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Population dynamics of *Culex pipiens fatigans*, the filariasis vector, in Pondicherry—Influence of climate and environment

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The influence of environment and climatic factors as they affect the dynamics of population growth of the bancroftian filariasis vector, *Culex pipiens fatigans*, in Pondicherry, has been analyzed. The various parameters as obtained in Pondicherry were compared to Delhi rural and urban areas which have extreme climatic conditions. In Pondicherry, which has no extremes of climate, only environmental conditions like breeding surface area regulate population growth. The impact of climate and environment on the transmission of filariasis is also discussed.

Key Words: Population dynamics, ***Culex pipiens fatigans***

Culex pipiens fatigans, the vector of bancroftian filariasis, is the commonest among the urban man biting mosquitoes and occur in very high densities in many areas in India. Perfect environmental sanitation accompanied by strict enforcement of civic laws against causing domestic effluent accumulation is the only sure way to control this species. However, this is not practicable in all towns in the prevailing economic conditions in many developing countries like India and therefore attempts aimed at reducing the density of the vector in filariasis endemic towns have not yielded the desired results. This mosquito is a ubiquitous breeder, is capable of surviving in many adverse conditions and has been studied very extensively by many workers throughout the world and the references are far too many to be listed here. The object of this paper is to discuss the dynamics of population of this species in one of the towns in the coromandel coast, Pondicherry, which is highly endemic for filariasis, and the influence of climate and environmental conditions on its reproductive potential.

The present urban area of Pondicherry extends to about 10 sq. km, with a population of 100,000. Between 1961 and 1971 the urban area increased from 3.98 sq. km to 6.21 sq. km (56% increase) while the urban population increased from 51,700 to 90,600 (75.2% increase). Except the old town which is interspersed with an open drainage system, the rest of the housing colonies and industrial areas have no waste water disposal system. As a result, it has become a common sight to see cesspits near almost every house.

These are occasionally emptied by the house owners but breeding continues. The vacant plots in the newly formed colonies receive the effluents from the houses and form large cesspools during rainy season. It has been estimated that there are about 86 kilometers of running drains, 4000 wells (many supporting breeding), about 430 major cesspits and many smaller ones, in addition to numerous large and small ground pools. There is a large dedicated staff under the National Filaria Control Programme, who routinely apply 'pyrosene' oil in breeding places. In spite of the control measures, the population of *C. fatigans* continues to be high.

Pondicherry has a moderate climate without any extremes. The maximum temperatures range between 29.2 °C to 35.1 °C and the minimum temperatures, between 22.3 °C to 26.9 °C (table 1.) Being a coastal area, the climate is highly humid. The area receives a few showers from the South West monsoon, but the North East monsoon is strong, November being the month of heaviest rainfall. The maximum saturation deficiency was seen in May (12.4 mm) when the mean maximum temperature was 35 °C.

Table 1 *Calculated survival rates, life expectancy, number of egg laying, generation time, reproductive rate, and finite rate of increase* (λ) for C.p. fatigans *in Pondicherry with meteorological data*

	Mean Max temperature (°C)	Mean Min temperature (°C)	Mean Rel. humidity (%)	Rainfall (mm)	Saturation deficiency (mm)	Immature survival rate	Adult survival rate	Expectation of life in days	No. of egg laying per emerging female	Generation time (days)	Net reproduction rate R_o	Finite rate of increase (λ)
Dec. 1977	29.7	22.4	84.5	27.6	4.72	.051	.785	4.13	2.54	18.6	5.47	1.6324
Jan. 1978	28.0	22.3	80.5	3.6	5.52	.233	.8	4.48	2.77	19.5	11.30	1.1321
Feb.	29.2	22.4	80.3	0	5.91	.322	.83	5.36	3.29	20.01	20.87	1.1640
Mar.	30.8	25.3	77.0	0	7.59	.306	.82	5.03	3.11	19.89	17.99	1.1564
Apr.	30.9	25.5	77.7	0.1	7.34	.381	.775	3.92	2.4	19.28	14.61	1.1492
May	35.1	26.9	70.5	4.3	12.42	.250	.78	4.02	2.47	19.33	10.07	1.1269
June	32.5	23.3	72.0	23.2	10.00	.110	.86	6.63	3.92	20.49	9.55	1.1164
July	34.7	25.8	72.2	101.0	11.39	.060	.73	3.17	1.85	18.87	1.50	1.0219
Aug.	34.2	25.3	75.6	73.2	9.88	.093	.83	5.37	3.29	20.04	6.01	1.0936
Sept.	32.7	24.2	79.5	306.7	7.38	.024	.89	8.58	4.67	21.1	2.8	1.0500
Oct.	31.5	25.2	81.6	272.2	6.27	.068	.81	4.75	2.93	19.7	3.6	1.0676
Nov.	29.6	24.0	81.0	564.9	5.79	.023	.72	3.04	1.77	18.64	0.53	.9668

The relative density measurements of resting mosquitoes serves only the limited purpose of comparing seasonal changes. The relative density (table 2) declined gradually after February mainly due to the drying up of the breeding places in the post monsoon. The first rains of South West monsoon was in June–July when many low lying areas and cesspools became filled with water resulting in a tremendous increase in the breeding surface area. The increasing trend in density was reversed in September due to flushing

Table 2 *Seasonal chagnes in relative density of* C. fatigans, *filarial infection and infectivity rates in mosquitoes and the estimated proportion of people bitten by an infective mosquito*

	Rel. density (No. of females per manhour)	No. of mosqitoes dissected	Infection rate (%)	Infectivity rate (%)	Estimated proportion of people bitten by an infective mosquito
Dec.	45.5	266	14.3	1.5	.0657
Jan.	45.5	258	17.4	1.6	.0554
Feb.	48.2	264	17.1	2.3	.0396
Mar.	44.0	267	20.2	2.2	.0486
Apr.	25.4	233	21.5	1.3	.0691
May	16.5	151	21.2	1.9	.1084
June	9.7	106	13.2	0.	.0
July	9.8	115	16.4	0.9	.1186
Aug.	19.2	201	7.9	1.0	.0151
Sept.	27.2	222	11.3	4.5	.0224
Oct.	28.2	271	7.5	0.7	.0176
Nov.	15.6	231	19.0	0.9	.1525

away of the drains as a result of heavy rainfall, which was marked in the month of November. Density measurements by hand collections have many drawbacks as the accuracy of such measurements will depend on the methods employed and catching proficiency and honesty of the individual collection. In urban areas it has been found that most of the mating swarms takes place outdoors (Menon & Rajagopalan 1977), though some swarming has also been observed indoors. Immediately after emergence, the mosquitoes rest outdoors near their breeding places and only after the mating swarms the females enter the house for their blood meal. Thus most of the newly emerged mosquitoes are either destroyed by the physical impact of rain or their capacity to disperse is considerably reduced. The density, as measured from resting mosquitoes does not give an accurate index of the capacity of the mosquito species to increase or decrease in a particular period.

Therefore, to understand the dynamics of population growth, three parameters are considered, viz., the oviposition cycle, natural survival rate of the immature stages and the adult survival rates. Oviposition cycle for *C. fatigans* remained same around 5 : 3 in all seasons. The immature survival rate was obtained from another study (Vector Control Research Centre—Annual Report) and the adult survival rates from filarial infection rates in mosquitoes (Laurence 1963). Mean life expectancy (3.04 to 8.58 days) and the average number of egg laying per female (1-77–4.67) (Cuellar 1969) varied in different months. The cohort generation time, T, fluctuated around 18–20 days in all months of the year. But the net reproductive rate (R_o) varied widely from 0.53 to 20.87, being very low during the monsoon season and high during the drier period. The finite rate of increase (λ) was more than 1 in all months except November. The results indicate that the population tended to increase in all months except in November, the month of heaviest rainfall (tables 1, 2).

It is evident from the above that temperature does not play any role in population regulation in Pondicherry as both immature and adult survival rates as well as the net reproductive rates are high during the dry and hot months. These rates are low only during the monsoon period. There is no winter season and no appreciable lowering of the maximum or minimum temperatures during the monsoon months which could affect the immature duration or survival rates. The highest saturation deficiency observed was during May to July (10 mm–12.42 mm). The thermal death points determined for this species (Mayne 1930) were never reached in Pondicherry. Since *C. fatigans* breeds in stagnant water, immature mortality was high during the rainy season, due to overflowing of the cesspits and the flushing of drains. The duration of the immature stages, which depends on the water temperatures, remained almost same throughout the year (11–12 days).

The data in Pondicherry were compared (table 3) with data for Delhi rural area (Yasuno 1974) and Delhi urban area (Rajagopalan et al. 1977) where the generation time and the net reproductive rates varied widely with the seasons. Both the areas have extreme climatic conditions with a very hot summer and a very cold winter, but they differed from each other in the breeding habitats. In the rural area, the innumerable irrigation wells are the main breeding habitats in the dry months, when water conditions are ideal for breeding. During the rainy season, there is a shift in the breeding places (Yasuno et al. 1977), when domestic receptacles become more important. The population first declines as a result of hot weather and maintains at a low plateau during the monsoon and decreases further thereafter in the winter months. In Delhi urban area, the drains are the major breeding places throughout the year. Two peaks of high density (post rainy months and post winter months) and two troughs of low density (hottest months and the coldest months) were observed. Thus in Delhi urban area, the population is controlled mainly due to very high summer temperatures (on many days exceeding the thermal death points) and the cold winters (when immature duration is prolonged considerably and survival rates are very low). Immature duration and survival rates, adult survival rates, oviposition cycle, cohort generation time and net reproductive rates were thus temperature-dependant in the Delhi area.

It has been determined (Buxton 1932) that the upper lethal temperature of most insects is about 40° C to 45° C. In the case of mosquitoes, a water temperature of 35° C is fatal to larvae. Similarly, the lowerl ethal temperatures are around 7° C to 10° C. The data would indicate that under the range of maximum and minimum temperatures found in Pondicherry, there is neither any mortality of adults nor of immatures due to temperatures, nor is there any retardation of development of larvae.

Senior White (1926, 1934) who had intensely studied the bionomics of this species in India had stated that *C. fatigans* is not a hardy species and is very susceptible to climatic conditions. Under natural conditions in the field the interpretation of the response of the mosquito to changes in climate alone is difficult because of other variables in the environment. While different responses to temperature and humidity are shown by mosquitoes of different age groups (Muirhead Thomson 1938) as far as population growth is concerned, mosquito population as a whole have to be considered. Atleast in Pondicherry, and in areas with similar climatic pattern, the physical environment more than temperature and humidity appear to regulate population growth.

Environmental conditions also effect the behavioural pattern. It was conclusively shown in earlier studies that dispersal in rural areas (WHO/ICMR—Monthly report) of Delhi where released, marked mosquitoes were recovered as far as 11 kilometers away. But in the urban areas, the dispersal is limited as the breeding places are adjacent to human habitations and their appetential needs are met. The maximum distance of dispersal observed in urban area was about 800 meters only. In Pondicherry also, a limited dispersal pattern could be expected

Table 3 *Reproductive potential of* Culex pipiens fatigans *in three areas*

Climate	DELHI RURAL AREA* (1972–73) Extremes	DELHI URBAN (FARIDABAD)** (1973–74) Extremes	PONDICHERRY URBAN (1978) Moderate
Max .temp. °C	22°C (February) to 42.5°C (May)	21.1°C (January) to 40.7°C (May, June)	28°C (January) to 35.1°C (May)
Min. temp. °C	6°C (February) to 28°C (June)	7.6°C (January) to 29.5°C (June)	22.3°C (January) to 26.9°C (May)
Rainy season	June to September	June to September	September to December
Rel. humi.	23.7% (May) to 84.1% (August)	18.7% (April) to 75% (August)	70.5% (May) to 84.5% (December)
Major Breeding Places	Irrigation wells in dry season, receptacles in wet season	Drains	Drains and Cesspits

	Immatures		Adults				Immatures		Adults				Immatures		Adults			
	Survival	Duration (days)	Survival	Oviposition (days)	R_o	T	Survival	Duration (days)	Survival	Oviposition (days)	R_o	T	Survival	Duration (days)	Survival	Oviposition (days)	R_o	T
Jan.	0.054	21	0.650	138.6	0.022	36.2	0.026	64	0.75	98.6	0.18	74.2	0.233	12	0.8	58.3	11.3	19.5
Feb.							0.039	45	0.53	58.3	0.14	52.0	0.322	,,	0.83	,,	20.8	20.0
Mar.	0.043	11	0.932	58.3	9.8	27.6	0.14	12	0.16	,,	1.05	17.8	0.306	,,	0.82	,,	17.9	19.9
Apr.							0.246	11	0.8	,,	12.4	19.2	0.381	,,	0.775	,,	14.6	19.3
May	0.016	11	0.854	,,	1.21	20.8			0.6	,,			0.250	,,	0.78	,,	10.1	19.3
June							0.104	11	0.6	,,	0.773	16.8	0.110	,,	0.86	,,	9.5	20.5
July	0.031	15	0.871	,,	2.47	25.7	0.100	15	0.7	,,	3.7	22.5	0.060	,,	0.73	,,	1.5	18.9
Aug.									0.8	,,			0.093	,,	0.83	,,	6.0	20.0
Sept.	0.26	15	0.818	,,	1.59	23.8			0.8	,,			0.024	,,	0.89	,,	2.8	21.1
Oct.									0.85	,,			0.068	,,	0.81	,,	3.6	19.7
Nov.							0.065	49	0.8	98.6	0.916	60.1	0.023	,,	0.72	,,	0.5	18.6
Dec.									0.85	98.6			0.051	,,	0.785	,,	5.9	18.6

R_o=Net reproduction rate T=Cohort generation time

* Yasuno 1974   ** Rajagopalan et al. 1978.

because of similar environmental conditions, though some random migration might also be taking place.

An earlier study (Rajagopalan et al. 1977) had shown that about 17% of the human population sampled in Pondicherry are microfilaria carriers. Mosquitoes collected routinely from six different localities every month were dissected and the results (table 2) showed that the filarial infection rate ranged from 7·5% (October) to 21.5% (May). This would indicate that in some months atleast one out of five mosquitoes had a chance to feed on a microfilaria carrier. If the data are taken for the whole year, the infection rate in mosquitoes come to about 14% which is close to the observed microfilaria rate in the population. The infectivity rate (proportion of mosquitoes with infective stage larva of *Wuchereria bancrofti*) ranged from 0.7% in October to 4.5% in September. None was positive in June, but the sample dissected in this month was the smallest and the absence of infective stage larva in the wild caught mosquito could be due to the chance factor and smaller sample size.

In Macdonald's malaria formula, the symbol 'x' represented the "proportion of bites on man which are infective to the mosquito" and which he called later as the "proportion of people affected i.e., showing parasitaemia" (Garret-Jones & Shidrawi 1969). In the case of malaria, one infective bite is likely to result in a man developing parasitaemia. But in the case of filariasis, this is not the case and several thousand repeated infective bites are estimated to be necessary to produce a microfilaria carrier. Therefore, though the model developed by Macdonald cannot be applied for filariasis, an attempt has been made to determine the proportion of people in Pondicherry being bitten by an infective masquito by using the modified formula of Macdonald (Garret-Jones & Shidrawi 1969) where a is the

$$x=\frac{S\,(-\log_e p)}{a\;(p^n=S)}$$

average number of men bitten by one mosquito in one day, which is assumed to be 1 in the case of *C. fatigans*; p, the probability of a mosquito surviving through one day, and S, the proportion of mosquitoes with infective stage larvae and n is the time taken for the extrinsic incubation period in the mosquito which is about 11 days for *W. bancrofti* in Pondicherry. For this calculation, the infectivity rate in the wild mosquito population has been taken as the value of S. Using this computation, the value of x (which in this case is the proportion of people bitten by an infective mosquito) varied in different months, ranging from 0.0151 in August to 0.1525 in November. Since the infectivity rate, S, for June as obtained from dissection results was zero, the value of x was also zero, though this may not be the true case. The data would indicate that even in Pondicherry with a high microfilaraemia rate, a large number of mosquitoes are necessary to give an infective bite to a man in different months. All the persons who are bitten by an infective mosquito do not actually receive the infective stage filarial larvae because, unlike in the case of malaria parasites, the filarial parasite is only deposited on the skin (Hairston & Jackowski 1918) at the site of bite and only a proportion of the parasites deposited on the skin actually penetrate the wound and enters the human system. The number of infective stage larvae per mosquito also varies. It has been estimated (Rajagopalan et al. 1977, Hairston & Jackowski 1918) that several thousand infective mosquito bites are necessary in order to produce a patent infection in man.

It has also been shown that low humidity imposes limits on infection with filaria and that filarial infection is a disease of the damp tropics. Buxton (1932) states, comparing filaria map of Acton and Rao (1931) with the rainfall map of India, that the presence of infection coincides with the area of high rainfall and that in the erstwhile Madras Presidency, filaria infection appears to be absent in areas in which the monsoon rainfall is below 250 mm. Some reasons are adduced, like mosquitoes not living long enough to become infective, low humidity affecting the development of the infective stage larvae, and, the dry air preventing infection of man at the critical moment when the infective stage leaves the mosquito proboscis, etc. Therefore, in Pondicherry, with the high humid climate, the factors are conducive for the efficient transmission of *W. bancrofti* throughout the year.

Except during the heavy rains in November, the reproductive potential of this mosquito has been high. There is no particular season when the increasing growth rate could be reduced. Control measures, including genetic control, if initiated in November should leave the population vulnerable to complete suppression in the post rainy season but the very high reproductive potential in this season would offset such an effort. One could probably hope for a decrease in the rate of increase. Because of the operation of density dependent factors, any initial reduction in the density would be compensated by higher survival. Since environmental factors directly control population growth, an alteration in environmental conditions alone, like reduction in the breeding surface area, would cause any decrease in the growth rate. Only permanent environmental sanitation, or, in the alternative, regular efficient larvicidal measures to prevent pupal emergence throughout the year, would result in any significant change in vector density and transmission potential in Pondicherry.

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