Panaji (Goa)

First site for the demonstration of bioenvironmental malaria control in urban areas. The field unit has made many outstanding contributions such as:

- For the first time a joint programme of work was developed with the Konkan Railways to concurrently study the proposed works at the design and construction stage and incorporate remedial measures. As a result 800 km rail track area is free from mosquito breeding
- Large-scale application of *Bacillus thuringiensis* and *Bacillus sphaericus* in the control of *Anopheles stephensi* at construction sites. This led to successful malaria control in Panaji
- Revision of municipal by-laws to prevent mosquito breeding
- For the first time malaria teaching is being offered as an optional subject for 10+2 school children. Every year 50,000 students study about malaria in Goa
- Mosquito control in Goa Port was demonstrated and the technology was transferred to the industry
- Work has begun on malaria burden estimation as per the World Bank procedure. This work has been taken up in Jharkhand state

**Background**

Goa field unit was established in June 1989 following a severe outbreak of malaria in 1986 at a large construction site in Panaji, the capital city of Goa. It is noteworthy that less than seven cases of malaria were reported from Panaji in 1984 and 1985. In May 1986, 167 malaria cases were reported from labour hutment in the vicinity of a swimming pool under construction in Campal area. Gradually malaria spread to adjoining Miramar area and the total cases reported were 352 including one case of *P. falciparum* with an API of 7.2 in 1986. In 1987, due to accelerated transmission, many parts of the city were severely affected and 4,406 malaria cases including seven *P. falciparum* cases were recorded with API of 87.8. In 1988, *Pf* incidence further rose sharply to 242 cases accounting for 4.26% of the total 5,677 cases detected with a further ascent of API to 110.4. A sharp increase in slide positivity rate (SPR) from 5.38% in 1986 to about 20% in both 1987 and 1988 was also noticed. In 1989, although the total malaria cases declined to 3,523 (API 64.9), yet the *Pf* incidence increased to 520 cases. Consequently, SFR and *Pf%* also increased to 2.47 and 15.2% respectively. On the request of the Govt. of Goa, a field unit was thus established at Panaji to investigate the role of migration malaria and to develop a suitable strategy for malaria control. Since 1989, the unit has undertaken studies on bioecology of malaria vector, evaluation of bioenvironmental methods of control, health impact assessment of Konkan Railways, transfer of vector control technology to Mormugao Port, malaria teaching programme in schools, monitoring of drug resistance in *P. falciparum*, etc.
Activities, Progress and Achievements

Bioenvironmental control of malaria in Panaji

The field unit started its operations in Panaji and in order to delimit the problem of malaria, launched two pronged approaches by starting vector and parasite surveillance in coordination with National Malaria Eradication Programme (now NVBDCP). Systematic weekly vector surveillance was conducted in 1989 and 1990. The city was divided into 15 sectors and 67,360 habitats were checked for vector breeding. Of these, 3,010 (4.5%) were found positive for immatures of different species of mosquitoes and 747 (1.1%) for An. stephensi (Kumar and Thavaselvam, 1992). Although 44.4% of the tyres checked were positive for different mosquito species, only 3.9% were found to contain malaria vector breeding. On the other hand, among 8.1% fountains with larvae, 4.8% had An. stephensi (Fig. 1). The remaining habitats showed positivity for the vector ranging from 0.4 to 2.4%. In terms of proportion of habitats supporting vector breeding, overhead tanks (34%), curing waters (16%) (Figs. 2 a and b), masonry tanks (16%) and wells (11%) were the major contributors (Fig. 3). Some of the activities under bioenvironmental control methods are shown in (Fig. 4).

Seasonal population trends of vector

To study the seasonal build-up of An. stephensi populations in different habitats, monthly data of immature stages were pooled up and analysed. It was observed that the vector positivity declined from 1% in January to 0.4% in March 1990 after which it showed upward trend as it reached its peak in June 1990. Thereafter, the vector immature populations declined to 0.5% in August and maintained a steady trend until December.

It may be noted that the rising population trend from March to June (Fig. 5) coincided with the increase in the minimum temperature from 20.7°C in February to 25.6°C in May 1990. On the other hand, the maximum temperature, which did not show much variation being 32.4°C in February and 32.5°C in June, did not seem to influence the vector population build-up (Kumar et al., 1991, 1997). Increase in the relative humidity from 80% in February to 91.5% in June seemed to favour longevity of the vector adults and thereby in prolonging transmission. This suggested that January to March months were crucial for vector control when the vector populations were at a low ebb and confined to relatively few breeding habitats. The vector build-up in the subsequent months of April to June, however, enhanced malaria transmission.

Another crucial factor in malaria transmission was the rainfall. It is noteworthy that Goa received an annual rainfall of 2500 mm during southwest monsoons from May to September (Data source: MET Office, Goa). During May and early June, rainy and intermittent dry hot spells coupled with high humidity were highly favourable for vector build-up. As the rains stabilised in July, there was decrease in maximum and minimum...
temperature (from 32.5°C in June to 28.6°C in August, 1990 compared with 36°C in May 1990). The relative humidity, however, touched its peak at 95%. From August onwards, malaria cases showed steady decline as the monsoon receded.

**Malaria incidence in construction workers**

The analysis of data showed that malaria incidence among construction workers was much higher than in the local residents in Panaji in 1990. In migrant workers (population: 2,829), the slide positive rate (25.7%), slide *falciparum* rate (5.6%), *Pf* percentage (21.8%) and parasite index (528.1) were significantly higher than the local residents (population: 54,122) being 19.8%, 3.6%, 13.4% and 37.97 respectively (p<0.05). Floor area under construction in the conservation zone (Wards 1–7) was 22,693 m² and there were 491
migrant workers in this zone. On the other hand, in the accelerated construction zone (Wards 8 to 13), 1,14,025 m² floor area was under construction with 2,338 migrant construction workers residing in this area (Kumar et al., 1991). It was observed that malaria incidence was significantly less in both local residents (API=17.7) and migrant workers (API=340.1) in the conservative zone as compared to the accelerated construction zone being 51 and 567.6 respectively. This situational analysis proved vital in prioritising both vector control and anti-parasitic measures. The parasite surveillance was made weekly and special squads were pressed into service to mop-up malaria cases amongst migrant construction workers.

**Vector control**

As part of bioenvironmental strategy, three methods were applied for vector control.

**Source reduction**

About 1000 tyres were dried and stored indoors, 1676 small, medium and large domestic containers were inverted or disposed off. Besides, 2300 barrels and tins were either inverted or disposed off, 4321 curing waters supporting increased vector breeding were dried up with sand, 167 ornamental tanks were also periodically dried up. Water was completely evacuated from 1250 underground masonry tanks, with pressure pump in the post-monsoon season. In 1789 masonry tanks a hole was drilled on the side wall near its bottom to drain out water completely to render them dry. Over 1500 overhead tanks were either inverted (if found disconnected) or covered after removing larvae from them.

**Larvivorous fish**

Larvivorous fishes were the main vector control tool. Over 2,70,000 fishes belonging to six species were introduced in the breeding habitats. Of these, 93.5% were indigenous fish *Aplocheilus blocki* and only 4.47% and 1.48% respectively belonged to *P. reticulata* and *G. affinis*. In 2,688 masonry tanks 1,30,000 fishes were introduced repeatedly at an interval of three months. Fishes were introduced in 2,786 wells, 317 ornamental fountains, 437 abandoned overhead tanks, 184 rain pools and ditches and 98 drains.

**Biolarvicides**

For the first time in the Goa state, *B. sphaericus* H5a 5b (B101) and *B. thuringiensis israelensis* H-14 strain 164 were applied @1g/m² in the positive habitats containing immature stages of anophelines. The maximum use of biolarvicides was done in the curing waters retained to cure newly cast cement slabs. Although curing waters were shallow, yet they supported heavy vector breeding. *B. thuringiensis israelensis* and *B. sphaericus* were sprayed in the anopheline breeding habitats as follows: curing water
(area sprayed 677 m² & 1645 m² respectively), ground water tanks (156 m² & 530 m²), masonry tanks (435 m² & 198 m²), rain water pools on terraces and slabs in the construction sites (433 m² & 145 m²), and storm water drains (69 m² & 51 m²) during initial phase of monsoons when in small water pockets anopheline breeding was encountered.

**Parasite control**

In addition to the existing passive case detection and treatment facility at the Urban Health Centre and the Goa Medical College Hospital, a malaria clinic was operated at Goa field unit. The services of the clinic were availed by the general public, Goa Medical College, general practitioners, health services for cross-examination of blood smears retrieved from different PHCs and UHCs of Goa and for training. On the advice of IDVC field unit, the NVBDCP (then NMEP) pressed into service special mobile squads for weekly active case detection in construction workers. The treatment to malaria patients was dispensed as per the NVBDCP drug policy within 24 h of malaria case detection.

**IEC and community participation**

IEC campaign included house-to-house visits, health exhibitions at construction sites near labour hutments and residential colonies in all wards of the city. At the beginning of the implementation of bioenvironmental control programme, there was a low awareness and knowledge about malaria in the community so much so that garbage and gutters were considered responsible for malaria. The private practitioners had little experience of treating malaria cases as they had not seen malaria earlier during their practice (Salelkar, 1993). So when the bioenvironmental malaria control project was launched in Panaji, a number of interactive programmes were initiated with private practitioners through Indian Medical Association of Goa. A great deal of emphasis was laid on health education to harness community participation in the programme. Health education was imparted through house visits, lectures and exhibitions in the educational institutions, residential colonies and labour camps (Kumar et al., 1994). Videos were shown on malaria and training was imparted on the prevention of malaria to the engineers and the supervisors working at the construction sites.

**Impact assessment**

A focused vector and parasite control approach in 1991 and 92 made desired impact on malaria transmission. Selective vector control interventions during January to May prevented build-up of the populations of *An. stephensi*. As a result, the peak in vector populations visible in 1990 during monsoon months was eliminated in 1991 and 92. This produced desired impact on malaria transmission as slide positive rates for malaria showed a steep decline from 22.5% in April 1991 to below 10% in the remaining months of 1991 and 1992. Similar trend was also seen in case of slide...
falciparum rates, which declined from 8% to less than 4% during this period. The child parasite rate and child falciparum rate also declined from 18.6 and 5.2% in 1990 to 11.1 and 1.5% in 1991 and to 1.6 and 0.5% in 1992 respectively. Similarly, infant parasite rate and infant falciparum rate also declined from 14 and 2% respectively in 1990 to 10.8 and 1.5% in 1991 and to nil in 1992. Thus, the introduction of bioenvironmental interventions led to control of malaria transmission in Panaji. The incidence of malaria in Panaji declined by 88.5%—from 3,938 cases in 1990 (API–88.08; SPR–19.7%) to 1,556 cases in 1991 (API–36.21; SPR–15.1%) and to a further low of 450 cases in 1992 (API–10.3; SPR–6.3%) (Fig. 6).

**Malaria education in schools**

With an aim to make students malaria literate in schools of Goa and to mount a self-action against the disease, a systematic curriculum-based education programme was launched in Goa (Lopes et al., 1993). The partners in this innovative programme besides Goa field unit were Indian Red Cross Society, Department of Education, Govt. of Goa and Goa Board of Secondary and Higher Secondary Education. During 1992–99, 29 workshops were organised for training 971 teachers (Fig. 7). To facilitate training of the teachers, a book entitled ‘Elementary Malariology’ was published by the Goa Board of Secondary and Higher Secondary Education (Kumar, 1996). The programme in schools was launched from standard 8th to 12th in 228 schools targeting 53,462 students throughout Goa (Table 1). The malaria education was imparted through trained teachers as per the Govt. approved syllabus and 147 malaria exhibitions were organised in schools. Students undertook community level projects and dissemination of information on malaria and its control to the community. Each student was assigned 10 houses to disseminate information on malaria. Students and residents identified mosquito breeding sources and undertook intervention (Fig. 8). This included inversion of small or large domestic containers/tanks, introduction of larvivorous fishes, mosquito-proofing of overflow pipes of overhead tanks, sumps and vent pipes of septic tanks with nylon nets, safe storage of tyres, clearing drain pipes of terraces and lintels and filling up small pools.

The performance of students was evaluated through examination. Successful completion of malaria course (as one of the five components taught as optional subject under Junior and Youth Red Cross) was essential for students to earn 5 marks at higher secondary level. This helped them to compete better for professional courses. To make learning pleasant and

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JRC: Junior Red Cross; YRC: Youth Red Cross
interesting, songs, dramas, monologue competition on malaria themes in schools were organised and awards were given by the Chief Secretary, Goa Government and Governor of Goa. In 1999, IDVC field unit assessed cost of the malaria teaching programme in the schools. The cost per household attended and visited by students worked out to Rs. 50.28 (US $ 1.17) with the major share coming from the community itself.

Health impact assessment of Konkan Railways project

Konkan Railway Corporation has constructed 760 km long coastal railway line connecting Roha in Maharashtra to Mangalore in Karnataka. Considering the difficult and challenging terrain through which the railways passes, the project can be appropriately described as engineering marvel with large number of major and minor bridges, culverts, tunnels, railway stations, washing yards, etc. Due to heavy rainfall in the Konkan region and possible obstructions to the natural watershed by the project, there was lurking fear in the minds of many that outbreaks of mosquito-borne diseases would be imminent due to project activities. Stepping in during the construction phase, IDVC field unit in collaboration with Directorate of Health Services, Goa, Konkan Railway Corporation engineers and a team of Nadiad field unit of Malaria Research Centre carried out detailed surveys in all railway project sites in Goa. To start with, IDVC field unit and DHS teams visited all the labour camps located on 105 km stretch in Goa sector and the entire migrant labour force was screened for malaria. Simultaneously their clinical profile was recorded by the DHS. Malaria cases detected were promptly treated to avert outbreaks. A detailed survey on mosquito-genic potential of the project was carried out along the Konkan Railway alignment and adequacies of cross drainages were assessed. IDVC field unit put forward the following recommendations to the Konkan Railway Corporation which were accepted (Fig. 9 a,b,c and d).

1. Sloping roof of the railway station and residential buildings.
2. Installation of mosquito proof overhead tanks at station buildings and residential quarters.
3. Construction of septic tanks and soak pits near staff quarters and railway stations.
given a set of following recommendations to incorporate in their corporate policy in case of expansion of the present project and for the similar future projects.

1. All the future stations, staff quarters and other buildings built by the Konkan Railway shall have sloping roofs.

2. Only mosquito proof overhead tanks and flush tanks shall be installed and their overflow pipes will be fitted with mosquito proof arrangement.

3. Large water tanks including overhead tanks and ground water sumps shall always be fitted with mosquito proof lid assembly as per the specifications provided.

4. Septic tanks in the buildings shall be kept hermetically sealed and their vents covered with nylon/iron mesh at all times.

5. The masonry tanks shall be demolished completely after construction so that no opportunity for water stagnation is provided.

6. No borrow pits shall be created anywhere.

7. Buildings and staff quarters to be provided with mosquito proof wire netting in the doors and windows.

8. Larvivorous fishes shall be introduced in water bodies and tanks along the railway alignment.

A film on the implementation of recommendation by the Konkan Railways Corporation was prepared by the Audio-visual division of MRC entitled ‘No Ticket for Mosquitoes’ which was released to the nation by the Director General, ICMR.

**Field evaluation of biolarvicide— *Bacillus thuringiensis israelensis* H-14 strain 164**

Field trials with *B. thuringiensis israelensis* (H-14) were conducted in Panaji, Goa, between April 1991 and February 1992 in three types of breeding habitats of *An. stephensi* like masonry tanks, curing water in construction sites and discarded overhead tanks to test the bioefficacy of the formulation. There was 97.8% mortality amongst III and IV instar larvae within 24 h of treatment of the curing water. Third/fourth instars were not encountered until seven days post-treatment (Kumar *et al*., 1995). In the masonry tanks also, the densities of III and IV instar larvae of *An. stephensi* in the treated tanks were significantly less than in the control tanks ($t = 5.16, df = 11, p = 0.0002$). Mortality among III and IV instar larvae was 100% in the masonry tanks within 48 h of application. Subsequently low densities were observed until Day 35 post-
treatment. No pupa was observed until Day 18 of the test and they remained at low densities till the study was concluded. Discarded overhead tanks on terraces were found supporting breeding of An. stephensi especially during the monsoon season. A high degree of mortality was achieved within 24 h post-application. Mortality of III and IV instar larvae reached 100% within 48 h of application. In these habitats although there was significant reduction in the population of late instars in the abandoned overhead tanks, pupal production resumed within seven days of post-treatment.

In an another trial in the Sada locality of Vasco-de-Gama, Goa, weekly spraying of B. sphaericus from April 1993 to March 1994 at 1 g/m² in cesspools, cesspits and septic tanks resulted in a sharp decline in the immature and adult populations of Cx. quinquefasciatus (Kumar et al., 1996). Throughout the study period, the per man hour adult densities, percent habitat positivity and immature densities were significantly lower in the treated area compared to that of the control area (Fig. 10).

In view of the development of resistance of An. stephensi to DDT, dieldrin and malathion in Goa (Thavaselvam et al., 1993), use of biolarvicides for malaria control was evaluated in a large malaria endemic area of Panaji. Weekly application of the biolarvicide B. sphaericus (strain 101, serotype H5a 5b) at the rate of 1 g/m² in the An. stephensi larval habitats, such as curing waters, masonry tanks and sump tanks (under construction) from April to December 1993 resulted in sharp decline in the habitat positivity (range 0.13–8%) as compared with rest of Panaji (range 2.2–30.6%) where temephos was used as the larvicide. B. sphaericus spraying also led to a significant decline in anopheline densities in positive habitats (range 0–7.3/10 dips) as compared with that of control habitats (range 0.9–53.0/10 dips). Concurrently, malaria incidence observed in the experimental area (slide positivity rate range 2.3—7.8%; monthly parasite index range 0.18–1.44) was lower than the control area (SPR range 14.3–25.5%; MPI range 1.75–6.12). Thus the impact was clearly discernible on malaria (Figs. 11 and 12).

**Malaria control in Candolim PHC using biolarvicides and fish**

A severe outbreak of malaria occurred in the coastal villages of Candolim PHC of Goa in 1993 and further intensified in 1994 (Kumar et al., 1998, 1999). The outbreak was associated with accelerated construction activity with an influx of migrant construction workers. Conventional methods of control (DDT spraying and
Pyrethrum fogging proved inadequate and alternate control strategies were required. Weekly application of *B. thuringiensis israelensis* @ 1 g/m² was introduced in shallow and small breeding habitats of *An. stephensi*, while an indigenous larvivorous fish, *A. blocki* was introduced in major breeding habitats from June 1994 onwards. The objective of this longitudinal study was to evaluate the effect of *Bti* and larvivorous fish on *An. stephensi* and subsequent transmission of malaria in Candolim PHC in Goa. In 1995, the populations of *An. stephensi* in larger and smaller habitats declined significantly compared with corresponding period in the previous year (Fig. 13). Similarly, a sharp decline in the malaria incidence also occurred in 1995 as compared to 1994 (Fig. 14). Comparative analysis of malaria incidence in Candolim PHC and the surrounding towns showed that SPR, SFR and parasite index in the experimental villages of Candolim PHC
declined by 57.3, 82.6 and 81.6%, respectively in 1995, but the incidence in two nearby malaria endemic towns (Panaji and Porvorim) increased substantially during 1995 as compared to 1994.

**Bioenvironmental control of malaria in Mormugao Port—A technology transfer project**

This project was initiated in the year 1997 following serious complaints of mosquito nuisance in the Port complex (Fig. 15) during night shifts in spite of substantial cost being incurred for mosquito control. The project was sponsored by the Port. Department of Medical Services and Civil Engineering Department of the Port were selected as the partners in implementation of bioenvironmental control of mosquitoes and transfer of technology to the Port. Till the year 2001, mosquito intervention was done (Fig. 16 & 17) which led to significant reduction in mosquito populations as well as malaria cases (Fig. 18). In the year 2002,
bioenvironmental control technology was transferred to the Port Medical and Civil Engineering Departments. Various components of transfer of technology such as constitution of committees, preparatory seminars, training on mosquito intervention, mosquito proofing, blue-print preparation, impact assessment, conduction of surveys, review of the interventions, etc. were done during April 2002 to February 2003 in a phased manner.

**Therapeutic efficacy of chloroquine in the treatment of uncomplicated *P. falciparum* malaria**

Recently, following a standard WHO protocol, a study was carried out in Panaji, Goa in 2003 and 2004 to assess the therapeutic efficacy of chloroquine in uncomplicated *P. falciparum* malaria. Out of 63 patients enrolled, 51 could be followed-up for 28 days. The patients were clinically examined and their blood smears were prepared and examined for *P. falciparum* parasitaemia on Days 0, 1, 2, 3, 7, 14, 21 and 28. Results of the trial showed that 43 (84.3%) of the patients did not respond to the chloroquine and adequate clinical and parasitological cure following treatment with chloroquine therapy was observed only in 15.7% of the patients (Fig. 19). Of the chloroquine resistant
cases, there was early treatment failure in 12 (23.5%) cases, late clinical failure in 7 (13.%) and late parasitological failure in 24 (47.0%) cases. A combination of sulphadoxine + pyrimethamine and artesunate was prescribed to such cases who were followed-up till they were completely cured. Based on the findings of this study, the NVBDCP has withdrawn use of chloroquine and introduced sulphadoxine-pyrimethamine for the treatment of uncomplicated *P. falciparum* malaria in Panaji.

### Insecticide resistance in mosquito vectors

Monitoring of insecticide resistance in malaria vectors is a priority area of operational research relevant to the needs of the NVBDCP. Susceptibility studies carried out in 1993 revealed that malaria vector—*An. stephensi*, filaria vector—*Cx. quinquefasciatus* and dengue vector—*Ae. aegypti* had developed resistance to DDT, dieldrin and malathion in Panaji (Thavaselvam *et al*., 1993).

Susceptibility of *An. stephensi* was evaluated in 2003–04 in North Goa district using diagnostic papers of DDT (4%), malathion (5%) and deltamethrin (0.25%) following WHO procedure and using standard kit. Two strains of *An. stephensi* from malaria endemic areas such as Panaji and Candolim-Calangute were reared in the field unit insectary. Knockdown effect of the insecticides and mortality after 24 h post-exposure were recorded. The findings are shown in Fig. 20.

Using *An. stephensi* Panaji strain, 100% knockdown was observed after 1 h exposure of deltamethrin papers although mortality was 89.4% after 24 h of holding. With *An. stephensi* Candolim strain, 99% knockdown was observed after 1 h exposure, while corrected mortality after 24 h was 88.9%. This indicates that both the strains were susceptible to deltamethrin although there was an indication of vigour tolerance as indicated by about 10% resistance in the test strains. With DDT papers, *An. stephensi* Panaji strain showed 48% knockdown after 1 h exposure although mortality was 10.5% after 24 h post exposure. *An. stephensi* Candolim strain showed 33% knockdown after 1 h exposure, while mortality at 24 h post-exposure was 11%. The results suggested that both strains of *An. stephensi* are highly resistant to DDT.

With malathion, knockdown of *An. stephensi* Panaji strain was only 1% after 1 h exposure and there was no mortality observed after 24 h post-exposure. *An. stephensi* Candolim strain had 5% knockdown after 1 h of exposure, while corrected mortality after 24 h post-exposure was 10.5%. The results showed that Panaji strain has become completely resistant to malathion. Even Candolim strain showed high resistance to malathion. There was hardly any knockdown even after 1 h of exposure in both the strains.

### Study on biting, resting behaviour and incrimination of vectors

Mosquito collections were made from three malaria endemic urban and suburban areas of Goa. In well-built houses, 67 h of collections did not yield a single *An. stephensi* mosquito, although other species were encountered. However, collections from construction sites and workers’ huts for 151 h yielded, 38 *An. stephensi* females resting in 15 types of sites at a height varying from 30 cm to 2.4 metres besides other mosquito species. In all, 11 mosquitoes were caught resting on unplastered surfaces, four each on plastered surface and on bamboo and wood surfaces, three on metal surfaces and four on others, thus showing a high variability for resting. Of 37 mosquitoes tested for the presence of circumsporozoite protein (CSP) by an ELISA technique, one was found to be *P. falciparum* CSP positive (Sumodan *et al*., 2004). This study suggested that IRS cannot be of much use in this area and selective larviciding would be the best choice for vector control.

A longitudinal study on biting behaviour of vectors conducted on human baits from 1800 to 0600 hrs in 75 all night mosquito collections in Goa in 1991
showed that six mosquito vector species—An. stephensi, Cx. quinquefasciatus, Cx. vishnui, Cx. pseudovishnui, Cx. tritaeniorhynchus and Ae. aegypti exhibit differential feeding pattern during different phases of night. Weather conditions were also found to influence feeding activity during different seasons. The peak biting of An. stephensi was observed between 2200 and 2400 hrs when 69% of biting was observed. The filarial vector Cx. quinquefasciatus bit throughout the night although peak biting was observed between 0100 and 0200 hrs. Peak biting time of Cx. vishnui was between 2300 and 2400 hrs and that of Cx. tritaeniorhynchus it was from 2400 to 0100 hrs. Ae. aegypti was predominantly crepuscular and its biting ceased at 2200 hrs although peak biting was observed between 1800 and 1900 hrs (Kumar et al., 1995).

Larvivorous fish surveys

Extensive surveys of larvivorous fishes were conducted covering ponds, backwaters, streams, lakes, paddy fields submerged under water, rivers/rivulets and irrigation canals in all parts of Goa (Sumodan and Kumar, 1998). Fifteen species of fishes were recorded such as Aplocheilus blocki, A. lineatus, Rasbora daniconius, Puntius vittatus, P. amphibious, P. melanopryx pradhani, Macropodus cupanus, Danio aequipinnatus, Osteochilichthys nashii, Hypselobarbus Dobsoni, Oreochromis mossambicus, Therapon jarbua, Heteropneustis sp., Etroplus suratensis and Mugil cephalus. Their habitat wise distribution was studied and density was recorded. In controlled experiments, mean consumption of Cx. quinquefasciatus larvae varied from 62.5 to 736 per fish by different species. On the basis of their extensive distribution, availability and usefulness, A. blocki (mean consumption: 102.6 larvae per day/fish) and R. daniconius (mean consumption: 464.3 larvae per day/fish) were recommended for malaria control operations in Goa.

Evaluation of rapid diagnostic tests

Field evaluation of rapid diagnostic tests was done to determine their efficacy and sensitivity (Kumar et al., 1996, 2000). The kits evaluated were ICT-Pf, Binax, Para-check®-Pf, Parascreen, Paramax and Falcivax. The field station also carried out quality control test on Paracheck®-Pf consignment procured by RITES India Ltd. for NVBDCP’s World Bank funded Enhanced Malaria Control project.
Isolation of mosquito pathogenic bacilli from Goa

Eight isolates of mosquito pathogenic bacilli were isolated from soil samples collected under sterile conditions from different parts of Goa devising a new protocol which was simple and avoided cumbersome procedure of isolation (Kumar et al., 2000; Dhindsa et al., 2002). Strains KSD 4, 7 and 8 which showed promising results during preliminary bioassays were further processed for biochemical characterisation for identification and bioassays against mosquito larvae. Commercial formulations of \textit{B. t. israelensis} H-14 strain 164 and \textit{B. sphaericus} (B101) H5a 5b were used as control for comparison. Scanning electron micrographs of all the new isolates and control strains were prepared.

Training programmes

IDVC field unit imparted training to participants from different departments, students of different schools, colleges, Goa University, Nursing school, multi-purpose workers, laboratory technicians, officials of various departments, doctors, civil engineers, sanitary inspectors, construction supervisors, teachers, builders and contractors, National Social Service volunteers and officers, conservators of forests, artists, municipal workers, etc.