CULEX QUINQUEFASCIATUS SAY: LIFE TABLE CHARACTERISTICS OF ADULTS REARED FROM WILD-CAUGHT PUPAE FROM NORTH WEST FRONTIER PROVINCE, PAKISTAN[1]

MOHAMMAD SULEMAN
Department of Zoology, University of Peshawar, Pakistan
WILLIAM K. REISEN,
Pakistan Medical Research Center, University of Maryland School of Medicine, 6, Birdwood Road, Lahore, Pakistan

ABSTRACT. Age-specific life tables were compiled for 3 cohorts of *Cx. quinquefasciatus* emerging from wild-caught pupae collected during autumn at Peshawar, North West Frontier Province, Pakistan and held in a room whose mean temperature ranged from 19° to 25°C and relative humidity ranged from 79 to 92%. Female life expectancy at emergence was 74.1 days, which was significantly longer than males, 30.0 days. The net reproductive rate was 58.6 females per female per generation, the innate rate of increase was 0.081 females per female and the generation time was 50.5 days. These results were compared with those presented for other geographic strains of *Cx. quinquefasciatus*.

Culex quinquefasciatus Say is a circumtropically distributed domestic mosquito which has been incriminated in the transmission of West Nile Virus and found naturally infected with *Wuchereria bancrofti* in Pakistan (Knight and Stone 1977, Burney and Munir 1966, Aslamkhan and Pervez unpubl.). As part of on-going studies on the bionomics of this species in the Peshawar area of North West Frontier Province, a horizontal life table was constructed for adults emerging from wild-caught pupae during autumn.

Complete birth and death schedules have been recently compiled for established colonies of *Cx. quinquefasciatus* from Bangkok, Thailand and Vero Beach, Florida, and Houston, Texas, U.S.A., (Walter and Hacker 1974) and from Caracas, Venezuela, (Gomez et al. 1977). Additional observations on adult longevity were presented by Wattal et al. (1961), Reddy (1976) and others. Much of the pertinent literature dealing with the laboratory bionomics of *Cx. quinquefasciatus* was summarized by Gomez et al. (1977).

The object of the present study was to describe the life table attributes of cohorts of adults emerging from wild-caught pupae during autumn. Since mosquitoes were kept under temperature and humidity regimens which approached room conditions, the present observations may approach the life table attributes of overwintering indoor resting *Cx. quinquefasciatus* at the University of Peshawar during late autumn and winter.

METHODS AND MATERIALS

BIOLOGICAL METHODS. At emergence 3 replicate cohorts of 100 males and 100 females were established in 30 × 30 × 30 cm cages from wild-caught pupae collected in a drain near the Department of Zoology, University of Peshawar. Adults were continuously offered 3% sucrose in vials with wicks, an oviposition cup filled with well-water and at night, a tethered laboratory mouse as a blood meal source. *Cx. quinquefasciatus* is normally nocturnal in its blood feeding habits (e.g. Rajagopalan et al. 1977) and thus the blood meal source was constantly available during the normal feeding period. Each morning all dead adults were removed and counted, and all egg rafts isolated individually in test tubes. Eggs were incubated for 2 days at 29°C and then the numbers of hatched and unhatched eggs

---

[1] Please address reprint requests to W. K. R.

were counted under a dissecting microscope.

Cohorts were held at room temperature and humidity in a room on the first floor of the Department of Zoology which was warmed with an electric heater. Two or three large earthen dishes filled with water were used to increase relative humidity. A 12L:12D photoperiod was established with two 100-watt incandescent and two 60-watt fluorescent lights; no crepuscular period was simulated. Although slightly warmer, these conditions approached those of the buildings at the University of Peshawar where *Cx. quinquefasciatus* may be collected overwintering.

STATISTICAL METHODS. Life table calculation procedures, formulae and rationale used in the present study essentially followed Reisen et al. (1979) and may be summarized as follows:

1. Age-specific survivorship, $l_x = y_x/y_0$ where y_x=number of males or females alive during each day, x.

2. Age-specific life expectancy, $e_x = T_x/l_x$, where $T_x = \sum_{x}^{w} L_x$ and $L_x = (l_x + l_{x+1})/2$; e_1 = life expectancy at emergence in days and w = the day the last individual died.

3. The form of the survivorship curve was ascertained by fitting a curvilinear regression of the form $\log_{10} l_x = \log_{10} a - x\log_{10} b$ and then testing the significance of the regression coefficient, $\log_{10} b$, by analysis of variance (Sokal and Rohlf 1969). A significant f ratio would indicate constant daily survivorship; i.e. Deevey's (1947) Type II curve. Significant deviations from regression would imply either a Deevey's (1947) Type I or III curve depending on the point of inflection. The daily survivorship rate could then be estimated by back-transforming the fitted regression coefficient.

4. The net reproductive rate per cohort, or the number of living females produced per female per generation, $R_0 = a \sum_{x=1}^{w} l_x m_x$, where a = the proportion of females that survive from egg through adult emergence and $m_x = E_x s$ with E_x = the number of larvae (i.e. hatching eggs) produced per female per age interval and s = the proportion of the offspring that were females. We assumed *a* to be constant and equal to 0.5; theoretical R_0 values were estimated by setting a = 1.00. Laboratory rearing experiments with the progeny of wild-caught females from Peshawar have resulted in estimates of a = 0.512 (Suleman unpublished) agreeing with the laboratory results of Gomez et al. (1977), a = 0.526, and Hayes and Hsi (1975) under semi-natural field conditions at similar temperatures. The number of eggs laid was counted for age intervals x = 1 to w, but the number of hatched and unhatched eggs was counted from x = 35 to w. The total hatch rate for rafts from x = 35 to 50 was used to estimate the number of larvae eclosing on x = 1 to 35 by multiplying the hatch rate times the number of eggs. Since there was no significant change in the hatch rate from x = 35 to w, this method was presumed to yield appropriate estimates of E_x. The sex ratio at emergence was 0.492 males/total; not significantly different from s = 0.5 ($P>0.05$) which was used as a constant.

5. Age of mean cohort reproduction, $T_0 = a \sum_{x=1}^{w} l_x m_x x / R_0$ starting at x = 1, the day of adult emergence.

6. The innate rate of increase, r_m, was calculated using the Dobzhansky et al. (1964) modification of the original Euler-Lotka equation solved by the Newton-Raphson iteration method, where $1 = a \sum_{x=1}^{w} l_x m_x e^{-r_m(x+D)}$, e = the base of natural logarithms, and D = the length of time from oviposition in the present generation to first oviposition in the F_1 generation. In 1 estimate a = 0.5 and D = 23 days; considering the duration of the immature stages to be 13 days (Suleman unpubl., Hayes and Hsi 1975) and the duration of the nulliparous period to be 10 days (Fig. 1). For compari-

son a theoretical r_m was also calculated with $a = 1.0$ and $D = 0.0$.

7. Mean generation time was then calculated as $G = (\ln R_o)/r_m$.

8. With the requisites of life constantly available, the value of r_m presumably approached its maximum expression and was relatively constant. Thus, the birth rate was estimated from the stable age distribution, where $b = \ln(1+\beta)$ and $1/\beta = \sum_{x=1}^{w} L_x e^{-r_m(x+1)}$.

9. The death rate $d = b - r_m$.

For each life table statistic, the mean and 95% confidence intervals were calculated for the 3 replicate values. Age-specific changes in fecundity and egg hatch were analyzed using replicated model II, regression analyses of variance with the experimental units being the mean number of eggs oviposited/egg raft during each 5 day interval and the total hatch rate of all eggs oviposited during each 5 day interval, respectively.

RESULTS AND DISCUSSION

The mean female life expectancy at emergence was significantly longer than that of the males (Table 1, Fig. 1). Male and female life expectancies in the present study were longer than those reported by Walter and Hacker (1974), but were not statistically different from those reported by Gomez et al. (1977) ($P>0.05$). Estimates reported by Wattal et al. (1961, e_1 ♀♀ = 20.16 and e_1♂♂ = 14.8) and Reddy (1976, e_1, males + females = 11.84 days) were considerably shorter. Increased life expectancy in the present study was attributed, in part, to slightly lower temperatures and higher humidities.

The linear regression of $\log_{10} l_x$ on x in days provided a highly significant fit for each of the 3 replicates ($P<0.001$) suggesting that the mortality rate was constant with age. In addition, the coefficients of determination, r^2, for the 3 cohorts were also high indicating a good fit of the data (females = 0.706, 0.839, 0.740; males = 0.820, 0.743, 0.714). The survivorship curve for *Cx. quinquefasciatus* was thus considered to be a typical Deevey (1947) Type II curve (Fig. 1) and not a Type III curve as concluded by Gomez et al. (1977). The backtransformed regression coefficients provided estimates of the daily survivorship rate which were significantly higher for females than males (s ♀♀ = 0.977±0.012) s♂♂ 0.916±0.002. Survivorship estimates obtained in nature using mark-release-recapture methods

Table 1. Summary of life table attributes of 5 strains of *Cx. quinquefasciatus*; $\bar{x} \pm 95\%$ confidence interval presented.

	STRAINS				
	Pakistan	Thailand	USA		Venezuela
	Peshawar	Bangkok[1]	Vero Beach[1]	Houston[1]	Caracas[2]
Temp (°C)	19.9–25.6	25–28	25–28	25–28	25 ± 1
RH (%)	78–92	75–80	75–80	75–80	73.5 ± 10
e_1♀♀[3]	74.13 ± 25.46	35.14 ± 5.09	45.20 ± 5.95	40.36 ± 7.45	48.06 ± 9.74
e_1♂♂[3]	30.04 ± 11.16	16.40 ± 7.46	23.64 ± 4.14	24.22 ± 2.86	30.60 ± 4.65
R_o[4]	58.57 ± 25.82	8.12 ± 3.64	24.29 ± 5.93	37.73 ± 22.00	80.68 ± 24.2
r_m[5]	.081 ± 020	.174 ± .086	.290 ± .114	.293 ± .086	.154 ± .016
G[6]	50.48 ± 6.97	32.04	26.78	28.52	57.02

[1] Recalculated from data presented by Walter and Hacker (1974).
[2] Recalculated from data presented by Gomez, et al. (1977).
[3] Mean life expectancy at emergence in days.
[4] Net reproductive rate; living females per female per generation, $a = 0.5$.
[5] Innate rate of increase, living females per female, as calculated by the authors.
[6] Generation time in days, calculated from the original data.

were significantly lower (Macdonald et al. 1968, s♀♀ = 0.90; Lindquist et al. 1967, s ♀♀ = 0.83, Yasuno and Rajagopalan 1977, s ♂♂, Oct. = 0.73, Jan. = 0.63, and Mar. = 0.84) and may give some indication of the impact of environmental resistance.

A mean ± 95% confidence interval of 27,695±8,572.0 eggs were oviposited by each cohort, of which 22,220.3±11,441.9 hatched. Fecundity (eggs/raft) was observed to decrease significantly as a function of female age, when tested by a replicated analysis of variance (Fig. 2). The mean square due to linear regression was highly significant ($P<0.001$) and the coefficient of determination of the fitted function was high, $r^2=0.892$, indicating the relationship was linear. Similar results were presented for 3 strains of *Cx. quinquefasciatus* by Walter and Hacker (1974). When tested by a similar regression analysis, egg hatch was found to be constant with female age for x = 35 to w and therefore, fertility (hatched eggs/raft) also declined in a linear fashion with female age relatively parallel with fecundity (Fig. 2). The overall egg hatch in the present

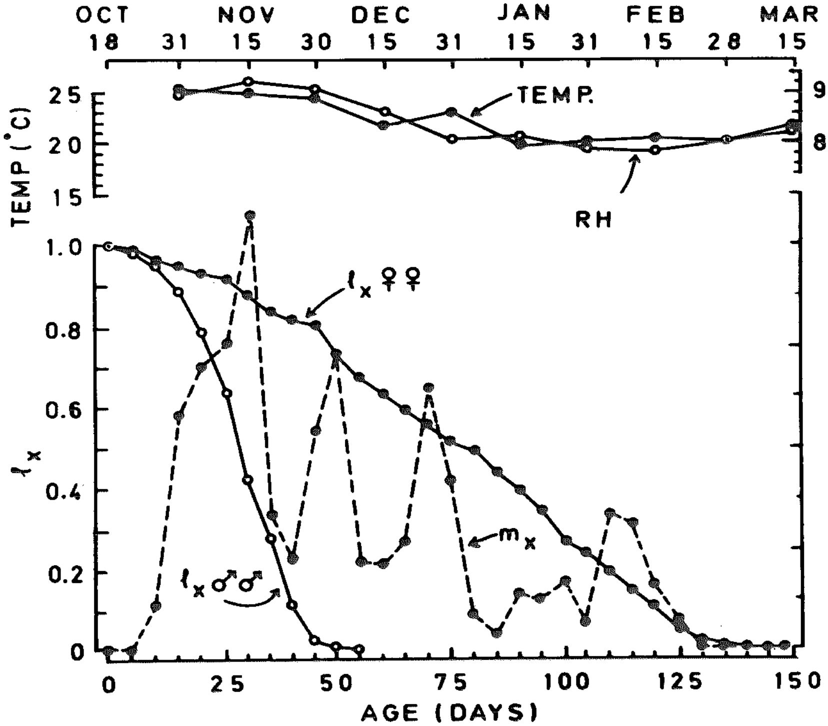

Fig. 1. Age specific survivorship for females and males (l_x) and reproductive effort (m_x) plotted as a function of adult age at 5 day intervals. m_x values were the mean number of hatching eggs per surviving female per day averaged at 5 day intervals. Mean daily temperature and relative humidity were tabulated for 15 day intervals.

experiment was 79.6±18.1%, slightly lower than observed for eggs from wild-caught females by de Meillon et al. (1967), but approaching the 82.08% reported for the progeny of laboratory adapted females by Gomez et al. (1977). Slight increases in the percent egg hatch would be expected as the colony became more adapted to mating under insectary conditions.

Reproductive effort, as indicated by mean m_x values, continued throughout the lifespan of the female, with egg rafts oviposited from intervals x = 8 to 128 (Fig. 1). m_x showed periods of marked increase followed by decreases in reproductive activity. Since blood meal hosts and oviposition substrates were offered continuously, the reasons for these oscillations remain cryptic. Similar changes in reproductive effort were depicted by Gomez et al. (1977); however, they offered blood meals at 4-day intervals and recorded ovipositions every 2nd day, which apparently synchronized the reproductive efforts of their cohorts, and correspondingly their m_x values were ca.10x the estimates presented in Fig. 1. This synchronization did not appear to alter the net reproductive rate which, when recalculated from their data, was statistically equal to R_0 in the present study. The R_0 estimates recalculated from the data of Walter and Hacker (1974) were considerably lower. When pre-reproductive age mortality was negated, i.e. a = 1.0, R_0 = 117.15±51.64 females per female for the Peshawar strain.

The intrinsic rate of increase when a = 0.5 and D = 23.0 days was r_m 0.081±0.020. The theoretical value when all offspring survive and reproduce instantly, i.e. a = 1.0 and D = 0.0, was r_m = 0.236±0.108. Walter and Hacker (1974) calculated r_m using a = 1.0 and D = 9 days and their estimates for the 2 North

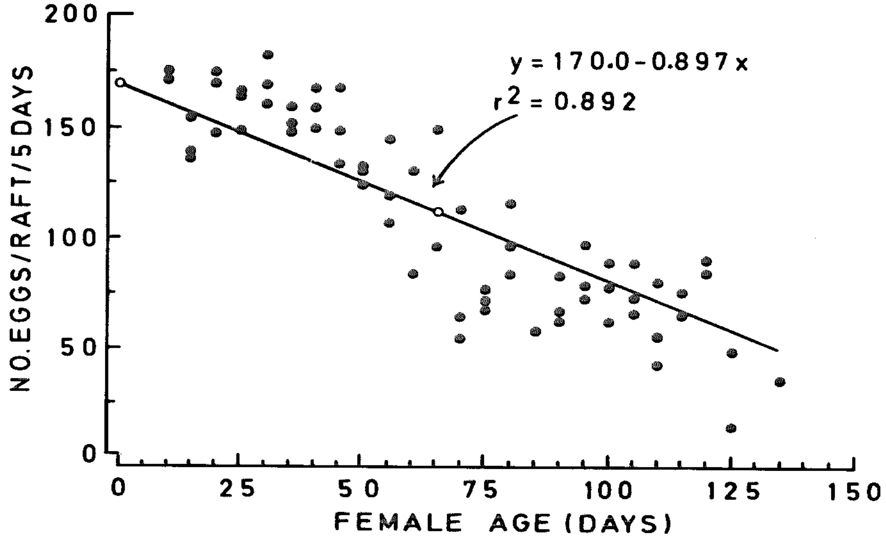

Fig. 2. The mean number of eggs per raft per cohort for each 5 day interval (y) plotted as a function of female age in days (x). Included is the fitted regression expression for replicate values of y and the coefficient of determination, r^2.

American strains were statistically equal to our theoretical values (Table 1). Gomez et al. (1977), using the formulae of Birch (1948) which does not include a or D, reported estimates of r^m for the Caracas strain which were significantly less than our theoretical estimate.

The age of mean cohort reproductive effort was $T_0 = 39.64 \pm 7.12$ days; very similar to the 44.67 ± 5.43 days reported by Gomez et al. (1977). The exact estimate of generation time was $G = 50.48 \pm 6.97$ days, again similar to the estimate of Gomez et al. (1977) when recalculated from their original data, but was considerably greater than the values presented by Walter and Hacker (1974) (Table 1). The theoretical estimate, i.e. when $a = 1.0$ and $D = 0.0$, was $G = 20.49 \pm 7.14$ days, considerably less than T_0. The instantaneous birth and death rates calculated from the stable age distribution were $b = 0.484 \pm 0.168$ and $d = 0.403 \pm 0.272$. The r_m/b ratio was 0.170 ± 0.058, lower than the estimate of Gomez et al. (1977), and supporting the supposition of Rabinovich (1974) that *Cx. quinquefasciatus* is an r strategist, but theoretically a poor colonizing species.

In conclusion, *Cx. quinquefasciatus* seemed able to overwinter at the University of Peshawar in a gonoactive state with females emerging during late autumn, persisting through the cold winter months and into early spring. Overwintering strategies of this nature coupled with a high degree of human and bird feeding, e.g. Reisen and Boreham (1979), seemed to indicate that this species could provide an overwintering mechanism for West Nile Virus in the Peshawar area.

ACKNOWLEDGMENTS

We thank Ms. Tasneem Khawar, Peshawar University, for help with the counting of the egg rafts and Dr. G. M. Malik, Engineering and Technological University, Lahore, and Mr. Asif Ali Shahid, Pakistan Medical Research Center, for helping with the computations. This research was funded, in part, by Grant No. AI-10049 from United States National Institute of Allergy and Infectious Diseases, N.I.H..

References Cited

Birch, L. C. 1948. The intrinsic rate of natural increase of an insect population. J. Anim. Ecol. 17:15–26.

Burney, M. I. and A. H. Munir. 1966. Role of arthropod borne viruses in human disease in Rawalpindi and Peshawar Area II. Isolation of West Nile virus from human blood and culicine mosquitoes in Rawalpindi Area. Pak. J. Med. Res. 5:271–184.

Deevey, E. A. 1947. Life tables for natural populations of animals. Quart. Rev. Biol. 22:283–314.

Dobzhansky, T., R. C. Lewontin and O. Pallovsky. 1964. The capacity for increase in chromosomally polymorphic and monomorphic populations of *Drosophila pseudoobscura*. Hered. 19:587–614.

de Meillon, B., A. Sebastian and Z. H. Khan. 1967. The duration of egg, larval and pupal stages of *Culex pipiens fatigans* in Rangoon, Burma. Bull. Wld. Hlth. Org. 36:7–14.

Gomez, C., J. E. Rabinovich and C. E. Machado-Allison. 1977. Population analysis of *Culex pipiens fatigans* Wied. (Diptera:Culicidae) under laboratory conditions. J. Med. Entomol. 13:453–463.

Hayes, J. and B. P. Hsi. 1975. Interrelationships between selected meteorologic phenomena and the immature stages of *Culex pipiens quinquefasciatus* Say; a study of an isolated population. J. Med. Entomol. 12:299–308.

Knight, K. L. and A. Stone. 1977. A catalog of the mosquitoes of the world (Diptera:Culicidae). 2nd Edn. The Thomas Say Foundation 6:1–611.

Lindquist, A. W., T. Ikeshoji, B. Grab, B. de Meillon and Z. H. Khan. 1967. Dispersion studies with *Culex pipiens fatigans* tagged with p^{32} in the Kemmendine area of Rangoon, Burma. Bull. Wld. Hlth. Org. 36:21–37.

Macdonald, W. W., A. Sebastian and Maung Maung Tun. 1968. A mark-release-recapture experiment with *Culex pipiens fatigans* in the village of Okpo, Burma. Ann. Trop. Med. Parasit. 62:200–209.

Rabinovich, J. E. 1974. Demographic strategies in animal populations: A regression analysis. In: *Tropical Ecological Systems.* F. B. Golley and E. Medina (Eds.) Ecological studies 11, Springer-Verlag, New York, pgs. 19–40.

Rajagopalan, P. K., G. D. Brooks, P. K. B.

Menon and T. R. Mani. 1977. Observations on the biting activity and flight periodicity of *Culex pipiens fatigans* in an urban area. J. Com. Dis. 9:22–31.

Reddy, S. R. 1976. Laboratory studies on the development, survival and life table of *Culex fatigans* and *Anopheles stephensi*. Proc. Indian Acad. Sci. (Sect. B) 84:117–123.

Reisen, W. K. and P. F. L. Boreham. 1979. Host selection patterns of some Pakistan mosquitoes. Amer. J. Trop. Med. Hyg. 28: 408–421.

Reisen, W. K., T. F. Siddiqui, Y. Aslam and G. M. Malik. 1979. Geographic variation among the life table characteristics of *Culex tritaeniorhynchus* Giles from Asia. Ann. Entomol. Soc. Amer. 72:700–709.

Sokal, R. R. and F. J. Rohlf. 1969. *Biometry*. W. H. Freeman & Co., San Francisco, CA., USA. 776 pgs.

Walter, N. M. and C. S. Hacker. 1974. Variation in life table characteristics among, three geographic strains of *Culex pipiens quinquefasciatus*. J. Med. Entomol. 11:541–550.

Wattal, B. L., N. L. Kalra and K. M. S. Bedi. 1961. Studies on culicine mosquitoes. 2. Laboratory studies on the longevity of adult *Culex fatigans* Wiedemann, 1828, Indian J. Mal. 15:321–337.

Yasuno, M. and P. K. Rajagopalan. 1977. Population estimation of *Culex fatigans* in Delhi villages. J. Com. Dis. 9:172–183.

PRELIMINARY TESTS ON THE USE OF TEMEPHOS FOR THE CONTROL OF BLACK FLIES (DIPTERA: SIMULIIDAE) IN NORTHERN QUEBEC

CHRISTIAN BACK, JEAN-GUY LANOUETTE AND ANTOINE AUBIN

Groupe de Recherche sur les Insectes Piqueurs, Pavillon B. Sulte, Département de
Chimie-Biologie, Université du Québec à Trois-Riviéres, C.P. 500, Trois-Rivieres,
Quebec, Canada G9A 5H7

ABSTRACT. Preliminary tests have been conducted in northern and southern Quebec on the use of temephos for the control of the larvae of *Simulium venustum* Say, the main man biter in those regions. The larvae are usually concentrated in the first 30 m of streams below lake outlets and control has to be done when the water temperature is around 8°C or 10°C. Our tests at 0.3, 1 and 3 ppm for 20 min with the emulsifiable concentrate of temephos in ground application show that efficiency of the larvicide immediately below site of application could be closely related to water temperature. At 8°C to 10°C percentage of larvae detaching from artificial substrates was lower than 20%.

INTRODUCTION

The recent development of northern Quebec has raised a problem to which urban populations of the south had not yet been exposed: biting flies, and especially black flies. Operational control of black flies being considered desirable for workers and their families, a study program was set up in 1976 for the village of Radisson to find: 1) where and when black fly larvae were breeding, 2) by which means breeding sites of biting species could be controlled, in a 10 to 15 kilometers radius around. The survey done in 1976 gave the answer to the first question. It turned out, as expected, that *Simulium venustum* Say was the main pest. Mature larvae were to be found by the end of May, when the water temperature had reached 8°C. The main breeding sites were medium to large streams, and high densities of larvae were usually restricted to the first 30 meters below lake outlets and beaver dams, as was already observed in southern Quebec (Back and Harper 1979). The next step was taken in 1977, when we tried to control typical breeding sites with a larvicide.