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Studies on the Anopheline Fauna of Kheda District and Species Specific Breeding Habitats

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Information on anopheline fauna of Kheda district in Gujarat dates back to 1950. Since then there have been vast ecological changes due to development projects and intensive irrigation. To study the anopheline fauna of Kheda district collections from 164 villages representing 7 talukas of the district were made. Sixteen anopheline species were recorded, of these 8 species were recorded for the first time. Maximum number of anopheline species (16) were recorded from canal irrigated area followed by 11 species from riverine area and 10 species from non-canal irrigated area. Four anopheline species namely *An.subpictus*, *An.culicifacies*, *An. annularis* and *An. stephensi* were predominant and constituted 99.9% of the total anophelines and rest of the 12 species accounted for 0.1%.

In this paper, results of the study on mosquito ecology with particular emphasis on species specific breeding preferences, associations and frequency of distribution in various types of aquatic habitats have been reported.

INTRODUCTION

Our present knowledge of the anopheline fauna of Gujarat is mainly from the works of Afridi *et al.* (1938), Jaswant Singh and Jacob (1943), Vishwanathan (1950), Nair and Samnotra (1967) and Singh *et al.* (1985). During the last three decades, there have been vast ecological changes in this area. Great importance has been given to agriculture, and there is a considerable increase in the canal irrigated area (from 500 hectares in 1950 to 61,300 hectares in 1980). Several factors like perennial irrigation and consequent multiple cropping coupled with increased water logging due to seepage and poor drainage have resulted in extensive mosquitogenic conditions. Further, deforestation, rapid urbanization, industrialisation and extensive use of insecticides in agriculture and public health may have brought about changes in the ecosystem and in the composition and bionomics of anophelines.

Thus, an attempt was made to study the anopheline fauna and their breeding preferences in Kheda district of Gujarat state. These studies should have relevance in organizing suitable antimosquito operations under the bio-environmental control strategy at present in operation in Kheda district.

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Table 1. Talukawise cultivable and irrigated land*

Taluka	Area in sq km				
	Total	Cultivable	Irrigated	Under paddy cultivation	Average no of wells per sq km
1. Anand	676	556.46	399.57	140.98	4.84
2. Kapadwanj	985.7	770.21	194.78	45.89	6.86
3. Nadiad	662.8	552.82	308.81	94.84	9.42
4. Mahemdabad	502.3	400.59	168.37	68.45	7.94
5. Matar	577	452.9	308.9	250.0	4.67
6. Petlad	475.2	414.81	232.13	100.36	8.56
7. Thasra	659.9	519.77	190.07	90.45	4.36

*As per 1982-83 Survey report, Directorate of Agriculture, Ahmedabad.

Table 2. Talukawise classification of villages

Taluka name	Canal irrigated villages	Non-canal irrigated villages	Riverine villages	Total
Adult collection				
1. Anand	10	—	1	11
2. Kapadwanj	—	19	4	23
3. Nadiad	43	30	18	91
4. Matar	11	1	4	16
5. Mahemdabad	—	11	—	11
6. Thasra	1	1	2	4
7. Petlad	8	—	—	8
Total	73	62	29	164
Larval collection				
1. Anand	16	—	1	17
2. Kapadwanj	—	4	2	6
3. Nadiad	36	26	18	80
4. Matar	11	—	1	12
5. Mahemdabad	—	9	—	9
6. Thasra	1	1	1	3
7. Petlad	5	—	—	5
Total	69	40	23	132

MATERIAL AND METHODS

Study area

Kheda district comprises of 10 talukas. It lies between 22° -7′ and 23° -18′ North latitudes and 72°-15′ and 73° -37′ East longitudes. The area is not homogenous in the sense that nearly half of the area is extensively canal irrigated and the villages are surrounded by a network of irrigation canals, distributaries and drainage systems (Table 1). Water logging and seepage from canals has created ideal mosquito breeding sources. Canal irrigation over the years has raised the subsoil water level high (upto 2 to 3 meters) even in summers. In the remaining area agriculture is dependent on tubewells and/or monsoons. Mosquitogenic potential in villages of the latter area is comparatively less in summer months. However, riverine villages continue to have perennial breeding potential.

Adult mosquito and immature collections were made from the villages of seven talukas namely Kapadwanj, Anand, Petlad, Matar, Mahemdabad, Thasra and Nadiad (Table 2). Out of these Nadiad and Kapadwanj talukas are under demonstration of bio-environmental control of malaria i.e., the application of environmental modification and manipulation and biological control methods.

Collection of immatures: Larval and pupal collections were made from all possible breeding habitats from April 1985 to May 1988. The breeding habitats surveyed, included ponds, small pools, hoof prints, river, riverbed pools, irrigation canals and channels, paddy fields, wells and various intradomestic water storage containers like earthen pots, tanks, barrels etc.

The immatures were collected by using either a dipper (9.5 cm diameter and 300 ml capacity), well net (25 cm diameter) or a teated glass dropper. The samples were brought to the laboratory in specimen tubes and reared in disposable plastic containers in the insectary, until adult emergence.

Adult collections: Regular adult mosquito collections were started from January 1984 in eight villages of Nadiad taluka. In 1985, 16 more villages were included in the study. In 1986 and 1987 collections were made from an additional 140 villages representing seven talukas of the district. Out of the total of 164 villages, 73 villages belonged to canal irrigated area, 62 to non-canal irrigated area and 29 to riverine area. The villages in which the application of water to crops was through an artificial channel using the stored water of rivers and lakes were grouped under the canal irrigated area. Non-canal irrigated area included villages in which only subsurface water from wells and/or tubewells was used to promote agriculture. Villages situated on the bank of the river or its vicinity were grouped under the riverine area.

Mosquitoes were collected from all the villages in the morning hours between 0500 to 0900 hrs using an aspirator. Collections were made from human dwellings, mixed dwellings and cattlesheds and were brought to the laboratory for species identification and record. All adult mosquitoes including those emerged from collections of immatures were killed with ether.

Mosquitoes were identified using the key of Christophers (1933).

RESULTS AND DISCUSSION

During the study period a total of 3,37,406 anopheline mosquitoes were collected representing 16 species. Table 3 gives the composition of different anopheline species in different geographical areas, namely canal irrigated, non-canal irrigated and riverine. A total of 16 species were recorded from canal irrigated area, followed by 11 from riverine and 10 from non-

Table 3. Per cent composition of different anopheline species

Species	Canal irrigated area		Non-canal irrigated area		Riverine area		Total	Per cent
	No. collected	Per cent	No. collected	Per cent	No. collected	Per cent		
1. *An. culicifacies,* Giles, 1901	9868	4.53	1629	2.43	5875	11.1	17372	5.15
2. *An. stephensi*, Liston, 1901	675	0.31	176	0.26	605	1.14	1456	0.431
3. *An. annularis,* Van der Wulp, 1884	9511	4.37	1263	1.88	710	1.34	11484	3.4
4. *An. subpictus*, Grassi, 1899	197368	90.68	63789	95.39	45648	86.28	306805	90.93
5. *An. aconitus,* Donitz, 1902	95	0.0436	1	0.0015	5	0.0094	101	0.03
6. *An. tessellatus*, Theobald, 1901	29	0.0133	3	0.0044	26	0.049	58	0.02
7. *An. turkhudi*, Liston, 1901	3	0.0013	4	0.006	27	0.051	34	0.01
8. *An. vagus*, Donitz, 1902	30	0.0137	1	0.0015	2	0.0037	33	0.01
9. *An. barbirostris,* Van der Wulp, 1884	21	0.0096	2	0.003	3	0.0056	26	0.008
10. *An. varuna*, Iyengar, 1924	23	0.0105					23	0.007
11. *An. fluviatilis*, James, 1902	4	0.0018			1	0.0018	5	0.001
12. *An. nigerrimus,* Giles, 1900	2	0.0009			1	0.0018	3	0.0008
13. *An. pallidus,* Theobald, 1901	2	0.0009					2	0.0006
14. *An. theobaldi,* Giles, 1901	1	0.0004	1	0.0015			2	0.0006
15. *An. pulcherrimus,* Theobald, 1902	1	0.0004					1	0.0003
16. *An. moghulensis,* Christophers,1924	1	0.0004					1	0.0003
Total	217634	100	66869	100	52903	100	337406	100

canal irrigated area. It was further observed that in all the three areas, *An. subpictus* was the most predominant species and it accounted for 86 to 95% of the total anopheline population. Composition of major anopheline species in three different areas has been given in Fig. 1, which shows that composition of *An. culicifacies* and *An. stephensi* was highest (11.1 and 1.14%) in riverine area followed by canal irrigated area (4.53 and 0.31%) and non-canal irrigated area (2.43 and 0.26%). Composition of *An. annularis* was highest in canal irrigated area (4.37%) followed by non-canal irrigated area (1.88%) and riverine area (1.34%). *An. subpictus* was represented highest in non-canal irrigated area (95.39%) followed by canal irrigated area (90.68%) and riverine area (86.28%). Rest of the species represented only 0.1% of the total anophelines in all the three areas.

The mosquito species also showed a marked variation in seasonal prevalence during the year. In non-canal irrigated area mosquito densities remained very low from January to June but in canal irrigated and riverine villages mosquito densities showed a peak in the month of March, apparently due to extensive canal irrigation and paddy cultivation in the former area and due to formation of river bed pools in the latter. Thereafter, the densities showed decline until the onset of monsoon in June, when an increase was deserved. Peak density occurred in

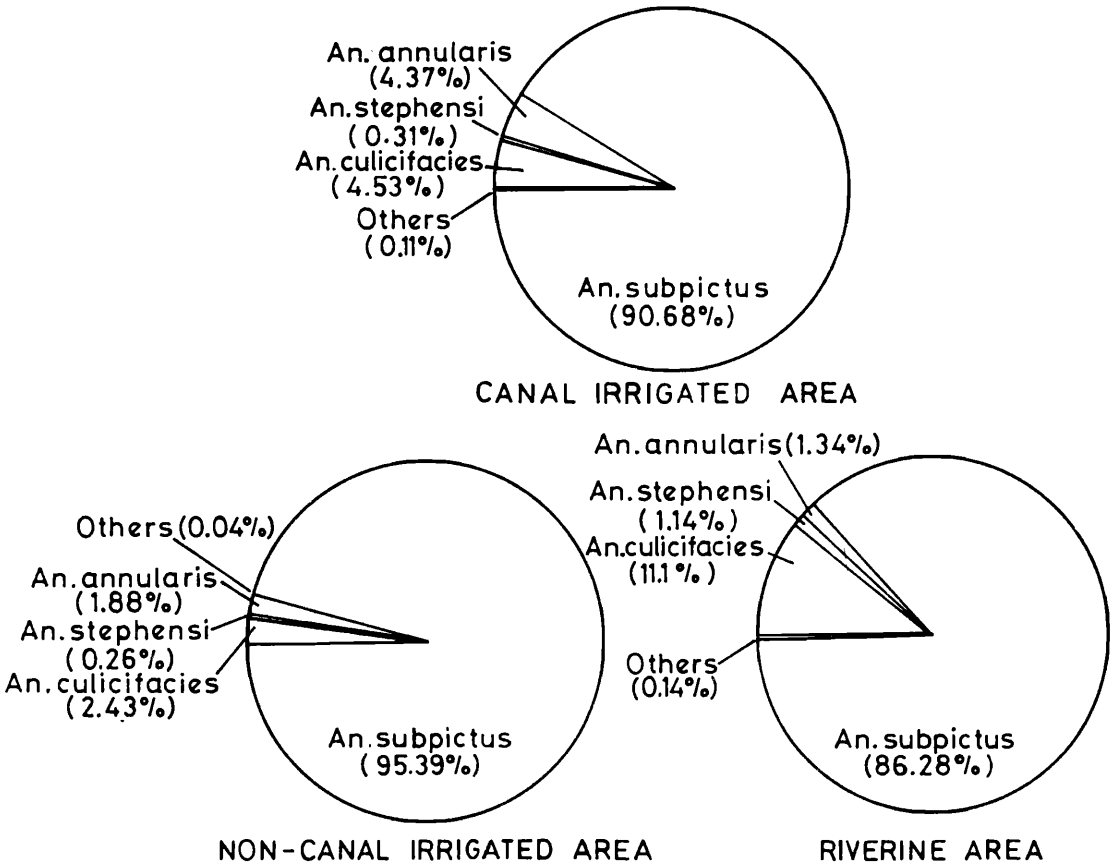

Fig. 1: Composition of anophelines.

Table 4. Per cent composition and sample positivity of anophelines in different breeding habitats

Species *	Ponds	Small pools	Hoof prints	Paddy fields	Canals	Irrigation channels	River	Riverbed pools	Wells	Intra-domestic
An. culicifacies	2.50 (12.36)	1.42 (6.20)	1.72 (5.55)	7.23 (28.13)	45.55 (53.08)	26.90 (19.76)	36.46 (60.73)	7.32 (34.78)	5.34 (14.13)	2.58 (5.60)
An. stephensi	0.74 (4.86)	0.48 (2.13)	0.69 (3.17)	1.14 (5.08)	3.24 (8.04)	0.70 (2.32)	1.16 (8.22)	1.57 (13.04)	48.35 (46.99)	69.46 (80.15)
An. annularis	8.20 (23.40)	1.94 (7.95)	1.17 (0.79)	14.70 (20.00)	9.12 (26.27)	3.60 (18.60)	5.28 (25.57)	0.39 (13.04)	1.50 (4.59)	0.11 (0.61)
An. subpictus	86.44 (81.01)	95.54 (87.78)	96.42 (84.92)	74.60 (74.91)	40.20 (37.53)	67.94 (68.60)	56.53 (42.92)	90.72 (91.30)	40.15 (44.87)	27.84 (27.40)
An. barbirostris	1.75 (7.06)	0.29 (1.65)		1.54 (3.39)	1.32 (3.75)	0.62 (2.32)	0.51 (4.57)		4.61 (11.66)	
An. tessellatus	0.01 (0.22)	0.23 (0.48)		0.46 (1.69)		0.08 (1.16)				0.01 (0.12)
An. nigerrimus	0.25 (2.43)	0.06 (0.77)		0.15 (1.02)	0.37 (2.41)	0.16 (1.16)	0.06 (0.91)			
An. aconitus	0.08 (0.66)	0.02 (0.29)		0.12 (0.68)	0.17 (1.34)					
An. pallidus		0.01 (0.19)		0.06 (0.34)	0.03 (0.27)					
An. varuna	0.33 (0.22)								0.05 (0.35)	
An. vagus		0.01 (0.19)								
Total adults emerged	5936	19402	1455	3248	3486	1279	3354	765	2060	6624
Total species emerged	9	10	4	9	8	7	6	4	6	5
Total samples collected	453	1031	126	295	373	86	219	23	283	821

*Per cent composition among total adults emerged from all the samples of the habitat.
Figures in parentheses are per cent samples positive for the respective species.

monsoon season in all three types of areas. However, peaks in the densities of *An. subpictus, An. culicifacies* and *An. annularis* were generally seen in the months of August, September and November, respectively.

In earlier studies 8 anopheline species viz., *An. annularis, An. culicifacies, An. multicolor, An. pallidus, An. stephensi, An. subpictus, An. tessellatus* and *An. vagus* were reported from Kheda district (Vishwanathan, 1950). In the present investigation a total of 16 anopheline species except *An. multicolor* were recorded. Therefore, 8 new records viz., *An. fluviatilis, An. varuna, An. pulcherrimus, An. turkhudi, An. theobaldi, An. moghulensis, An. nigerrimus, An. aconitus* and *An. barbirostris* were found in the area. *An. fluviatilis* was conspicuously present in the canal irrigated and riverine areas (the species is normally recorded from foothill areas).

To study ecology of the anophelines with particular emphasis on species specific breeding preferences and frequency of the distribution of different species in various types of aquatic habitats, 3,710 samples of immatures from 10 different peri- and intradomestic mosquito breeding habitats were collected. These habitats included breeding places of temporary (hoof prints, riverbed pools), semi permanent (small pools, paddy fields, irrigation canals and channels) and permanent nature (ponds, river, wells and intradomestic sources). From the samples collected, a total of 47,609 adults emerged which represented 11 anopheline species. The samples of immatures produced five species less than those found in indoor collections.

Table 4 gives the per cent composition of different species among the total adults emerged from all samples of a particular habitat and sample positivity rate of anophelines in different habitats. *An. culicifacies* preferred to breed mostly in the canals, river, irrigation channels, riverbed pools and paddy fields. Per cent composition of *An. culicifacies* in the total adults emerged from the samples brought from these habitats was 45.55, 36.46, 26.9, 7.32 and 7.23% respectively. Its composition for wells and intradomestic containers was 5.34 and 2.58% respectively. Sample positivity rate of different habitats showed that *An. culicifacies* was present in 60.73% samples of immatures from river, 53.08% from irrigation canal, 34.78% from riverbed pools, 28.13% from paddy fields, 19.76% from irrigation channels, 14.13% from wells, 12.36% from ponds and between 5 to 6% in intradomestic containers, hoof prints and small pools. *An. culicifacies* has been reported ubiquitous in all types of breeding places except leaf axils and man-made cement or iron cisterns (Rao, 1984). But in the present study *An. culicifacies* breeding was observed in overhead tanks, ground level tanks, iron cisterns (barrels) and earthen pots also. Average composition of *An. culicifacies* in the total adults emerged from the samples collected from above mentioned breeding sources was 2.58% with an average sample positivity rate of 5.6%.

An. stephensi was observed breeding mainly in wells and intradomestic containers. Of the total adults emerged in the samples from wells, this species accounted for 48.35% and for 69.46% from intradomestic samples. 46.99% samples of immatures from wells and 80.15% samples from intradomestic sources were found positive for *An. stephensi* breeding. Except wells, other peridomestic habitats were not preferred by it, though its breeding was recorded from all the habitats searched. These findings further confirm the view that *An. stephensi* prefers to breed in wells and also in intradomestic containers.

An. annularis was found to breed in all types of habitats but its breeding was mainly recorded from paddy fields, irrigation canals, ponds, river and irrigation channels having some aquatic vegetation or grassy margins. Its composition in

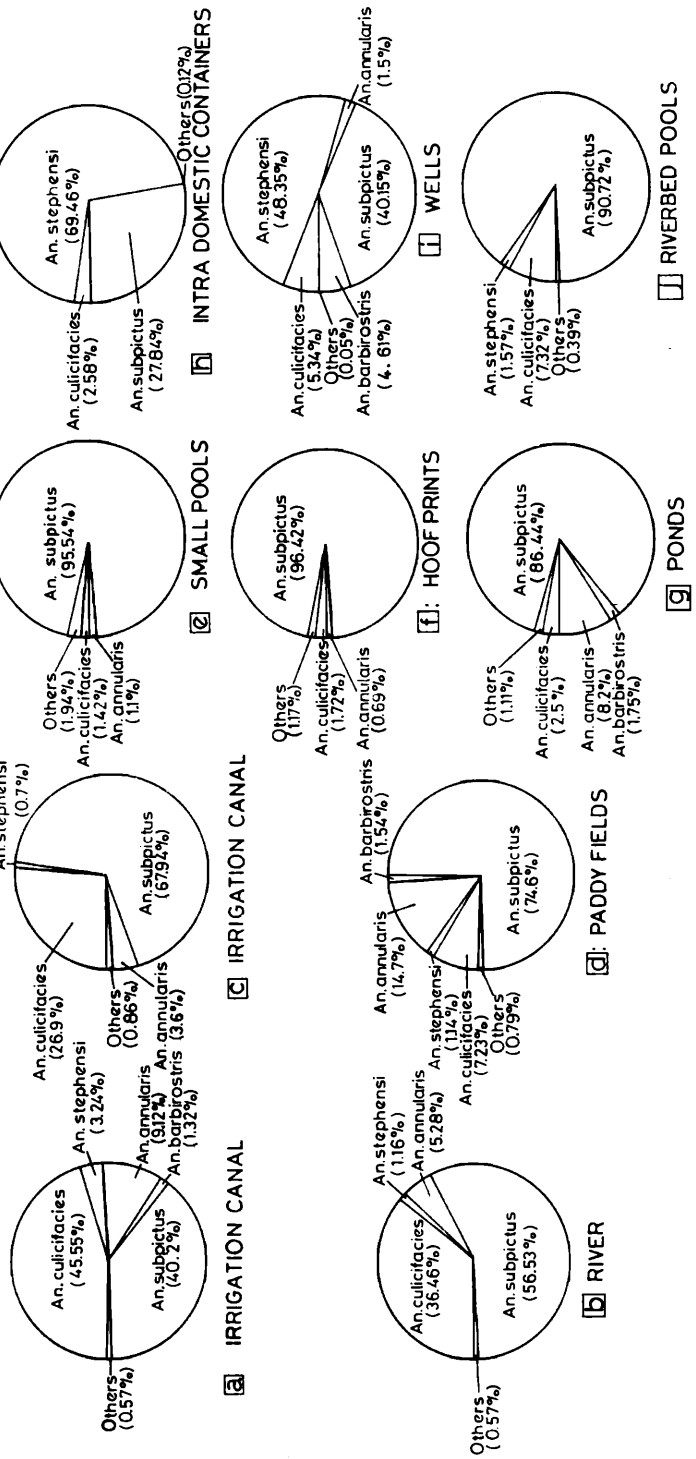

Fig. 2: **Habitatwise composition of anophelines.**

adults emerged from samples of these habitats was 14.7, 9.12, 8.2, 5.28 and 3.6% respectively, whereas sample positivity rate was 20.0, 26.27, 23.4, 25.57 and 18.6% respectively. Russell and Rao (1941) found that *An. annularis* was breeding 13 times out of 1240 in wells (1.04%) whereas we have found that 4.59% samples of the wells were breeding for this species.

An. subpictus appeared to be an ubiquitous species as it was observed breeding prolifically in all the breeding habitats searched. Its composition in total adults emerged from peridomestic samples ranged between 40.15% in wells to 96.42% in hoof prints with a sample positivity rate ranging between 44.87 to 84.92%. Intradomestic habitats were preferred by it to a lesser extent with a composition of 27.84% and sample positivity of 27.4%. Rao (1984) also made similar observations and found that the species was widely distributed in many types of breeding habitats.

Among other species *An. barbirostris* showed a breeding preference for wells though it was recorded breeding in all peridomestic places searched except hoof prints and riverbed pools. *An. tessellatus* was found to breed in ponds, pools, paddy fields, irrigation channels and intradomestic sources; *An. nigerrimus* in ponds, small pools, river, irrigation canals, paddy fields and irrigation channels; *An. aconitus* in ponds, small pools, irrigation canals and paddy fields; *An. varuna* in ponds and wells; *An. vagus* in small pools and *An. pallidus* in small pools, paddy fields and irrigation canals.

Habitatwise per cent composition of major anopheline species found in the samples have been summarised in Fig. 2a-j. From Fig. 2 it can be seen that the irrigation canals supported maximum *An. culicifacies* breeding, whereas river, irrigation channels, paddy fields, small pools, hoof prints, ponds and riverbed pools supported maximum breeding of *An. subpictus,* wells and intradomestic sources supported the breeding of *An. stephensi*. In irrigation canals, intradomestic sources and wells *An. subpictus* was the second most predominant species. Similarly in river, irrigation channels, small pools, hoof prints and riverbed pools *An. culicifacies,* and in paddy fields and ponds *An. annularis* were the second most predominant species.

Our observations further revealed that in river, canals, irrigation channels and small pools *An. annularis* and in paddy fields, ponds, intradomestic sources and wells *An. culicifacies* were third most predominant species found to breed. In the adults emerged from samples of wells composition of *An. barbirostris* was 5% whereas in those from ponds, small pools, paddy fields, irrigation canals, irrigation channels and river it was less than two per cent each.

Looking at the number of species emerged from a particular habitat the sequence was as follows: Small pools (10), ponds and paddy fields (9 each), irrigation canal (8), irrigation channels (7), river and wells (6 each), intradomestic containers (5), and hoof prints and riverbed pools (4 each) as given in Table 4.

This study is of immense importance for planning anti-larval operations such as being tried under alternative approach through bio-environmental control of malaria in Kheda district of Gujarat and elsewhere in India (Sharma *et al.*, 1986). For successful implementation of such an approach it is essential to identify the breeding habitats of vectors and then work towards species sanitation. For example present study revealed that *An. stephensi* prefers to breed in intradomestic water containers and wells. Mosquito breeding in intradomestic sources can be effectively controlled by introducing larvivorous fish (Guppy) and/or regular cleaning and covering the sources. Breeding in wells can be controlled by fish, by covering the water surface of disused

wells with expanded polystyrene beads, as was successfully demonstrated by Sharma *et al.* (1985) and also by sealing, if feasible. Breeding in ponds can be effectively controlled by introducing larvivorous fishes after proper margining and deweeding, in small pools and riverbed pools by emptying water or by filling with earth. It was further observed that paddy fields, irrigation canals and channels and river supported extensive breeding of *An. culicifacies.* To control mosquito breeding in these habitats, besides use of fish, other methods such as use of siphons in river (Macdonald, 1939), use of biocides and intermittent irrigation of paddy fields, and flushing of canals would have to be evaluated and implemented. This study also pointed out that composition of *An. subpictus* which is a non-vector species, but a major cause of nuisance was very high in almost every habitat investigated during the study.

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REFERENCES

1. Afridi, M.K., S.A. Majid and Jaswant Singh (1938). Malaria in Kutch State. *J. Mal. Inst. Ind.,* **1** : 187-213.
2. Christophers, S.R. (1933). *The fauna of British India including Ceylon and Burma,* v. 4. (Today and Tomorrow's Printers and Publishers, New Delhi): 1-359.
3. Jaswant Singh and V.P. Jacob (1943). Malaria in Ahmedabad. *J. Mal. Inst. Ind.,* **5** : 127.
4. Macdonald, G. (1939). A design of flushing siphon for control of anopheline breeding. *J. Mal. Inst. Ind.,* **2** : 63-69.
5. Nair, C.P. and K.G. Samnotra (1967). A note on urban malaria, Broach Town, Gujarat State, India. *Bull. Ind. Soc. Mal. Com. Dis.,* **4** : 285-295.
6. Rao, T. Ramachandra (1984). *The Anophelines of India.* Rev. ed. (Malaria Research Centre, ICMR, Delhi).
7. Russell, P.F. and T. Ramachandra Rao (1941). On seasonal prevalence of Anopheles species in southeastern India. *J. Mal. Inst. Ind.,* **4** : 263-296.
8. Sharma, R.C., R.S. Yadav and V.P. Sharma (1985). Field trials on the application of expanded polystyrene (EPS) beads in mosquito control. *Indian J. Malariol.,* **22** (2) : 107-109.
9. Sharma, V.P., R.C. Sharma and A.S. Gautam (1986). Bio-environmental control of malaria in Nadiad, Kheda district, Gujarat. *Indian J. Malariol.,* **23** (2) : 95-117.
10. Singh, Neeru, B.N. Nagpal and V.P. Sharma (1985). Mosquitoes of Kutch, Gujarat. *Indian J. Malariol.,* **22** (1) : 17-20.
11. Vishwanathan, D.K. (1950). *Malaria and its control in Bombay State.* (Aryabhusan Press, Poona).