Bionomics of black flies (Diptera: Simuliidae) in Costa Rica. VI. Correlations with ecological factors*

by

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Abstract: Observation on 100 streams in Costa Rica over a two-year period indicated no strong correlations of either larval populations or biting adults with such stream factors as substrate, temperature, altitude, water speed and turbulence, pollution or shade. Small differences and some reversals in the data suggest only trends.

Previous studies of black flies in Costa Rica have covered some general and specific aspects of the ecology of these insects (Vargas and Travis, 1973; Vargas *et al.*, 1977; Zeledón and Vieto, 1957).

The primary objective of this research was to understand the general bionomics of simuliids both larvae and biting adults. Special efforts were made to obtain quantitative data on the correlation of various ecological factors and the population of larvae and man-biting adults. The observations were based on the general population level and not on species, which will be included later in the taxonomic reports.

The location and physical characteristics of the 100 study streams in Costa Rica have been described by Vargas and Travis (1973), information which provides a baseline either to recheck future black fly populations in Costa Rica or to encourage other biological studies in the same streams.

MATERIAL AND METHODS

During the first year of the project (1968-1969) monthly observations were made on 53 streams located in the Central Valley of Costa Rica around San José

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(group A). In the second year (1969-1970) bi-monthly observations were made on 47 streams located outside the Central Valley (group B). Group C consisted of data from 28 of the 53 streams first studied. These were selected as being most typical of the Valle Central and were observed again bi-monthly during the second year in order to demonstrate any differences in the breeding indices.

The streams for these studies included almost all of those that crossed the major highways in the study areas. Thus, the number of streams included with each ecological factor reflects the total of such streams within the study area.

At each observation, the numbers of both inunature stages and biting adults were correlated with the following ecological factors as recorded for each stream: substrate (rocks and vegetation); water temperature; altitude, determined with an altimeter (500 m increments); water velocity and turbulence estimated on a four point scale (fast, turbulent; fast, intermittently turbulent; slow, not turbulent; and trickle streams); pollution, estimated on a three point scale (none apparent, light but obvious and moderate to heavy); and shade estimated on a three point scale (none, partial and complete).

The correlations of the ecological factors were made at each observation and were used to calculate an annual breeding index for each stream. If no specimens were located, the score was "O"; if specimens averaged five or less per leaf or rock unit of 25 cm^2, the score was "1"; for 6 to 20, "2"; for 21 or more, "3". Also, if the populations occurred on less than half the units a hyphen (-) was added to the score, i.e., 1-, 2-, 3-.

If the populations occurred on more than half of the units, a plus sign (+) was added to the score, i. e., 1+,2+, or 3+. These seven population levels for each stream were converted to a single annual breeding index figure. The conversions of the population estimates to annual index figures were made by multiplying the population estimates (number in parenthesis) by the appropiate population levels (number following the multiplication sign) at each observation, (0) x 1, (1-) x 2, (2-) x 3 etc. to (3-) x 7. The sums of the products for each stream observation were divided equally into five index categories varying from 0 to 4, with the index number 4 being the most productive.

RESULTS AND OBSERVATIONS

When the data were summarized, the differences between the larval, pupal and cocoon production indices were so small that only the data for the larvae and the biting adults were used in this report.

In correlation Tables 1 to 6 are listed the ranges of each ecological factor, the number of streams included, the average breeding index and the average number of biting adults in each of the four groups.

Substrate: The vegetation in the streams that furnished a substrate for larvae and pupae was of several types, the most important of which were grasses and the torch ginger *Hedychium coronarium* that trailed from the stream banks into the water. Occasionally plants that grew on the stream bottom were used, and also leaves from trees and shrubs that were lodged in the stream. However, the larvae and pupae were seldom attached in any numbers to leaves that were rough and hairy, preferring the smooth ones. It is also interesting to note that larvae would readily attach to fabrics and plastics found in some of the polluted streams. The preferences of larvae for either rock or vegetation substrates are depicted in Figure 1. The large variation in breeding indices shown in the bar graphs, indicates that the

larvae did not consistently select either rock or vegetation substrates. Also the data from the smaller group of 28 selected streams showed less variability in the same year and the indices were very similar in the second year of observation as well.

There were no indications of any correlations of the stream breeding indices either of larval populations or of the average number of biting adults and the substrate.

TABLE 1

Correlation of breeding indices and biting adults with minimum stream temperature (69 = 1968–69; 70 = 1969–70)

Minimum Temperature C	Number streams		Average breeding index on indicated substrate and date: Rocks		Vegetation		Average number biting adults	
	69	70	69	70	69	70	69	70
A. 53 streams observed in 1968–69 (Inside Central Valley)								
11–13	11		1.8		1.7		0.9	
14–16	20		2.5		2.6		5.6	
17–19	20		1.9		2.5		7.4	
20–22	2		0		1.0		5.0	
B. 47 streams observed in 1969–70 (Outside Central Valley)								
14–16		3		1.3		2.0		1.7
17–19		12		1.8		2.8		5.2
20–22		22		1.5		2.5		7.2
23–26		10		1.7		1.9		0
C. 28 of the 53 streams observed in 1968–69 and 1969–70 (Inside Central Valley)								
8–10		1,0		1.0		1.0		0.0
11–13	6	5	2.5	2.0	2.0	1.6	1.0	1.4
14–16	11	9	3.3	2.4	3.3	2.2	9.1	6.0
17–19	10	11	2.0	2.4	2.6	2.4	5.4	12.6
20–22	1	2	0	1.0	1.0	1.5	5.0	4.5

Minimum stream temperatures: The minimum temperatures of the streams (Table 1) inside the Central Valley were lower (range 9 to 22 C) than those of the streams outside the Central Valley (range 14 to 26 C). The coldest stream in the Central Valley (42) had a low reading of 11 C in 1968-69 and 9 C in 1969-70; the warmest stream in group A (5) had a minimum range of 19-26 C. Outside the Central Valley the coldest stream (67 in group B) had a low range of 14 to 17 C.

The largest larval populations and the highest average number of biting adults were observed at minimum temperatures of 14 to 19 C inside the Central Valley and 17 to 22 C outside.

TABLE 2

Correlation of breeding indices and biting adults with ranges of stream temperature (69 = 1968–69; 70 = 1969–70)

Temperature range C	Number streams		Average breeding index on indicated substrate and date: Rocks		Vegetation		Average number biting adults	
	69	70	69	70	69	70	69	70
A. 53 streams observed in 1968–69 (Inside Central Valley)								
1–3	9		2.4		2.4		5.1	
4–6	26		1.9		2.1		5.4	
7–9	15		2.0		2.5		4.8	
10–13	3		2.3		3.0		7.3	
B. 47 streams observed in 1969–70 (Outside Central Valley)								
1–3		23		1.7		2.5		6.9
4–6		16		1.4		2.3		3.3
7–9		8		2.1		2.4		2.1
C. 28 of the 53 streams observed in 1968–69 and 1969–70 (Inside Central Valley)								
1–3	1	10	0.0	2.3	2.0	2.1	0	14.2
4–6	17	16	2.5	2.1	2.5	2.1	6.9	3.9
7–9	7	1	2.3	3.0	2.9	3.0	7.1	5.0
10–13	3	1	3.3	2.0	3.7	1.0	11.7	0

Ranges of stream temperatures: The annual temperature ranges in the Costa Rican streams (Table 2) were strikingly small. In the Central Valley the most common temperature ranges were 4 to 9 C and outside the Central Valley 1 to 6 C. In group D, two streams (7 and 14a) and in group B, three streams (68,93 and 98) had an annual temperature range of only 1 C; the latter streams were among the largest studied. It is not possible to suggest any correlations with either the populations of larvae or the biting adults and the range of stream temperatures.

TABLE 3

Correlation of breeding indices and biting adults with altitudes (69 = 1968–69; 70 = 1969–70)

Altitude (meters)	Number streams		Average breeding index on indicated substrate and date: Rocks		Vegetation		Average number biting adults	
	69	70	69	70	69	70	69	70
A. 53 streams observed in 1968–69 (Inside Central Valley)								
500–1000	17		1.5		2.1		2.2	
1001–1500	23		2.5		2.7		10.0	
1501–2000	8		2.3		2.3		1.4	
2001–2500	3		1.3		1.3		0.3	
2501–3000	2		2.5		1.5		0.5	
B. 47 streams observed in 1969–70 (Outside Central Valley)								
0–500		30		1.6		2.3		2.3
501–1000		15		1.8		2.6		10.3
1001–1500		1		1.0		3.0		0
1501–2000		0		0		0		0
2001–2500		1		0		1.0		0
C. 28 of 53 streams observed in 1968–69 and 1969–70 (Inside Central Valley)								
500–1000	5	5	1.0	1.4	2.0	1.6	2.4	4.8
1001–1500	15	15	3.0	2.5	3.1	2.7	12.1	11.8
1501–2000	6	6	2.6	2.3	2.5	1.7	1.5	1.3
2001–2500	0	0	0	0	0	0	0	0
2501–3000	2	2	1.5	1.5	1.5	0	1.0	0

Altitude: In the Central Valley, the streams are closely associated with the mountains and most of the study stations are at altitudes of 500 m to 1500 m, whereas outside the Valley they are in the broad coastal plains, at 0 to 1500 m. The altitude of the study streams in groups A,C and D (Table 3) is thus much higher, from 575 m (stream 18) to 2790 m (42), than that of group B which range from 10 (97) to 1325 m (67). The largest larval populations in groups A, C, and D were at 1000 to 1500 m, and in group B they were found at 500 to 1500 m. The greatest numbersof biting adults were observed at the same levels.

TABLE 4

Correlation of breeding indices and biting adults with stream velocity (69 = 1968–69; 70 = 1969–70)

Stream speed and turbulence	Number streams		Average breeding index on indicated substrate and date: Rocks		Vegetation		Average number biting adults	
	69	70	69	70	69	70	69	70
A. 53 streams observed in 1968–69 (Inside Central Valley)								
Fast, turbulent (1)	20		2.4		2.5		2.1	
Fast, intermittently turbulent (2)	23		2.3		2.4		7.3	
Slow not turbulent (3)	5		1.0		2.0		10.2	
Trickle streams (4)	5		0.6		1.4		4.2	
B. 47 streams observed in 1969–70 (Outside Central Valley)								
Fast, turbulent (1)		15		1.7		2.2		2.
Fast, intermittently turbulent (2)		22		1.5		2.4		6.
Slow not turbulent (3)		9		1.8		2.7		3.
Trickle streams (4)		1		2.0		2.0		1.
C. 28 of the 53 streams observed in 1968–69 and 1969–70 (Inside Central Valley)								
Fast, turbulent (1)	12	12	2.7	2.3	2.8	2.1	2.1	3.
Fast intermittently turbulent (2)	14	14	2.6	2.1	2.8	2.2	12.3	11.
Slow not turbulent (3)	0	0	0	0	0	0	0	0
Trickle streams (4)	2	2	0.5	0	1.0	1.0	2.5	2.

Water velocity: Most of the streams are fast and either continuously turbulent for long distances or with intermittent turbulent areas (Table 4) although in both the Central Valley and in the coastal areas a few are slow with little or no turbulence.

The larval populations were greatest in the streams of groups A, C, and D that were fast and turbulent.

In group B the larvae were not significantly different in the four categories.

In all locations the biting adults tended to be more abundant near fast streams with at least intermittent turbulence.

Pollution: More than half the streams under observation showed varying degrees of obvious contamination (Table 5). Generally the highest larval populations were found in those that were less polluted. In Costa Rica it has been customary to

TABLE 5

Correlation of breeding indices and biting adults with stream pollution (69 = 1968–69; 70 = 1969–70)

Degree pollution	Number streams		Average breeding index on indicated substrate and date: Rocks		Vegetation		Average number biting adults	
	69	70	69	70	69	70	69	70
A. 53 streams observed in 1968–69 (Inside Central Valley)								
None apparent (0)	25	–	1.7	–	2.0	–	5.3	–
Light but obvious (–)	19	–	2.6	–	2.8	–	4.7	–
Moderate to heavy (÷)	9	–	2.0	–	2.1	–	6.3	–
B. 47 streams observed in 1969–70 (Outside Central Valley)								
None apparent (0)		18	–	1.8	–	2.7	–	9.3
Light but obvious (–)		24	–	1.6	–	2.3	–	2.3
Moderate to heavy (÷)		5	–	1.0	–	1.8	–	0
C. 28 of the 53 streams observed in 1968–69 and 1969–70 (Inside Central Valley)								
None apparent (0)	12	12	2.1	1.9	2.1	2.4	6.6	13.2
Light but obvious (–)	11	11	2.9	2.5	3.1	2.4	8.3	2.7
Moderate to heavy (÷)	5	5	2.8	2.2	2.8	1.6	6.4	4.0

dump wastes of the coffee harvest in the streams that cross the plantations, contaminating them especially with the pulp of the coffee bean hulls. This effectively eliminates the immature forms of the flies as the abundance of solid materials is not tolerated by the larvae probably because of the mecanical action of the larger particles obstructing their mouth-brushes. But as the solid waste became diluted or when even the wastes of the coffee beans were liquid, the populations of larvae increased and became exceedingly large as a result of the input of nutrients into the ecosystem. This was observed in streams 5,9, and 14, the larval population of the latter reaching more than a thousand in 6.45 cm^2. Recent concern about the problem of stream contamination and the processing of the coffee wastes will eventually reduce this periodic increase of black fly populations.

It is also common in areas of crop cultivations that empty pesticide containers with small residues are discarded into the streams; this probably

TABLE 6

Correlation of breeding indices and biting adults with shade (69 = 1968–69; 70 = 1969–70)

Amount of shade	Number streams		Average breeding index on indicated substrate and date: Rocks		Vegetation		Average number biting adults	
	69	70	69	70	69	70	69	70
A. 53 streams observed in 1968–69 (Inside Central Valley)								
None (0)	18	–	1.8	–	2.1	–	7.6	–
Partial (–)	20	–	2.7	–	2.6	–	3.7	–
Complete (÷)	15	–	1.6	–	2.2	–	4.6	–
B. 47 streams observed in 1969–70 (Outside Central Valley)								
None (0)	–	19	–	1.5	–	2.3	–	4.9
Partial (–)	–	19	–	1.7	–	2.5	–	5.1
Complete (÷)	–	9	–	1.8	–	2.3	–	3.6
C. 28 of the 53 streams observed in 1968–69 and 1969–70 (Inside Central Valley)								
None (0)	9	9	2.0	1.7	1.3	2.1	13.3	15.0
Partial (–)	12	12	3.2	2.6	2.9	2.1	3.9	2.
Complete (÷)	7	7	2.0	2.0	2.7	2.0	5.1	6.

accounts for the absence of immature forms from some streams (39,40, and 41).

The prevalence rates of biting adults were so variable both inside and outside the Central Valley that no trends related to pollution were indicated from our data.

It is important to note that physicochemical data of the waters not available for this study should be obtained in the future to have a much better understanding of the importance of the quality of the waters in the population dynamics of simuliids.

Shade: The sectors of the streams studied were sufficiently variable in the amount of shade (Table 6) to provide some data on the effect of shade on black fly breeding. Larval populations in all four groups were more abundant in streams that were partially shaded. This was also true in biting adults in group B, whereas in the other groups, none were found in sites with no shade, probably a reflection of the altitude and subsequently cooler atmosphere in the Central Valley.

Other observations: No immature forms were found for one or more occasions in the following stream sites: 3, 5, 5a, 7, 9, 13, 14a, 15, 18, 19, 22, 23, 24, 25, 28, 29, 32, 32a, 34, 35, 38, 39, 40, 41, 42, 43, 50, 51, 53, 54, 55, 56, 57, 61, 62, 63, 64, 73, 76, 79, 80, 83, 84, 89, 90, 92, 95, and 97. Also important in understanding population changes is the fact that some of the smaller streams dried up at some time during the dry season, as happened with 5a, 14a, 15, 17 and 20. This and the absence of immature larvae in so many streams (49 of 100) indicate the need of several continued observations to adequately establish the productivity of black flies in any given stream.

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RESUMEN

Un estudio de los simúlidos en 100 ríos y riachuelos de Costa Rica por un período de dos años no mostró estrechas correlaciones entre las poblaciones larvales, ni en la de adultos picadores del hombre, con los siguientes factores: substrato, altitud, sombra, velocidad, turbulencia y contaminación del agua.

La información obtenida muestra sólo pequeñas diferencias que permiten delinear tendencias de asociación entre las variables estudiadas.

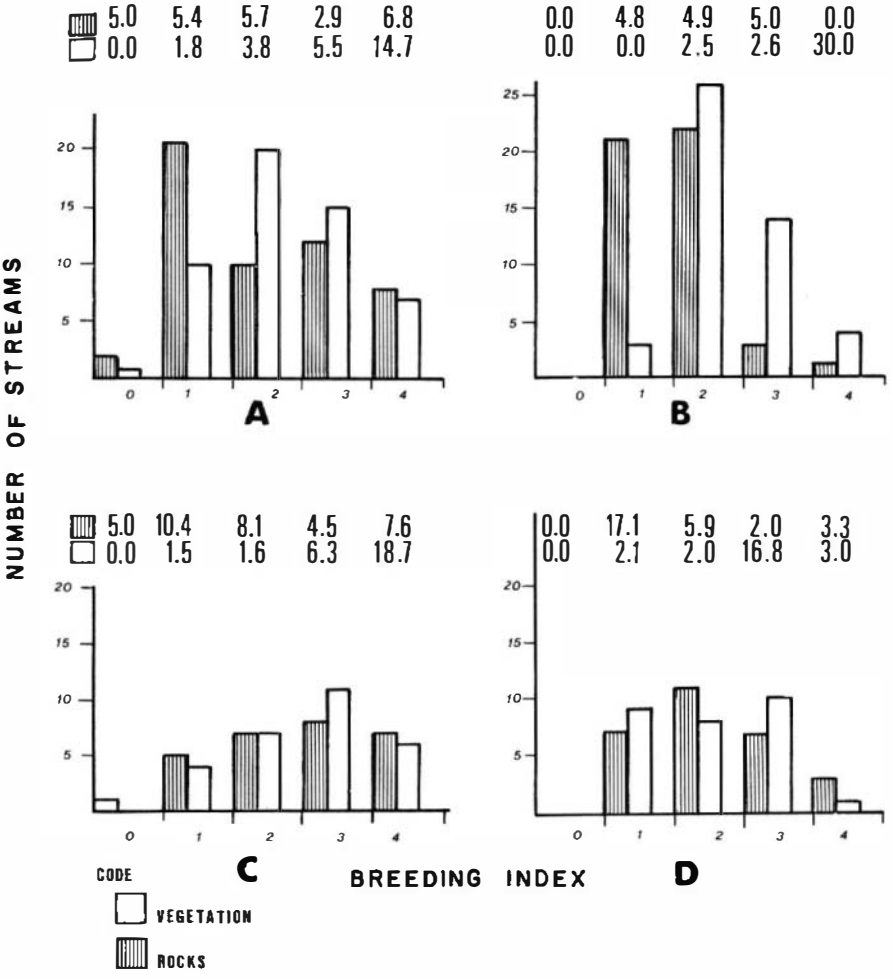
LITERATURE CITED

Vargas V., M., & B. V. Travis
1973. Bionomía de los Simúlidos (Diptera: Simuliidae) en Costa Rica. IV. Localización y descripción de los lugares de recolección. *Rev. Biol. Trop.*, 21: 143-175.

Vargas V., M., B. V. Travis, A. Díaz Nájera, & F. Fallas B.
1977. Bionomics of black flies (Diptera: Simuliidae) in Costa Rica. VII. Genus *Simulium* subgenus *Hearlea*. *Rev. Biol. Trop.*, 25: 137-149.

Zeledón, R., & P. L. Vieto
1957. Contribución al estudio de los Simúlidos de Costa Rica (Diptera: Nematocera). 1. Sobre el *Simulium panamense* Fairchild, 1940. *Rev. Biol. Trop.*, 5: 19-33.

1. Correlation of the average number of biting adults (figures above the bar graphs) and the larval production indices (bar graphs) on rocks and vegetation: A,53 streams observed in the Central Valley in 1968-69; B,47 streams mostly outside the Central Valley. 1969-70; C,28 of the 53 streams inside the Central Valley, 1968-69; and D,28 of the 53 streams inside the Central Valley, 1969-70.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0.0 1.8 3.8 5.5 14.7
0.0 4.8 4.9 5.0 0.0
0.0 0.0 2.5 2.6 30.0
NUMBER OF STREAMS
A
B
5.0 10.4 8.1 4.5 7.6
0.0 1.5 1.6 6.3 18.7
0.0 17.1 5.9 2.0 3.3
0.0 2.1 2.0 16.8 3.0
C
BREEDING INDEX
D
CODE
VEGETATION
ROCKS