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Haldwani (Uttaranchal)

This was the first field unit opened by the NIMR for in-depth epidemiological work on malaria and for the training of staff in malariology. Bioenvironmental malaria control was demonstrated in *Bhabar* and *Terai*, and the technology was transferred to the state health department. Classical entomological and epidemiological investigations were carried out in this area, e.g. ecological succession of malaria vectors, bioecology of malaria vectors in forests, changing formula of malaria, disappearance of *P. malariae* and *An. minimus* as a result of green revolution in *Terai* etc. This area has been the training ground of malaria since the ancient times. The examples are the training of engineers on irrigation malaria and preventive methods, training in malariology, and specialised training for national and international staff. The field unit has been closed and staff redeployed.

Background

In the 1970s, malaria was on the rise in *terai* plains in north India. The study area covered Nainital and Udham Singh Nagar districts in Uttaranchal state. Malaria vectors in different physiographic regions such as foothills, *bhabar* and *terai* were not known and malaria transmission dynamics was little understood. During the above period, DDT (75% WP) and HCH (50% WP) were sprayed indoors for malaria control.

In 1978, a field unit of Malaria Research Centre (now NIMR) was opened in Rudrapur, Nainital district to study transmission dynamics of malaria. Later in 1980, the unit was moved to Haldwani. The unit started functioning under the IDVC project since 1986.

Activities, Progress and Achievements

Biology of malaria vectors

Anopheline fauna comprised of 24 species (Table 1). There are three distinct physiographic zones—hill, *bhabar* and *terai*. Nainital and Udham Singh Nagar districts have two important malaria vectors—*An. fluviatilis* and *An. culicifacies*. Percent composition of *An. fluviatilis* in all anophelines in *bhabar* area was 39.7% and that of *An. culicifacies* in *terai* area was 49.7%.

Table 1: Anopheline fauna in Nainital district

S. No.	Anopheline species	S. No.	Anopheline species
1.	*An. aconitus*	13.	*An. minimus*
2.	*An. aitkeni*	14.	*An. nigerrimus*
3.	*An. annularis*	15.	*An. pallidus*
4.	*An. barbirostris*	16.	*An. pulcherrimus*
5.	*An. culicifacies*	17.	*An. splendidus*
6.	*An. fluviatilis*	18.	*An. stephensi*
7.	*An. gigas*	19.	*An. subpictus*
8.	*An. karwari*	20.	*An. tessellatus*
9.	*An. kochi*	21.	*An. theobaldi*
10.	*An. lindesayi*	22.	*An. umbrosus*
11.	*An. maculatus*	23.	*An. vagus*
12.	*An. majidi*	24.	*An. varuna*

High density of *An. culicifacies* was observed only in the month of August in hill area, whereas in *bhabar* and *terai* highest densities were observed in monsoon. The highest density of *An. fluviatilis* was recorded in April in hilly terrain and during pre- and post-monsoon months in *bhabar* and *terai* .

An. culicifacies and *An. fluviatilis* were incriminated in *terai* terrain from 1982–85. Recently, *An. fluviatilis* was

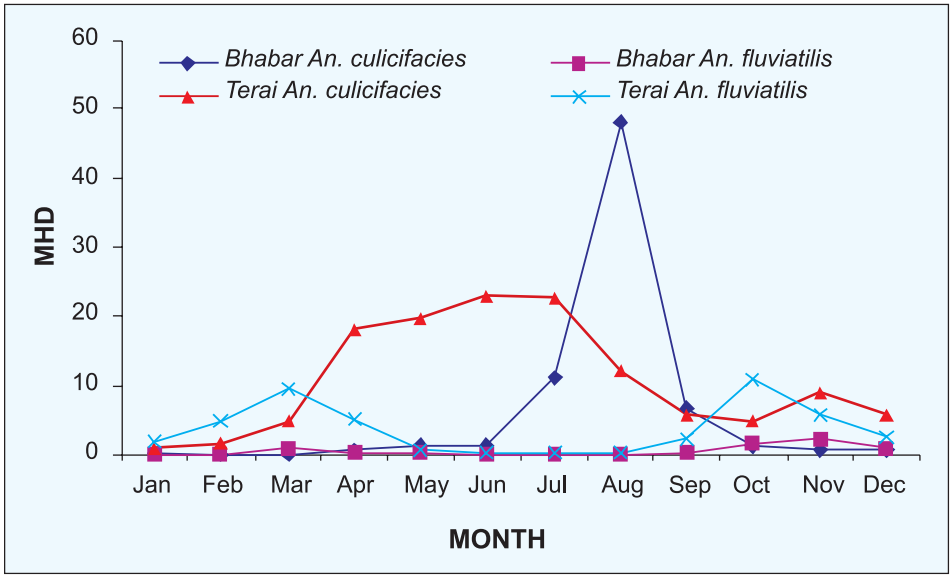

Fig. 1: Seasonal fluctuations in densities of *An. culicifacies* and *An. fluviatilis* in *bhabar* and *terai* regions of Nainital district

incriminated in forest areas as well (Shukla *et al*., 2001). *An. culicifacies* is a vector in forest-fringe areas.

Resting habits of both *An. culicifacies* and *An. fluviatilis* observed in various studies revealed high density of both vectors in cattlesheds than in human dwellings. Results of indoor hand collection revealed that both *An. culicifacies* and *An. fluviatilis* were predominantly resting indoors. However, light-trap collections carried out in the forested area revealed some exophilic tendency in *An. culicifacies* and *An. fluviatilis*. The numbers per night per trap of these species were 1.8 and 7.3 respectively (Shukla *et al.*, 2001). Results of whole night biting of *An. fluviatilis* on cattle and human baits revealed more biting on the former than on the latter. Biting on cattle occurred throughout night with peak during the second quarter. In *terai*, biting of *An. fluviatilis* on human bait was very low ranging from 0.08 to 0.33 bites/bait/night, whereas in the forest area the average biting rate on human bait was 2.05. The average human biting rate of *An. culicifacies* was 0.95 in the forest area and 0.2 in *terai* plains. Biting rate for both the species was high in outdoor collections compared to indoors.

Breeding source surveys of vector anophelines were carried out from time-to-time. In the rice agro-ecosystem of *terai* and *bhabar*, a study from July 1992 to June 1994 revealed breeding of *An. fluviatilis* in ponds in *bhabar* and in streams and irrigation channels in *terai* (Shukla *et al*., 1995). In other short-term studies, breeding of *An. fluviatilis* was observed in tanks, seasonal streams, cesspits near irrigation channels from February to April and in June. Breeding of *An. culicifacies* was recorded in *bhabar* in tanks, ponds, paddy-fields, margins of seasonal drains and roadside pits and ponds. In *terai,* high density of *An. culicifacies* immatures was noted in river-bed pools, streams, while low breeding in paddy-fields.

Cytogenetic studies carried out in forest area revealed the presence of sibling species B and C of *An. culicifacies.* Their composition was 87.7 and 12.3%, respectively. The human blood index (HBI) of species B was 0.009. In the same study, sibling species S and T of *An. fluviatilis* were found with a proportion of 1.3 and 98.7% and the HBI was 0.3 and 0.004, respectively. In earlier studies in *terai*, sibling species T and U were found and species U was exclusively zoophagic, whereas T had only 0.01 HBI (Shukla *et al*., 1998). Recent surveys indicated high malaria incidence in forest ecotypes, possibly due to high vector densities (Fig. 1).

Assessment of true incidence of malaria

A pilot study was conducted in Kichha and Gadarpur PHCs with the main objective to assess/estimate the true annual malaria parasite rate in a community. In Kichha PHC, the study was done from March 1981 to February 1982 (Shukla *et al.,* 1984). The slide positivity rate (SPR) varied from 3.5 to 38%. Majority of the cases were of *P. vivax* with very few cases of *P. falciparum*. Peak malaria was recorded in April, July and

September. In mass blood surveys, SPR ranged from 0.4 to 4.1%. The average SPR of 12 sections as recorded in the study was 22.1% compared with 4.7% reported through routine surveillance by the state malaria control programme. Thus, the actual incidence of malaria was much higher than that reported by the surveillance.

The pilot study was continued in Gadarpur PHC from April 1982 to March 1983. During above investigations an outbreak of malaria was detected. The SPR varied from 15.9 to 94.3, with a peak in the month of November. In all malaria cases, 9,332 (71.8%) were *P. falciparum* and 3,652 (28.2%) were *P. vivax*. *P. vivax* incidence was high in August, whereas *P. falciparum* incidence was high during September and November. The attack rates showed a progressive increase from infants to 16–25 year age group when it reached a maximum of 227.8. The attack rate in Bhuksa tribes was 166.7 and in non-Bhuksas it was 240.8. *An. culicifacies* and *An. fluviatilis* were incriminated as vectors of malaria (Chaudhary *et al.,* 1983). In a study carried out in Gadarpur town during 1982–83, high incidence of malaria was observed throughout the year. The SPR and SFR were 58.66 and 34.58 respectively and highest SPR (90.43) and SFR (88.04) were recorded in the month of November. In comparison, the state malaria control programme recorded 5.27 and 1.61% SPR and SFR, respectively during the same period.

Seroepidemiology of malaria

Blood samples were collected during 1989–93 in non-transmission and transmission seasons from children to monitor antibodies by ELISA using RI and *Pf* antigens (Roy *et al*., 1996). The antibody levels were high during transmission season in 1989. The results revealed that in children aged 0–5 years antibody titres in the non-transmission season were low and showed a positive correlation with annual parasite incidence (Table 2). The annual parasite incidence of previous year of sample collection gave an estimate of annual malaria exposure and it corresponded with ELISA optical density values for the next year's non-transmission season. Both the antigens showed a decline in the antibody titres in sentinel population during non-transmission season that showed decline of malaria. The study indicated that peptide ELISA may offer a way to measure malaria endemicity in a region with declining malaria.

A feasibility study on integrated methods of malaria control

A feasibility study for the control of malaria using integrated approach without the use of indoor residual spraying was carried out in Haldwani from 1986 to 1991 in 108 villages (population 33,000). The control strategy had following components.

Source reduction

It involved elimination, filling and draining of mosquito breeding sites through minor engineering methods.

Community participation

Temporary and seasonal breeding sites were tackled by community participation (Fig. 2). The mosquito breeding sites near the human dwellings were filled with sand using tractor-trolleys. People were involved through *Shramdans* (voluntary labour).

Table 2: Epidemiological and serological response in Haldwani population during 1989–93

Season	% of children examined	Numbers	Month	Year	API	SPR	ELISA O.D.	
							RI	*Pf*
Transmission	23.54	208	Oct	1989	52.2	20.4	0.695	0.672
Non-transmission	40.16	684	Jan–Feb	1990	42.3	20.3	0.628	0.572
Non-transmission	18.56	161	Jan–Feb	1991	17.4	17.5	0.244	0.242
Non-transmission	47.20	104	Nov	1991	5.2	5.8	0.134	0.137
Transmission	33.60	104	Sep–Oct	1992	4.2	7.5	0.145	0.310
Non-transmission	54.70	146	Jan	1993	6.0	6.8	0.269	0.255

Fig. 2: Filling-up of mosquito breeding habitats with earth and stones

Biological control

Gambusia affinis fish were mass reared in 162 ponds of fish farmers and used as a biological control agent in Nainital district. This made good impact on larval breeding in lakes, ponds, tanks and rice-fields (Fig. 3). Four local fishes—*Puntius ticto, Esomus danricus, Danio rerio and Chela laubuca* (Fig. 4) released in paddy-fields showed 31 to 100% reduction in anopheline density up to 28 days (Malhotra and Prakash, 1992; Malhotra and Sharma, 1994).

Health education

Health camps were organised in villages to educate people about malaria and mosquitoes and harmful effects of the disease on the well being and health. For this, pamphlets were distributed and exhibitions were organised. The villagers from study area were informed about the activities of the field unit for their cooperation. In addition, live biological material demonstration, video-films and slides on the life-cycle of malaria parasites and mosquitoes were shown to the public. Group meetings were organised to sensitise the community.

Social forestry

Nurseries of *Eucalyptus* plants were raised and thousands of eucalyptus saplings were distributed. The land for the nursery belonged to the villagers. Earnings from the sale of plants were given to the villagers

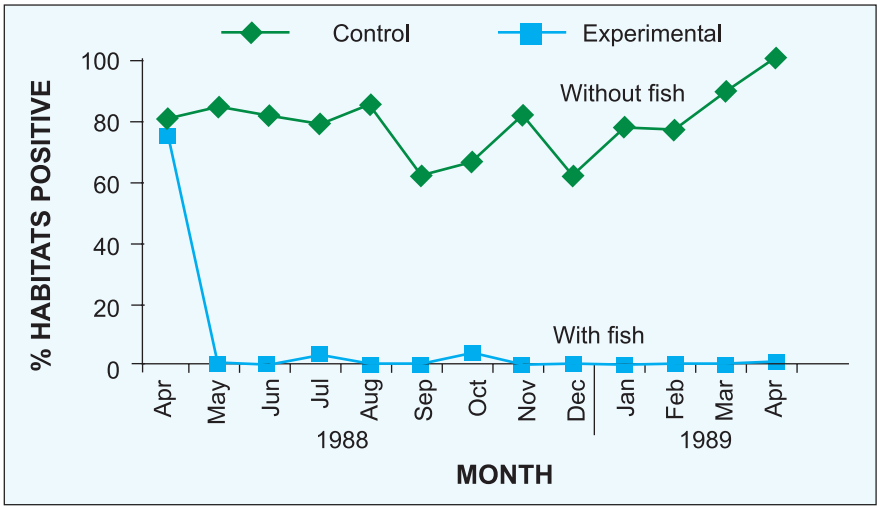

Fig. 3: Impact of *G. affinis* on mosquito breeding in Haldwani

Danio rerio

Esomus danricus

Puntius ticto

Fig. 4: Local larvivorous fish used for larval control in paddy fields

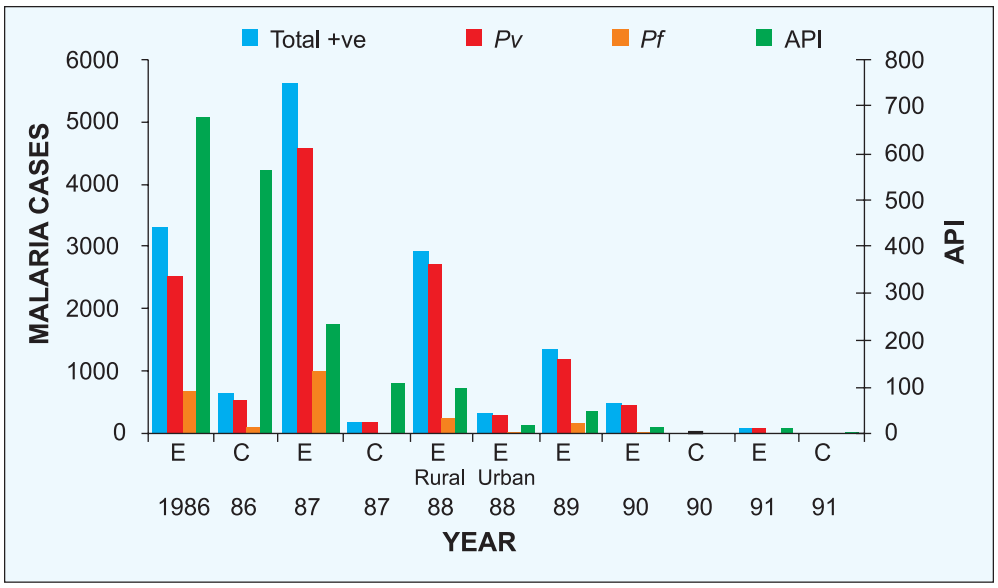

Fig. 5: Impact of IDVC interventions on malaria in Haldwani during 1986–91. E—Experimental areas and C—Control

or the Panchayat. Plantations were carried out in the marshy areas to eliminate mosquito breeding on permanent basis.

Inter-sectoral coordination

To control mosquito breeding, cooperation was sought from the departments of irrigation, Public Works Department and fisheries for water management. For environmental improvement the Department of Non-conventional Energy Development provided improved *chulhas* and installed solar lights on the streets. *Yuvak Mangal Dal*, a non-government organisation, was intimately associated with all the developmental activities.

Early detection and prompt treatment

Early case detection and prompt treatment (EDPT) was an integral pat of the strategy and together with bioenvironmental interventions resulted in decline in malaria morbidity considerably (Fig. 5) as compared with routine control areas (Malhotra and Ojha, 1993).

Malaria transmission dynamics under changing ecological scenario

Dynamics of malaria transmission under changing ecological scenario in and around Nanak Matta Dam was conducted in three different ecotypes—watershed (forest), seepage (dam) and plain (non-forest and non-dam) areas of Nainital and Udham Singh Nagar districts from July 1996 to June 1997 (Shukla *et al*., 2001). In watershed, seepage and plain areas, the SPR was 48.5, 0 and 1.8, the SFR was 35.7, 0, 0, the API was 245.8, 0 and 1.2 and ABER was 50.7, 4.8 and 6.4, respectively (Table 3). The highest malaria incidence was thus recorded in forest as compared to the other two ecotypes revealing active malaria transmission. This was further confirmed by detecting sporozoites in *An. fluviatilis* in forest eco-type. Higher malaria and vector prevalence in forest might be due to favourable ecological niche and other supporting settings.

Sensitivity of *P. falciparum and P. vivax* to chloroquine

A simplified *in vivo* sensitivity test of chloroquine

Table 3: Results of active surveillance in three different ecotypes (July 1996 to June 1997)

Ecotype	Population	BSE	*Pv*	*Pf*	Total (+)ve	SPR	SFR	API	ABER
Forest	537	272	35	97	132	48.5	35.7	245.8	50.7
Dam site	1,162	56	0	0	0	0.0	0.0	0.0	4.8
Plain	849	54	1	0	1	1.8	0.0	1.2	6.4

against *P. falciparum* was conducted from December 1995 to February 1996. Of 48 strains, 70.84% showed sensitivity to CQ, whereas 27.08 and 2.08% revealed RI and RII level of resistance to it. In yet another study in 1992, relapses in *P. vivax* were studied up to 12 months. Out of 59 cases studied, 37 reported relapses showing 62.7% relapse rate. Of these, single relapse was observed in 21 cases, two relapses in 13 cases and three relapses in three cases.

Malariogenic stratification

Malariogenic stratification of Districts Nainital and Udham Singh Nagar was conducted during 2000–01. Results revealed high to very high incidence of malaria in four PHCs—Gadarpur and Kelakhera in *terai* and Belparao and Motahaldu in *bhabar* area. Information from district level on spraying, house structures, social conditions, breeding systems, vector prevalence, etc. when analysed revealed that malaria in the *terai* and *bhabar* was maintained locally by *An. culicifacies* and *An. fluviatilis*.

Genetic studies among Bhuksa tribes

A genetic study among Bhuksa tribes in terai was conducted from 1984 to 1986. The results revealed that about 24% of Bhuksa population had protective heterozygous genotypes of either G-6-PD or sickle-cell haemoglobin (Table 4). Also a high incidence of haptoglobinemia was observed in the population (Joshi *et al.*, 1998).

Table 4: Distribution of genetic markers among Bhuksa tribes of Haldwani

System phenotype	Total samples		Malaria groups			Non-malaria group
	No. obs	Gene freq	Total	*Pf*	*Pv*	
ABO						
A	299 (41.2)	P=0.327	90 (39.65)	81 (42.6)	9 (24.3)	209 (41.9)
B	185 (25.5)	Q=0.219	57 (25.11)	46 (24.2)	11 (29.7)	128 (25.65)
AB	98 (13.5)	R=0.445	28 (12.33)	24 (12.6)	4 (10.8)	70 (14.0)
O	144 (19.8)		52 (22.91)	39 (20.6)	13 (35.2)	92 (18.45)
Total	726					
Haptoglobin						
1-1	15 (2.2)		3 (1.4)	2 (1.1)	1 (2.9)	12 (2.6)
2-1	120 (17.7)	Hp^1=0.122*	43 (20.0)	31 (17.1)	12 (35.3)	77 (16.6)
2-2	478 (70.4)	Hp^2=0.878*	136 (63.3)	115 (63.6)	21 (61.8)	342 (73.7)
0-0	66 (9.7)		33 (15.3)	33 (18.2)	0 (0.0)	33 (7.1)
Total	679					
Haemoglobin						
AA	644 (96.1)	Hb^A=0.979	200 (97.1)	172 (99.4)	28 (84.9)	444 (95.7)
AS	24 (3.6)	Hb^S=0.021	6 (2.9)	1 (0.6)	5 (15.1)	18† (3.9)
SS	2 (0.3)		0 (0.0)	0 (0.0)	0 (0.0)	2 (0.4)
Total	670					
G-6-PD-Deficiency variants (only males)						
Deficient	47 (11.4)	Gd^d=0.114	19 (14.5)	17 (14.9)	2 (11.8)	28 (9.9)
Non-Def	366 (88.6)	Gd^D=0.886	112 (85.5)	97 (85.1)	15 (88.2)	254 (0.1)
Total	413					

*Calculated after deleting Hp 0-0 numbers; †One sample had G-6-PD deficiency also; No. obs—Numbers observed; Gene freq—Gene frequency; *Pf—Plasmodium falciparum*; *Pv—P. vivax*; Figures in parentheses are percentages.

Table 5: Results of parasitological survey undertaken in affected villages of Bhojpur PHC, District Moradabad (U.P.)

Village	Population	BSE	*Pv*	*Pf*	Mix	Total	SPR	SFR
Lakhanpur	860	63	0	46	0	46	73.0	73.0
Nakatpuri	960	77	4	66	3	73	94.8	89.6
Rahamat Nagar	767	23	0	18	1	19	82.6	82.6
Total	2,587	163	4	130	4	138	84.7	82.2

Investigation of malaria outbreaks

Rajasthan

Jaisalmer and Barmer districts in Rajasthan received unprecedented rainfall in 1994 leading to an outbreak of malaria. Surveys revealed the presence of small foci of malaria in Pokharan PHC with SPR, SFR and spleen rate of 60.1, 56.9 and 86.7%, respectively. In these areas, large water bodies (ponds/lakes) were found. Villages experienced epidemic and deaths. *An. culicifacies* and *An. stephensi* were the major vectors of malaria. In Nachana PHC, irrigation channels of Indira Gandhi Canal contributed to excessive vector breeding. *P. falciparum* was predominant species, SPR was 52.3%, SFR was 50.5% and spleen rate was >80%. In Godamalani PHC, SPR and SFR were 28.9 and 24.2% with 80% spleen rate. Results of susceptibility tests revealed 70% mortality in *An. culicifacies* to DDT, 80% to dieldrin and cent percent susceptibility to malathion. However, heavy breeding of *An. culicifacies* and *An. stephensi* and its expansion due to rain water collection and poor drainage were the main factors in maintaining malaria endemicity in the region (Shukla *et al*., 1995).

Uttar Pradesh

Based on the reports of 18 fever related deaths in Bhojpur PHC of District Moradabad, Uttar Pradesh, a study was undertaken during September and October 2000 to investigate the cause of deaths. The SPR and SFR were 84.7 and 82.2%, respectively. The average enlarged spleen (AES) was 1.9 and SPR up to a maximum of 94.8 (Table 5). The susceptibility tests revealed that *An. culicifacies* was less susceptible to DDT than malathion but fully susceptible to deltamethrin. The results revealed that the outbreak was of malaria with predominance of *P. falciparum* causing several deaths in affected villages (Shukla *et al*., 2002).

Evaluation of larvicides

Evaluation of biolarvicides

Bacillus sphaericus was applied at 1.0 g/m^2 dose and *B. thuringiensis israelensis* was applied at 0.5 g/m^2 dose in domestic ponds and cemented tanks to study their impact in the control of anopheline breeding (Shukla *et al.*, 1997). The former was found very effective in controlling mosquito breeding in cemented tanks up to 6 weeks and up to three days in domestic ponds, while the latter was effective in tanks up to 7 days but its effect in domestic ponds was very low (Figs. 6 and 7). Small-scale field trial of granular formulation of *B. thuringiensis* (*Bti*) (Wockhardt product) against mosquito larvae was conducted in 2001. There was 100% mortality of mosquito larvae when the formulation was applied @ 0.5 g/m^2 surface area. The impact was similar on various mosquito species breeding in different habitats. No side-effect of *Bti* was observed on non-target organisms.

Evaluation of endosulfan

Endosulfan (thiodone) when tested @ 0.1 ml/m^2 in laboratory caused 12.8% mortality in anopheline larvae. At 0.2 ml/m^2 dose, larval mortality was 85.3%.

Evaluation of pyriproxyfen, an IGR compound

In 2003, granular formulation of pyriproxyfen (0.5%) was tested against malaria, filariasis, dengue and JE vectors breeding around Haldwani at 3 different doses. The inhibition of emergence (EI) of adults from larvae brought from treated domestic pits supporting *Culex* breeding was 18.2 to 90% at the dose of 0.01 ppm, 49.2 to 100% at the dose of 0.02 ppm and 56.6 to 100% at the dose of 0.05 ppm. The percent EI (Inhibition of emergence) of the above mosquito species varied from 48 to 100% at the dose of 0.02 ppm in

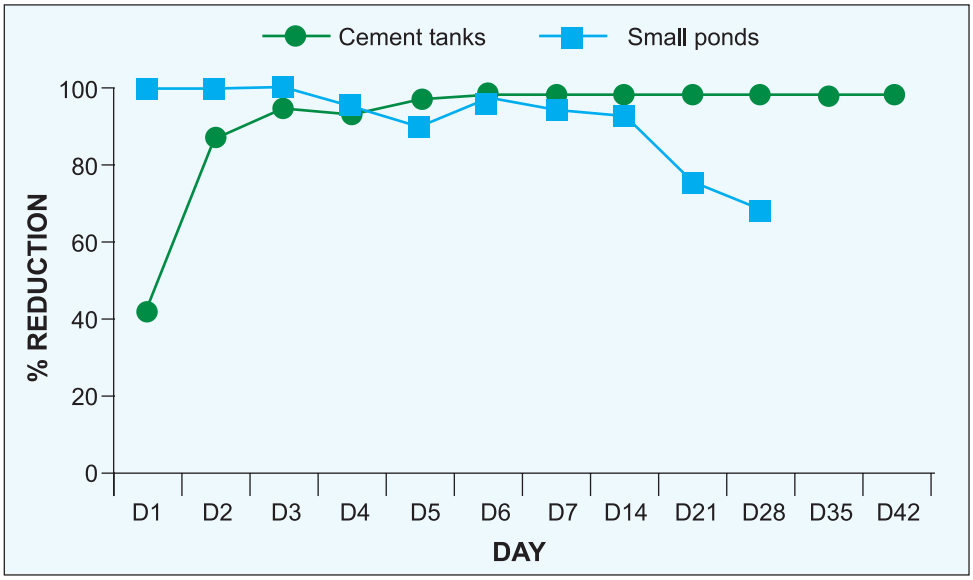

Fig. 6: Larvicidal efficacy of *B. sphaericus* on anopheline larvae

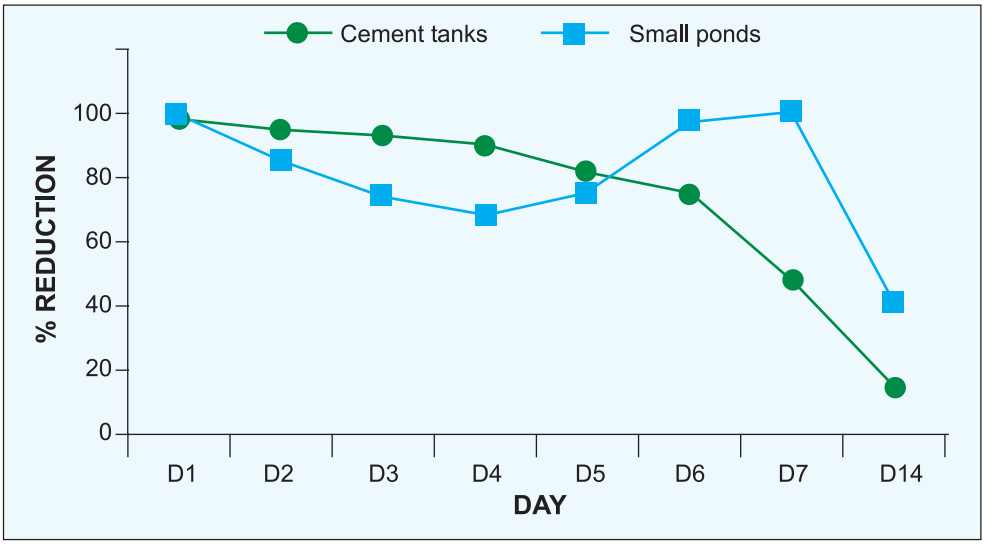

Fig. 7: Larvicidal efficacy of *B. thuringiensis israelensis* against anopheline larvae

tanks. Similar results were obtained in water trapped in disused tyres supporting *Aedes* breeding and in river-bed pools supporting breeding of *An. culicifacies.* The emergence was equally inhibited at dosages of 0.01 and 0.02 ppm. No harmful effect was observed on the non-target organisms.

Evaluation of insecticide efficacy and susceptibility

Insecticide susceptibility tests carried out during 1984–85 in *terai* villages found resistance of *An. culicifacies* to dieldrin (14% mortality) and DDT (8.3–15% mortality). *An. fluviatilis* was found 85% susceptible to DDT. Tests conducted in 1997 in the forest ecotype revealed that *An. culicifacies* (1.1% mortality) and *An. fluviatilis* (21.6% mortality) were resistant to DDT but both vectors were fully susceptible to deltamethrin and lambdacyhalothrin (Sharma *et al*., 1999). Tests carried out in high malaria risk PHCs of Nainital and Udham Singh Nagar districts in 2002 and 2003 revealed that susceptibility of *An. culicifacies* to DDT ranged from 2.6 to 24.4% and to malathion from 63 to 100%, whereas susceptibility of *An. fluviatilis* was 18.8 to 44.4% to DDT and 100% to malathion. The study suggested that the two major vectors in the area were resistant to DDT and were susceptible to malathion and synthetic pyrethroids.

In 2001 and 2002, impact of DDT spraying was eval-

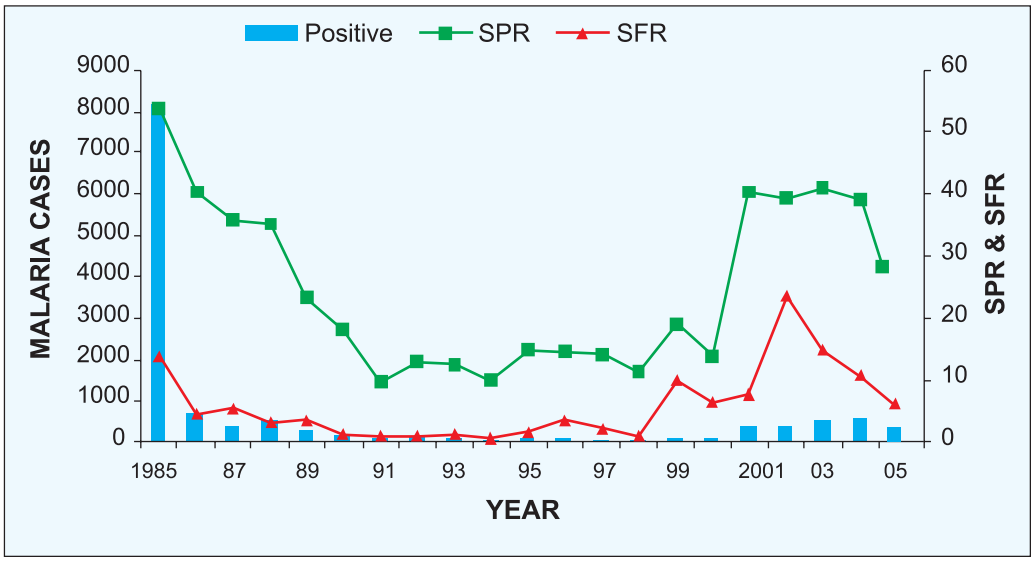

Fig. 8: Malaria clinic data of IDVC field unit, Haldwani

uated in six villages of Shergarh PHC, Bareilly district, U.P. The results revealed reduction in indoor densities of *An. culicifacies* after spraying despite its low mortality (21.4%) in susceptibility tests using DDT impregnated papers. Parasitological indices also indicated decline in malaria incidence after two rounds of DDT spraying. A good impact on vector densities and malaria was achieved through qualitative coverage and appropriate dosages of DDT spraying.

Other vector borne diseases

Surveys for the prevalence of dengue vector in Haldwani

The survey of dengue vector was carried out in 1997 in 4 urban localities—Gurunanakpura, Gobindpura, Subhash Nagar and Avas Vikas. The surveys showed *Ae. aegypti* house index of 51.3, 64.2, 22.6 and 8.7, the container index of 48.8, 54.5, 16.7 and 8.3 and Breteau index of 143.5, 191.0, 47.9 and 11.2 respectively in the above mentioned four localities. The habitat wise results of dengue vector, *Ae. aegypti* revealed highest breeding in old/used tyres (52.5%) followed by that in desert coolers (41.8%), mudpots (34.6%), drums and buckets (22.8%), discarded bottles (19.1%), cement tanks (14.5%) and flower pots (4.1%). The findings highlighted that the town had a high receptivity level for dengue fever (Shukla and Sharma, 1999).

Filariasis in terai region

A filariasis survey among migratory and stable communities of *terai* was conducted in 1992. The microfilariae rate was higher in the migratory (4.4%) than in the static (1.08%) population.

Malaria clinic

Since 1982, a malaria clinic functioned in the area. From 1982 to 2003, examination of blood slides of 52,587 patients showed 44.5 and 13.4% SPR and SFR, respectively. Yearwise data revealed high SPR (54.3%) and SFR (27.9%) in 1985 (Malhotra *et al*., 1985) and 2001 (Fig. 8). Further an increasing trend of *P. falciparum* malaria was recorded from 1999 onwards and cases from forest area showed highest malaria positivity.

Training

The field unit served as a field training site for many malariology and medical entomology courses conducted by NAMP, NICD, VCRC, WHO and NIMR. Participants of several training courses such as microscopists, laboratory technicians, medical entomology students, entomologists, senior officers from India and other countries visited the field sites in the *terai* and *bhabar* areas, especially the water resources projects.

❑