SEASONAL AND METEOROLOGICAL EFFECTS ON ACTIVITY OF *CHRYSOPS VARIEGATUS* (DIPTERA: TABANIDAE) IN PARAGUAY[1]

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ABSTRACT. Activity of adult, female *Chrysops variegatus* was studied for 17 months near Aregúa, Paraguay. The population was sampled by walking along a forest path while swinging an insect net. Results of sampling indicated that this species followed no seasonal pattern of activity. Fluctuation in activity appeared to follow a 13-week cycle. Meteorological effects on activity were studied during 2 weeks of peak tabanid abundance. Temperature, humidity, and wind accounted for 89% of the variation observed during the 23 weeks. Activity of this species observed on a particular day appeared to be the result of the overall population level and meteorological conditions at the time.

INTRODUCTION

Chrysops variegatus (De Geer) is a small, yellow-and-brown tabanid occurring from Mexico to Argentina and in the West Indies (Fairchild 1971). This species is particularly abundant in the central region of Paraguay, where it is common in forested areas near water. The habits of *Chrysops variegatus* suggest that it may be of veterinary significance. Since the species readily attacks livestock, production of cattle and working equines might be impaired where the fly is locally abundant. Also, distribution of *Chrysops variegatus* coincides with some of the areas endemic for *mal de caderas* (Russo 1954), a serious equine disease caused by *Trypanosoma evansi* (Steel) (=*T. equinum*) and thought to be transmitted by biting flies (Hoare 1972).

Although there are no previous studies of the bionomics of *Chrysops variegatus* in Paraguay, observations on this species in other regions have been published. Fairchild (1942), working in the Chagres River Valley of Panama, collected relatively few specimens. The species appeared to follow no particular season of abundance. Bouvier (1952) collected 132 female specimens (reported as *Chrysops lynchii* Brethes, synonymized to *Chrysops variegatus* by Fairchild (1971)) during nearly 3 years of study in Campinas, Brazil. All were collected during the warmer, wetter seasons (September through May). In Cali, Colombia, Wilkerson (1979) collected 28 female *Chrysops variegatus* during 1½ years of study. All specimens were collected during September through April at temperatures ranging from 21° to 31°C and relative humidities ranging from 58% to 91%. In a one-year study in Manaus, Brazil, Rafael (1982) collected 17 female *Chrysops variegatus* during the months of February, April, July, September and October.

A large population of *Chrysops variegatus* near Areguá, Departmento Central, Paraguay, provided an opportunity to study bionomics of this species. Seasonal and meteorological effects on activity of female *Chrysops variegatus* were examined from Feburary 1979 to June 1980. This paper describes results of that study.

MATERIALS AND METHODS

The study area was located 4 km northwest of the railroad station of Areguá (25°20'S, 57°25'W), adjacent to Lake Ypacarai. The area consisted of a sandy, wooded (3–15 m high) strip of land about 500 m wide, bordered on one side by the shallow waters of the lake and on the other side by a low-lying, grassy swamp. A narrow (3 m width) road ran along the center of the strip of land. The degree of canopy along the road varied from near complete coverage where the forest was thickest to no coverage at all in clearings. The climate was typical of the subtropics with average maximum and minimum temperatures in December through February of 32.5° and 23°C respectively, and average maximum and minimum temperatures in June through August of 21.5° and 13°C respectively. Rainfall was moderate (1475 mm from November 1978 to November 1979) and not seasonally concentrated during the study.

A number of techniques for measuring tabanid populations were attempted initially. All of these involved capturing and killing the flies. Trials of these methods indicated that removal of tabanids from an area affected subsequent measurements of a population. Consequently, a technique was developed which allowed release of captured flies following identification and marking.

We collected specimens by swinging an insect

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net (30 cm diam) in front of the face and shoulders while walking slowly. A number of previous workers have made similar use of nets, especially for sampling *Chrysops* (Roth and Lindquist 1948, Thompson 1969, Gojmerac and Devenport 1971, Dale and Axtell 1975, Thorpe and Hansens 1978). The collecting technique was standardized for this study by marking off nine 35 m sections of the road where *Chrysops variegatus* was most abundant. The net was swung constantly in front of the head and shoulders while walking slowly (about 1 minute) through a section. At the end of the section, the tabanids were identified, marked with a date-coded pattern in India ink and released.

Meteorological records of wind, temperature and humidity were kept for each day's sampling. Measurement of wind speed was taken at the end of each section by observing the deflection of the insect net. Scores of 0 to 4 were assigned to easily distinguished degrees of deflection. Calibration with an anemometer in the laboratory indicated that 0 and 1 corresponded to winds less that 2 kph, 2 to winds up to 11 kph, 3 to winds up to 22 kph and 4 to winds greater than 22 kph. A mean value of wind for the entire sampling period was obtained by averaging the scores from the 9 sections. Relative humidity and temperature were measured with a sling psychrometer at the end of the final section of sampling.

This technique was employed to study the effects of season, temperature, wind speed, and humidity on number of flying female *Chrysops variegatus*. All sampling was begun in the afternoon, following sunrise by ¾ of the number of hours of daylight. This time of sampling was chosen based on preliminary observations of the time when flies were most reliably present. In an effort to avoid recounting flies following the collector, only unmarked flies or flies marked on a previous day were counted toward the populations. This adjustment had little effect on the data because the number of flies which were recaptured on the same day was very small (1.5%). Seasonality was studied by sampling the population one to several times each week, except for a month (May 1979) when injury prevented trips to the field. Effects of temperature, wind, and humidity were studied by daily sampling during the 2 weeks of the study when the tabanids were most abundant (March 24 through April 7, 1979). By concentrating on this short period, meteorological effects were studied independently from fluctuations in population level.

SAS Statistical Analysis System (SAS Institute 1979) was used to perform all statistical analyses. Seasonal distribution was analyzed using 2 different methods. First, differences among monthly means of flies captured were tested using an analysis of variance followed by Duncan's multiple range test. Second, weekly means of number of flies captured from the second week of September 1979 (week number 32) through the first week of June 1980 (week number 70) were tested for periodicity. This segment was chosen because it included no collecting interruptions and encompassed the final warm seasons of the study. Using modifications of the techniques of Hayes and Downs (1980), analysis for periodicity was accomplished by estimating parameters of a cosin equation with the SAS "NLIN" procedure/"DUD" method. The equation was of the form:

$$Y=A+\{B \cdot \cos[(C \cdot X)-D]\}$$

where Y=number of flies captured,

A=mean number of flies throughout the time of study,
B=degree of amplitude of the periodic waves,
C=length of periods, where the period in weeks is equal to (2 pi)/C,
X=week number,
D=shift of phase.

Significance of the results were inferred from the Kolmogorov-Smirnov test of difference from white noise and from the asymptotic 95% confidence limits of the calculated period.

Effect of meteorological factors on activity of the flies was analyzed using multiple linear regression. The form of the equation was:

$$Y=A+(B \cdot X_1)+(C \cdot X_2)+(D \cdot X_3)$$

where Y=number of flies captured,

X_1=dry-bulb temperature in °C,
X_2=wind speed on a scale of 0 to 4,
X_3=relative humidity in percent.

This analysis was performed separately on the entire 17-month study and on the 2 weeks of consecutive, daily sampling in March and April 1979.

RESULTS

Female *Chrysops variegatus* remained active throughout the year with no seasonal pattern of abundance (Table 1). Except for a peak of activity in March and April 1979, the months of sampling did not differ significantly from one another.

Table 1. Mean of number of female *Chrysops variegatus* captured and of dry-bulb temperatures at the times of capture. Tabanids were captured by swinging a net constantly while walking along forested road. Aregúa, Paraguay, 1979–1980.

Month	No. of observations	Mean per observation ± S.D. Flies captured	Temperature (°C)
Feb	6	9.3 ± 5[b]	32.7 ± 2.9
Mar	11	18.7 ± 10.4[a]	28.3 ± 2.4
Apr	7	24.3 ± 20.1[a]	22.0 ± 4.1
May	No data	—	—
Jun	2	5.0 ± 1.4[b]	24.5 ± 0.7
Jul	4	0.8 ± 1.5[b]	22.0 ± 7.9
Aug	7	2.9 ± 2.8[b]	25.6 ± 4.2
Sep	5	3.8 ± 4.7[b]	22.4 ± 5.8
Oct	7	4.0 ± 3.3[b]	27.1 ± 2.8
Nov	8	1.0 ± 1.1[b]	28.5 ± 2.6
Dec	8	2.5 ± 1.8[b]	28.8 ± 3.8
Jan	7	2.0 ± 2.3[b]	30.6 ± 2.2
Feb	7	0.4 ± 0.5[b]	31.7 ± 1.8
Mar	6	1.5 ± 1.5[b]	31.8 ± 1.6
Apr	8	1.5 ± 2.2[b]	29.1 ± 4.1
May	7	0.3 ± 0.8[b]	26.3 ± 4.6
Jun	3	0.7 ± 1.2[b]	23.0 ± 3.6

* Means of flies captured not followed by the same superscripted letter were significantly different at the 95% level.

Close examination of the weekly mean number of tabanids captured during the final 38 weeks of the study indicated a definite periodicity with decreasing amplitude (Fig. 1). The length of the period was 12.7 weeks with 95% confidence interval of 11.7 to 14.0 weeks. The Kolmogorov-Smirnov statistic for the data (0.39) was significant at the 99% confidence level, suggesting that variation in the data was not random or "white noise."

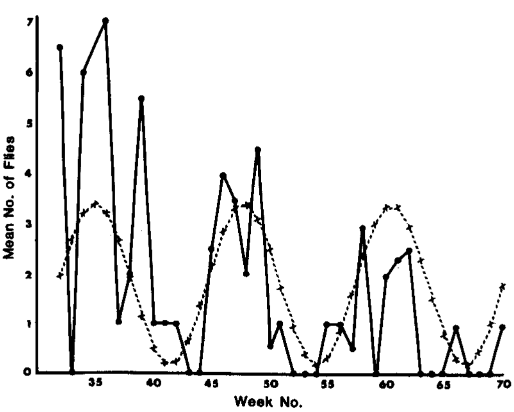

Fig. 1. Mean of number of female *Chrysops variegatus* captured (solid line and circles) compared to fitted cosin curve (dashed line and X's). Aregua, Paraguay, September 1979 through June 1980.

Temperature, wind and relative humidity were good predictors of activity over a short period, but not when applied to data from the entire study. Multiple linear regression applied to all of the data resulted in an R^2 value of 0.065 (6.5% of the variation accounted for by the model). The same equation applied to 2 weeks of daily, consecutive sampling during the peak period of abundance resulted in a highly significant R^2 value of 0.89 with estimated parameters as follows: A (Y intercept) = −130.6, B (parameter for temperature) = 3.3, C (parameter for wind speed) = −17.4, D (parameter for relative humidity) = 1.5. Each parameter was significantly different from zero at the 99% level. The model as a whole had an F value significant at the 99% level. During the 2-week interval, temperature varied from 17 to 30°C, wind from a mean of 1.0 to a mean of 2.8 scored units and relative humidity from 53 to 81%.

DISCUSSION

General discussions about seasonal flight activity of adult tabanids in the tropics (Fairchild 1942, Fain 1969, Goodwin 1982) have suggested several temporal patterns. These patterns fall into 2 broad categories. In the first category, adult flies are active during a part of the year and absent the rest of the time. Activity in these cases is usually determined by some seasonal phenomenon, such as a wet season. In the second category, adult flies are active all year and may or may not follow an obvious pattern of seasonal abundance.

Previous workers have not clearly assigned *Chrysops variegatus* to one of these categories of seasonal distribution. Wilkerson (1979) found adults only in non-summer months while Bouvier (1952) found adults only in non-winter months. On the other hand, Fairchild (1942) and Rafael (1982) found adults throughout the year. The small number of specimens and varied means of collection in these studies make it difficult to form any conclusions on geographic or seasonal effects. Our study, with the advantage of a consistent collecting technique and a large population, documented the presence of adults during all parts of the year. No pattern of seasonal abundance was detected.

The non-seasonal pattern of activity of *Chrysops variegatus* was unusual among tabanids in the region. The only other species with such broad seasonal distribution in Aregúa were an unnamed *Chrysops* and *Tabanus triangulum* Wiedemann (Strickman 1982). Hack (1970), in northern Argentina, reported only *Tabanus triangulum* and *Tabanus claripennis* (Bigot) as present during most of the year. Of 43 species studied by Bouvier (1952) in Campinas, Brazil, only 5 species of the *Tabanus lineola* complex (cited as *triangulus, ochrohphilus, carneus, stenocephalus* and *lineola*; named here according to Fairchild (1983)) as present all year. In all 3 of these studies, winter was the main seasonal influence on other species.

Although no seasonal pattern of activity was observed, a periodic pattern of abundance was detected in data from the final 9 months of the study. The length of the period was approximately 13 weeks. The significance of this periodicity is not known, but it may represent the time necessary between generations.

Meteorological factors had a great influence on activity, though they were not sufficient to explain abundance throughout the year. Temperature, wind and relative humidity accounted for 89% of the variation in activity observed during a short period in which the population as a whole did not vary. Meteorological factors were poor predictors when superimposed on fluctuations of the population during the year. Evidently, weather conditions influenced activity levels of individuals, but the number of individuals present varied during the year.

Other work on meteorological effects on flight activity indicate variation in response of tabanids to weather factors. In a study similar to ours, Dale and Axtell (1975) found no correlation between weather factors and activity of *Chrysops fuliginosus* Wiedemann in North Carolina, USA. In the same study, they found a strong correlation of activity of adult *Chrysops atlanticus* Pechuman with temperature and humidity, but not with wind. Thorpe and Hansens (1978), in New Jersey, USA, also studied *Chrysops atlanticus*, finding correlations of activity with wind and humidity, but not temperature. These studies and our work on *Chrysops variegatus* imply that members of the genus are not consistent in their response to weather conditions. The source of this variation in response is not clear at this time, but possibilities include interspecific differences, local adaptation to particular hosts, and biases of sampling techniques.

The factors affecting abundance of flying *Chrysops variegatus* appear to proceed from general influences on the population to specific conditions for activity. The total population of adults probably follows relatively long-term trends, though season has no effect. Determiners of these trends might include weather history, abundance of natural enemies, or some other element of the environment which does not follow a strict seasonal cycle. The population varies periodically within these longer trends, possibly due to partial synchronization of generations. Given a certain population level, the number of females flying is almost totally determined by weather conditions at the time.

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References Cited

Bouvier, G. 1952. Notes sur les tabanidés de la région do Campinas (Estado S. Paulo)—Brésil. Mem. Inst. Oswaldo Cruz Rio De J. 50:581 –596.

Dale, W. E. and R. C. Axtell. 1975. Flight of the salt marsh Tabanidae (Diptera), *Tabanus nigrovittatus, Chrysops atlanticus* and *C. fuliginosus*: Correlation with temperature, light, moisture and wind velocity. J. Med. Entomol. 12:551–557.

Fain, A. 1969. Notes sur la distribution géographique de la filaire *Loa loa* et des tabanidés du genre *Chrysops* au Congo et au Rwanda. Ann. Soc. Belge Méd. Trop. 49:499–530.

Fairchild, G. B. 1942. The seasonal distribution of some Tabanidae (Dipt.) in Panama. Ann. Entomol. Soc. Am. 35:85–91.

Fairchild, G. B. 1971. A catalogue of the Diptera of the Americas south of the United States. 28. Family Tabanidae. Museu de Zoologia, Universidade de Sao Paulo, pp. 1–163.

Fairchild, G. B. 1983. Notes on neotropical Tabanidae (Diptera). XIX. The *Tabanus lineola* complex. Misc. Pub. Entomol. Soc. Am. 57:1–51.

Gojmerac, W. L. and E. C. Devenport. 1971. Tabanidae (Diptera) of Kegonsa State Park, Madison, Wisconsin: Distribution and seasonal occurrence as determined by trapping and netting. Mosq. News 31:572–575.

Goodwin, J. T. 1982. The Tabanidae (Diptera) of Mali. Misc. Pub. Entomol. Soc. Am. 13:1–141.

Hack, W. H. 1970. Datos bionomicos de Tabanidos de Corrientes. Acta Zool. Lilloana 27:269–298.

Hayes, J. and T. D. Downs. 1980. Seasonal changes in an isolated population of *Culex pipiens quinquefasciatus* (Diptera: Culicidae): A time series analysis. J. Med. Entomol. 17:63–69.

Hoare, C. A. 1972. The trypanosomes of mammals: A zoological monograph. Blackwell Scientific Publications, Oxford.

Rafael, J. A. 1982. Ocorrência sazonal e abundância relativa de Tabanidae (Diptera) no Campus Universitário, Manaus, Amazonas, Acta Amazonica 12:225–229.

Roth, A. R. and A. W. Lindquist. 1948. Ecological notes on the deer fly at Summer Lake, Oregon. J. Econ. Entomol. 41:473–476.

Russo, J. V. 1954. El mal de caderas en el Chaco Paraguayo (Tripanosomiasis Equina). Registro de la Propiedad Intelectual No. 2361, Asuncion, Paraguay.

SAS Institute, Inc. 1979. SAS user's guide, 1979 ed. SAS Institute, Raleigh, NC.

Strickman, D. 1982. Notes on Tabanidae (Diptera) from Paraguay. J. Med. Entomol. 19:399–402.

Thompson, P.H. 1969. Collecting methods for Tabanidae (Diptera). Ann. Entomol. Soc. Am. 62:50–57.

Thorpe, K. W. and E. J. Hansens. 1978. Diurnal activity of *Chrysops atlanticus:* Some questions concerning sampling techniques. Environ. Entomol 7:871–873.

Wilkerson, R. C. 1979. Horse flies (Diptera: Tabanidae) of the Colombian departments of Choco, Valle, and Cauca. Cespedesia 8:99–432.