry season habitat in river edge pools containing abundant filamentous algae (Forattini, 1962).

In Guayana, the flooded forest habitat was shaded, the water was turbid, and there was a thin surface film on the water. No larvae were collected at this site throughout the study and in our experience, this type of habitat characteristically has no anophelines. Characteristics such as shade, ammonia, alkalinity, and plant material may or may not have an effect on the presence and abundance of *An. aquasalis* and other anophelines (Beattie, 1932; Root & Andrews, 1938; Senior-White, 1951; Milward de Andrade, 1953a, b; Silvian & Pajot, 1981). At present more definitive studies need to be conducted in order to quantify the effect of these physico-chemical factors on anopheline larvae and to determine if they can be used as indicators of presence and abundance of larvae.

Temporal distribution – The seasonal occurrence of *An. aquasalis* larvae in Sucre State was similar to that recorded in past studies in the Americas (Deane et al., 1948; Senior-White, 1951). Larval abundance increased when the wet season began and decreased in the dry season when temporary habitats were dry. The other species collected also had seasonal trends in abundance similar to those reported by previous researchers (Forattini, 1962; Faran, 1980; Linthicum, 1988). *An. pseudopunctipennis* was collected in large numbers in the dry season in riverside pools, but when the rains began the pools were washed out and this species was found in very low numbers only in the remaining permanent habitats. *An. argryitarsis* showed the same trend as *An. pseudopunctipennis* in the dry season, but was also present in low numbers in other habitats during the wet season. The anopheline, *An. albitarsis* was collected only in the freshwater lagoon in Guayana and its abundance was greater during the dry season compared to the wet season. It has been previously recorded in greater numbers in the wet season, for adults and larvae (Deane et al., 1948; Rubio-Palis, 1991). In concurrent studies on adult anophelines in Guayana we did not collect *An. albitarsis;* even though the capture site was less than one km from the lagoon (Berti et al., 1993). However, one night we did collect adults biting humans when we sat next to the lagoon.

This study demonstrated the importance of the interplay among habitat types over time and space. For some anopheline species, habitat availability increased in the wet season and for others it decreased. One cannot assume that wet season habitats are more favorable than dry season habitats regardless of larval abundance. Many other factors such as aquatic community structure, distance between breeding sites and number of potential breeding sites may influence habitat selection. More research need to be conducted on these factors before we can understand the dynamics of habitat selection and habitat importance in anopheline biology.

Using larval abundance as the principal criteria it would appear that the most important breeding site for control in Guayana was the brackish marsh. In Santa Fé, temporary ponds 18 and 19 were the most important habitats. The mangrove site in Santa Fé could actually be more important than the temporary ponds, but we need to do a more thorough survey in the mangrove area to measure abundance and distribution of *An. aquasalis* by subhabitat (i.e. plant species, Senior-White, 1951).

We previously showed that *An. aquasalis* was the most important vector of malaria in Sucre State (Berti et al., 1993). In the present study we demonstrated that its breeding sites could be located and ranked according to larval presence and abundance over time and space. This indicated to us that larval control could be a major component of the malaria control program in Sucre State.

With respect to the potential secondary vector of malaria in Santa Fé, *An. pseudopunctipennis,* (Berti et al., 1993) its rareness in freshwater habitats other than river edge pools would indicate that larval control would be tailored to the river pool habitat and in the dry season.

The type of larval control used, whether it be environmental modification or larvicide application would depend on cost, persistance of the control measure and its effect on habitat quality. In such a control program, habitat should be ranked not only by overall larval abundance, but also by the probability that larvae could be present during a certain time of year.

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