Integrated Vector Management

Bioenvironmental Control in Different Paradigms

An alternative strategy of malaria control based on non-insecticide components was launched by NIMR in mid-1980s. The components of this bioenvironmental control methodology for malaria control were:

Source reduction by

(i) Minor engineering works;
(ii) Environmental manipulation/improvement; and
(iii) Biological control agents.

Treatment by

(i) Early detection; and
(ii) Prompt treatment.

Soliciting

(i) Community participation by creating awareness through health education; and
(ii) Intersectoral coordination.

This approach is naturalistic and holistic. To demonstrate the feasibility of bioenvironmental control strategy in rural areas, Nadiad field unit of NIMR in District Kheda, Gujarat was established in March 1983. Kheda district was selected because of prevailing epidemic situation and other operational as well as technical constraints faced by the antimalaria programme. This methodology was then extended to different eco-epidemiological zones of the country like urban areas, industrial complexes, tribal areas, island ecosystem, north-eastern areas and many other rural areas.

Rural Malaria

The project was launched in seven villages of Nadiad taluka without the use of insecticides and to develop a cost-effective strategy. The main components of the strategy comprised of reduction of mosquito breeding sources, use of EPS beads in unused wells, biological control using mosquito larvivorous fishes, health education, community participation, early case detection and treatment, environmental improvement through social forestry in marsh lands and intersectoral coordination (Sharma *et al* 1985, 1991; Sharma and Sharma 1989). Following initial success, the study area was gradually extended to cover the entire Nadiad and Kapadwanj talukas covering 7,00,000 population by 1987. In order to disseminate the experience gained in the Kheda project, several transfer of technology workshops and training programmes for different categories of health personnel, such as district malaria officers, PHC medical officers, different functionaries of the state health department, municipal corporations, etc. were organised.

Community participation for source reduction of mosquito breeding

This strategy has been accepted in NVBDCP-EMCP World Bank assisted Project.
WHO recognises this strategy as sustainable alternative strategy for malaria control

Environmental Improvement by Community Involvement

At many places community came forward to participate in the activities like source reduction, environmental modification and manipulation and use of biological control agents for the control of mosquito breeding. To make the community self-sustainable and motivated, economic incentive schemes like culturing edible fish in large ponds in the area and growing eucalyptus and neem saplings were encouraged.

Economic Incentive Schemes

Success of the Kheda project led NIMR to test the strategy at other rural sites in the country, namely Haldwani in District Nainital, Uttarakhand and Dadraul PHC in District Shahjahanpur and Shankargarh block in District Allahabad, Uttar Pradesh, and PHC Kamasamudram in District Kolar, and PHCs Banavara and Kanakatte in District Hassan, Karnataka. The strategies used were similar to those mentioned above, except in Karnataka where emphasis was given on biological control by larvivorous fish.

In Shahjahanpur, *G. affinis* was extensively used in wells to control vector breeding. Studies carried out in Shahjahanpur revealed that *G. affinis* successfully controlled breeding of mosquitoes and percent positivity of wells reduced from 60–80% to almost nil (Fig. 1).

In Haldwani of Nainital district, *G. affinis* controlled mosquito breeding in ponds very effectively (Fig. 2). These fishes were introduced in ponds during April. By the end of September, fish multiplied many fold and percent positivity of ponds came down from over 80% positivity of ponds to negligible levels.

PHCs where larvivorous fish have been used extensively in Karnataka were PHC Kamasamudram in District Kolar and Banavara and Kanakatte in District Hassan.

In PHC Kamasamudram, in 93 vilages, about 36,000 *Poecilia reticulata* (guppy) were released in wells and tanks during January to April 1994. In this area wells, tanks and streams are the main breeding sites of *An. culicifacies*, the major vector of malaria. Since guppy could not do well in tanks, *Gambusia affinis* was released in tanks during 1996. A significant reduction was observed in all species in all habitats ($p < 0.001$ and < 0.025) (Fig. 3). Significant reduction in *An. culicifacies* densities was observed ($p < 0.001$), while no reduction was observed in *An. fluviatilis* densities ($p > 0.05$) (Fig. 4). Introduction of fish had a major impact in decreasing the malaria incidence in this area as well. In 1993 the API was 41.8, and there was steady decrease in API in the following years. Number of malaria cases reported in the study

Fish culture in ponds (edible fish and prawns were cultured)

Growing of eucalyptus for plantation

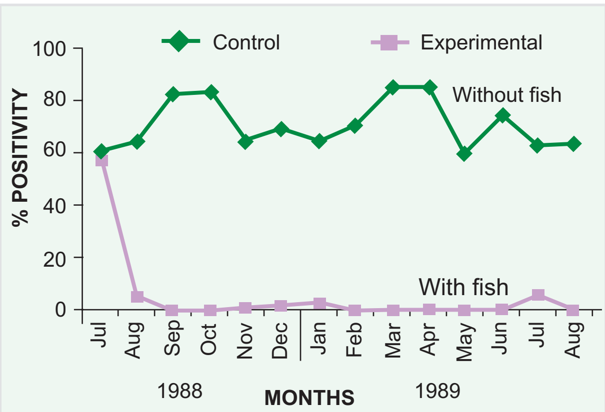

Fig. 1: Impact of *Gambusia* on mosquito breeding in wells in Shahjahanpur

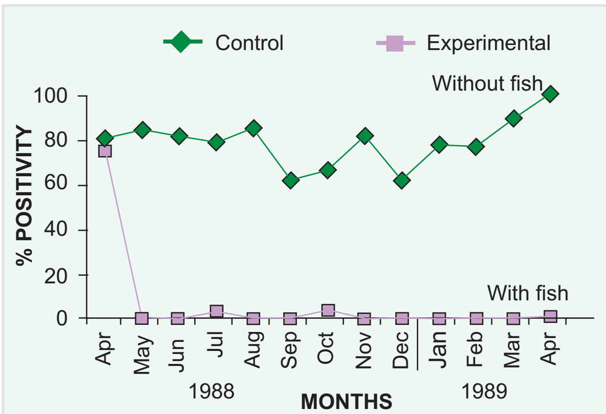

Fig. 2: Impact of *Gambusia* on mosquito breeding in ponds in Haldwani

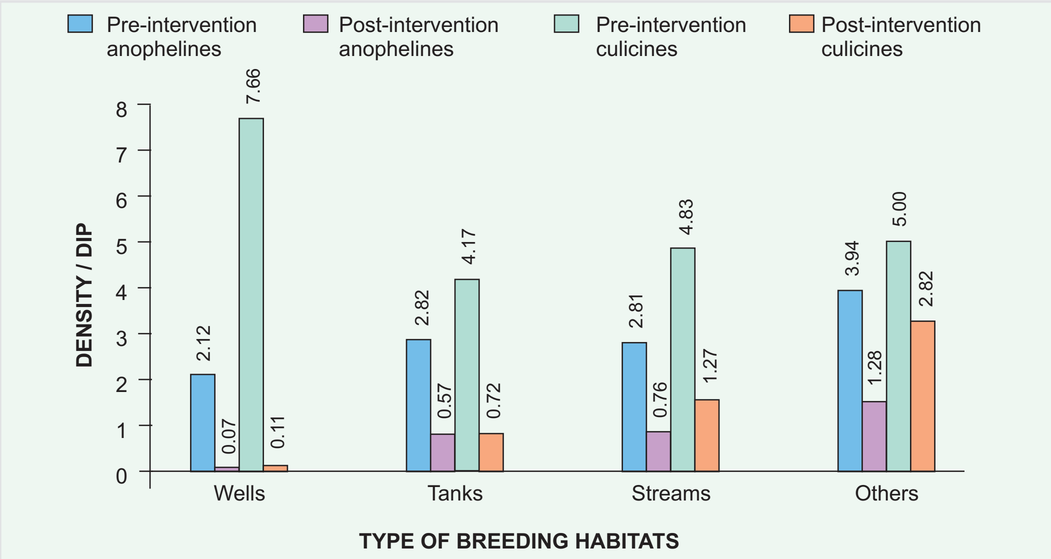

Fig. 3: **Changes in larval densities of anophelines and culicines following intervention with larvivorous fish in different breeding habitats in PHC Kamasamudram, District Kolar (Pre-intervention — 1994 to 1996; Post-intervention—1997, 1999 and 2001)**

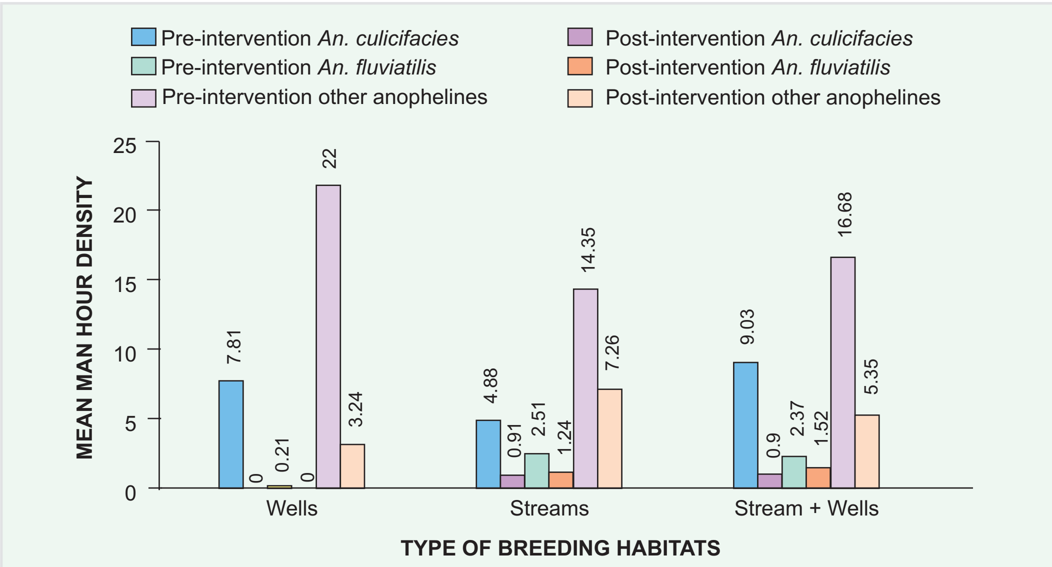

Fig. 4: **Changes in adult densities (mean MHD) of anophelines in villages having different types of breeding habitats following intervention with larvivorous fish in PHC Kamasamudram, District Kolar (Pre-intervention—1994 to 1996; Post-intervention—1997, 1999 and 2001)**

villages of PHC Kamasamudram from 1993 to 2006 are shown in Fig. 5. There was a drastic decline in number of malaria cases in intervention villages.

A strong focus on malaria contributing 25% of malaria cases of the state involving congruent talukas from four districts, namely Tumkur, Hassan, Chikmagalur and Chitradurga was identified in 2000 by NIMR. As in Kamasamudram of Kolar district and Banvara and Kanakatte of Hassan district, wells and tanks are the main breeding sites and *An. culicifacies* is the major vector. After a detailed geographical reconnaissance fish are being introduced. NIMR had carried out this operation in collaboration with state health personnel. Fish were released in 1766 villages covering a population of 1.2 million in four talukas. There was a considerable decline in malaria vectors

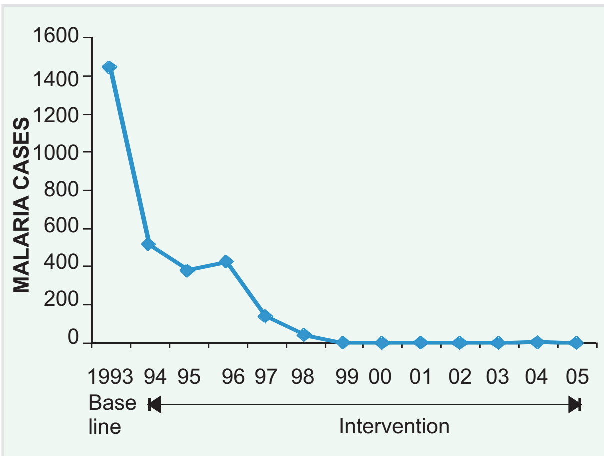

Fig. 5: **Impact of larvivorous fish on malaria incidence in villages of PHC Kamasamudram, Karnataka**

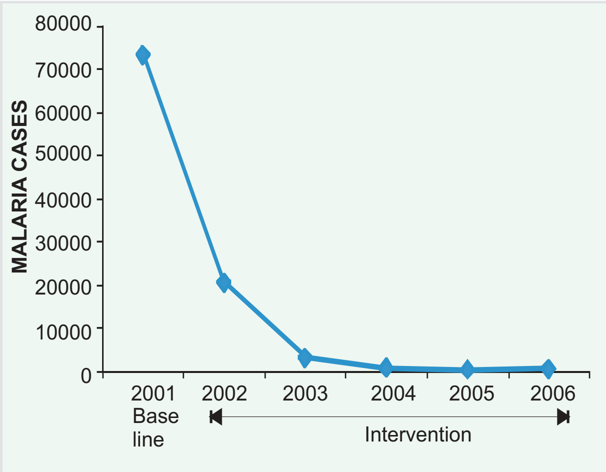

Fig. 6: Impact of larvivorous fish on malaria incidence in 1766 villages in Tumkur, Hassan, Chikmagalur and Chitradurga districts, Karnataka

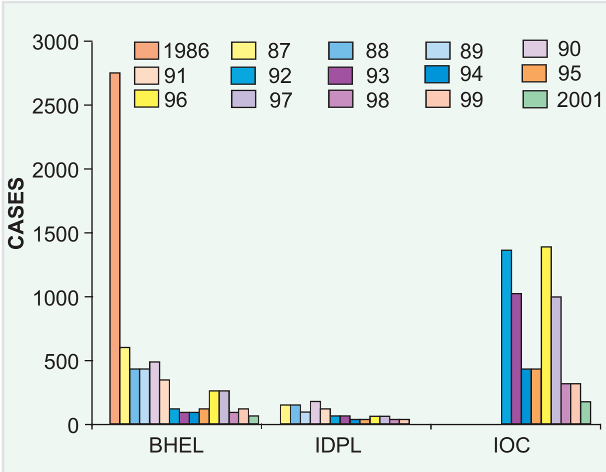

Fig. 7: Incidence of malaria in BHEL, IDPL and IOC industrial complexes

in these villages. Malaria incidence was also decreased significantly in the intervention villages (Fig. 6)

Industrial Malaria Control in BHEL and IDPL Complexes

To find a solution to malaria in industrial areas, the bioenvironmental strategy was tested in the industrial complex of the Bharat Heavy Electricals Limited (BHEL) in Hardwar beginning July 1986 and later on extended to Indian Drugs and Pharmaceuticals Limited (IDPL), Rishikesh (Dua *et al* 1991, 1997, 2000). Surveys were also conducted in areas of IOC, Mathura, NTPC, Shakti Nagar, Rihand Nagar and Unchahar, HEC, Ranchi, Visakhapatnam Steel Plant and Ordnance Factory, Tundla. Mosquito breeding sites in the industrial townships were sluice valve chambers, underground tanks, overhead tanks, ornamental tanks, septic tanks (abandoned), open and blocked drains, stormwater drains, culverts, fire hydrants, open man-holes, used or abandoned wells, pitwells, ponds, oxidation ponds, artificial lakes, coolers and factory scrap like tyres, iron scraps, a large number of borrow pits and low-lying areas.

The intervention strategy used the existing infrastructure of the industries which comprised of filling of borrow pits with fly ash and burnt hard coke ash, construction of sand posts near water taps, soakpits, construction of cemented drains, mosquito-proofing of overhead tanks, application of EPS beads in small underground tanks, sluice valve chambers and choked man-holes, desilting and canalisation, introduction of guppy and *Gambusia* fishes in storm drains and large tanks, periodic cleaning of intradomestic containers, and improvement in case detection and treatment.

Filling up of breeding sites by fly ash

There was a marked reduction in malaria cases from 1986 (base year) to 2001 (Fig. 7). Only eight cases were recorded in 2001 as compared to 3049 in 1986. The strategy was found to be cost-effective (Dua *et al* 1997). In IOC, Mathura, malaria cases declined during the period from 1992 to 1995 but increased in 1996 due to flood situation in adjoining areas. It is to point out that the cases declined sharply after 1996.

Overall, the bioenvironmental control of malaria strategy was found feasible, appropriate and cost-effective in industrial complexes. By implementing this strategy, a major reduction in insecticide residues was recorded.

Urban Malaria Control

Goa

A severe epidemic of malaria in Panaji during 1986–87 was traced due to accelerated developmental activities and importation of labourers. The malaria incidence rose from a mere 10 cases in 1985 to 352 cases in 1986 (API 8.1). It further increased to 4406 cases in 1987 (API 102.4) and 5677 cases in 1988 (API 132). Owing to a public health crisis and threat to economy, a NIMR field unit was set up in 1989 to conduct epidemiological study and evaluate feasibility of bioenvironmental control. Ecology of *An. stephensi* was delineated (Kumar and

Use of guppies in drains to control mosquito larvae

Thavaselvam 1992). Fig. 8 shows contribution of various habitats to breeding of *An. stephensi* in Panaji.

Seasonality of *An. stephensi* was studied. Malaria incidence in construction workers and local community was measured by surveillance. Malaria was strongly related to construction activities (Kumar *et al* 1991). As a part of bioenvironmental strategy, methods applied for vector control were: source reduction (disposal of tyres, domestic containers, barrels, filling of sand in curing tanks, drainage of ornamental tanks and underground masonry tanks with motorised suction pumps, removal of defunct overhead tanks and providing proper cover); introduction of larvivorous fish *Aplocheilus blocki*, *P. reticulata* and *G. affinis*; and use of biolarvicides—*Bacillus sphaericus* H5a5b (B101) and *B. thuringiensis* var *israelensis* H-14 strain 164 in *An. stephensi* larval habitats. Malaria surveillance and case treatment were improved. Health education campaigns were organised to solicit community participation including help of private doctors and the Indian Medical Association. Overall, introduction of bioenvironmental interventions led to malaria transmission control in Panaji and decline in malaria

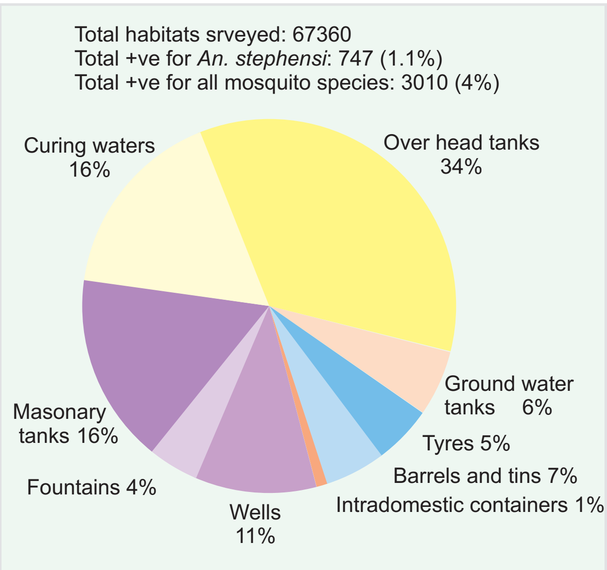

Fig. 8: Contribution of various habitats in breeding of *An. stephensi* in Panaji, Goa

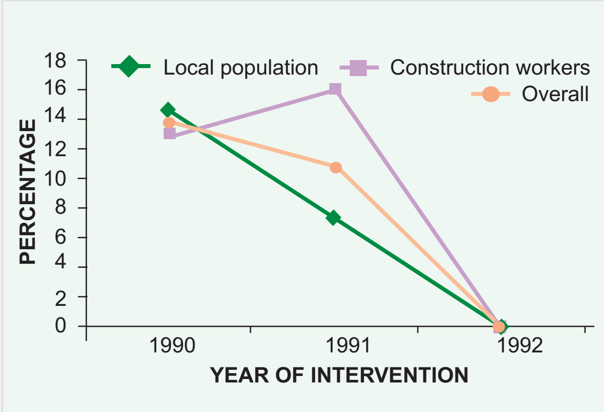

Fig. 9: Impact of bioenvironmental interventions on malaria in Panaji

incidence up to 88.5% by 1992 (Fig. 9).

In conclusion, the bioenvironmental strategy was found to be effective for urban malaria control. However, prior to its implementation, there is a need to study biology and breeding behaviour of vector and then design the strategy suiting to local situation. The focus on vector breeding, source reduction and biological control measures should be greater prior to the vector build-up so that the peak populations are suppressed and active transmission is curtailed. There is also a need to identify population at greater risk so that they are targeted for active parasite surveillance for early detection and prompt treatment. Information, education and communication (IEC) and intersectoral coordination are also beneficial in source reduction and early detection and prompt treatment.

Chennai

A feasibility study on the bioenvironmental control of urban malaria was undertaken in Chennai City during 1987–92. The study was carried out in malaria endemic areas of Chintadripet and Sowcarpet in north Chennai. *An. stephensi* is the vector of malaria in Chennai. Overhead tanks (OHTs), wells and cisterns are the preferred breeding sites. Most of the OHTs and wells are either opened or partially opened. Potential breeding sites were enumerated.

Intervention measures included the use of *G. affinis* fish in tanks and wells, mosquito-proofing of potential breeding sources, application of EPS beads, source reduction and case detection. In OHTs with chlorinated water, fish were not released. Anopheline breeding and presence of fish in OHTs and wells were checked weekly. Many OHTs were permanently mosquito-proofed. Holes were drilled in defunct OHTs to prevent accumulation of water. Fish were introduced in 2657 open OHTs and 2213 open wells and were regularly monitored. No anopheline mosquitoes were observed breeding in OHTs and wells with fish. *Anopheles* breeding was, however, prevalent in breeding habitats without fishes (Fig. 10). Malaria case detection at the Corporation clinics, active case detection and mass blood surveys were

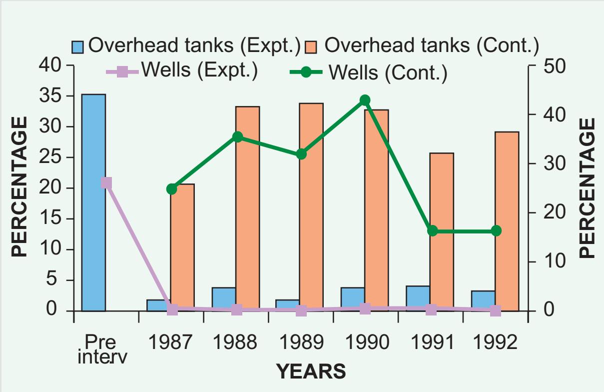

Fig. 10: Breeding of *An. stephensi* in wells and overhead tanks in Chennai, Tamil Nadu

undertaken in slums and at construction sites for early diagnosis and prompt treatment of patients. Health education was given to generate awareness in the community.

These measures resulted in significant control of mosquito breeding and vector densities. There was a steady decrease in slide positivity rate from 0.35 in 1987 to 0.005% in 1990 in Chintadripet area. In Sowcarpet area also, there was a reduction from 2.25 in 1987 to 1.07% in 1989. The study demonstrated the feasibility of bioenvironmental control in an urban area. To provide a sustained solution for malaria control in Chennai, a 7-point action plan for malaria control was developed.

The plan is simple, indigenous, environment-friendly, sustainable and cost-effective, the salient features are: (i) construction and maintenance agencies of government and private buildings were made responsible for taking adequate preventive measures for the control of mosquito breeding; (ii) vector control programme in the city was reorganised with close interaction of City Corporation, Municipality and State Health Department; (iii) Municipal bye-laws must be implemented rigidly; (iv) for any new construction plan clearance from health department was made mandatory; (v) at all construction sites incoming labourers must be screened for malaria infection and given radical treatment; (vi) implementation of malaria control in phased manner; and (vii) constitution of committees for monitoring action plan.

Delhi Action Plan

Mosquito problem in Delhi is mainly due to blocked surface drains, poor sewage disposal, ill-constructed drains, silting of drains, poor maintenance of water supply system, overhead tanks, cisterns, etc. Malaria has also increased in peri-urban areas and at construction sites. In order to organise an effective mosquito control programme and to identify the malariogenic potential, geographical reconnaissance was carried out during 1989–91. An extensive survey was carried out to assess the magnitude of the problem related to actual and potential breeding sites in 12 zones of Delhi, namely Shahdara, Civil Lines, City zone, Sadar Pahar Ganj, Karol Bagh, West zone, South zone, New Delhi, Narela, Nazafgarh, Delhi Cantt. and NDMC zones. All the breeding sites were mapped. Point prevalence survey for malaria incidence was also carried out during 1991–92. In addition, suitable permanent water bodies were also identified for development of hatcheries for larvivorous fishes to be used for urban malaria control programme. Based on the findings of the survey, a detailed Master Action Plan was prepared and handed over to the Government of the National Capital Territory, Delhi for implementation.

Ahmedabad and Surat Cities

Due to the alarming rise in malaria in urban areas, NIMR conducted two studies during 1996–2000 in Ahmedabad and Surat cities with a view to develop comprehensive strategies to control malaria and dengue vectors. The Ahmedabad study had the specific objectives to map mosquito breeding habitats by geographical reconnaissance to plan antilarval measures, study bionomics of vector species, ascertain the knowledge, attitude and practices related to mosquito-borne diseases to implement a health education strategy, estimate the burden of malaria, review malaria surveillance mechanisms and staffing pattern, rationalisation of antilarval measures, test the feasibility of integrated control of malaria and dengue vectors with emphasis on bioenvironmental management of vectors of diseases and develop an antimalaria action plan.

The ongoing Urban Malaria Scheme was reviewed with respect to antilarval and anti-adult measures, malaria case detection and reporting mechanism, entomological monitoring, IEC activities, staffing pattern, laboratory services, training needs and the implementation of public health bye-laws. Following this exercise the rationalising measures undertaken included refresher or reorientation training of antimalaria staff, reorganisation of field staff laying more emphasis on mosquito breeding control in domestic sources, development and use of larvivorous fish resource to reduce reliance on chemical larvicides, strengthening of health education activities especially by involving school children, emphasis on legislative measures to control mosquito breeding and identification of key urban sectors for allocation of responsibilities for taking preventive/ remedial measures.

To evaluate feasibility of the integrated methods of control in Ahmedabad City, four malaria endemic wards with similar ecological conditions were selected randomly on either side of the River Sabarmati. By random allocation, two municipal wards (population 1,65,584) were assigned to integrated strategy comprising larval control using fish, survey and elimination of larval breeding in domestic water storage, community participation in prevention of breeding/larval control, engineering works (e.g.

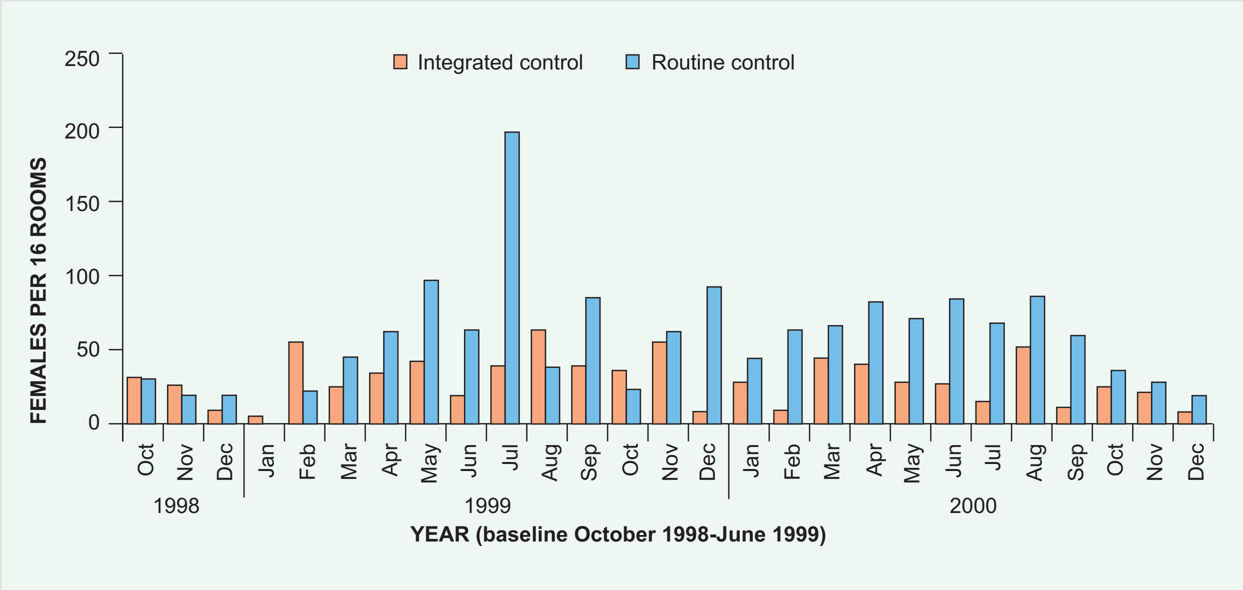

Fig. 11: Impact of integrated control on *An. stephensi* densities in Ahmedabad City

leakage repairs, mosquito-proofing), development of hatcheries and ward-level distribution tanks, removal of tyres/scraps, source reduction and health education. Another two comparison wards (population 1,60,176) continued with the routine control measures of chemical larviciding, fogging and general health education. During the baseline period malaria incidence and vector densities were comparable. During the intervention period beginning July 1999, the integrated strategy reduced malaria incidence and the population densities of *An. stephensi* and *Aedes* species more effectively than the routine control strategy (Figs. 11–12).

The per capita annual operational cost of the integrated strategy (Rs. 8.1; US$ 0.19— Prices of year 2000) was comparable/lesser than the routine control (Rs. 9.3; US$ 0.21). Thus, the integrated control has scope to reduce use of insecticides, improve the urban environment, decrease school absenteeism, generate community awareness, and encourage long-term sustainability. The integrated control strategy implemented in Ahmedabad City is

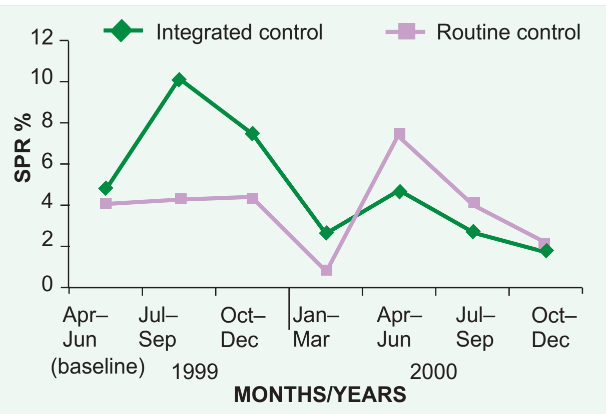

Fig. 12: Malaria incidence in areas under integ-rated control *vs.* routine control in Ahmedabad City

evolving as a model that needs to be carried forward and implemented in other towns of Gujarat and all over India. The benefits of the integrated control strategy may potentially extend to increased community control, reduced insecticide use, improved urban environment, decreased school absenteeism, better community awareness, and long-term sustainability.

Based on this study a comprehensive action plan for management of malaria and dengue is being prepared and would comprise the elements of: (a) early detection and prompt treatment, and establishment of a malaria information system; (b) integrated vector management; (c) capacity strengthening; (d) IEC and inter-sectoral partnership; (e) implementation of legislative measures; (f) health impact assessment of urban development planning to incorporate health safeguards in urban expansion/ regeneration projects; and (g) operational research on vector-borne diseases to support the control programme.

Surat City is endemic for malaria and filariasis and dengue is an emerging disease. The U.K. Department for International Development supported a study by NIMR in Surat during 1998–2000. Bionomics of malaria, dengue and filariasis vectors and the epidemiology of malaria were studied. A geographical reconnaissance by land-use pattern led to an assessment of the need for environmental and engineering methods of control of malaria, dengue and filariasis. An entomological monitoring unit was set up and all staff trained. Use of malathion indoor spraying in slums was stopped following evaluation of susceptibility of vectors to insecticides. Spraying of pyrethroids indoors has also been stopped for the last two years and reliance on environmental methods involving engineers, architects and builders association, use of fish, and IEC is on the increase. During 2001 and 2002, NIMR staff has participated in transfer of technology workshops organised by the Surat Corporation to follow-up the work done.

Tribal and Island Malaria Control

The bioenvironmental control startegy was also evaluated in tribal dominated forest areas of Sonapur (Assam), Mandla (Madhya Pradesh) and Rourkela (Orissa) and in Car Nicobar Island by the respective NIMR field units. Overall, because of the presence of innumerable water collections, channels and seepages in inaccessible forested terrains, the environmental management methods were not found practicable and feasible. In view of this, an integrated approach involving insecticide-impregnated bednets along with other methods was tested and found suitable.

Development of Strategy for Integrated Control of Vectors of Malaria and Dengue in Northern Gujarat

The study supported by WHO was undertaken in collaboration with Government of Gujarat from 2002 to 2004 to contribute to the development of rational strategies and policies for control of malaria and dengue. In eight talukas covering six districts, mosquito breeding potential was assessed through survey of domestic water storage practices and geographical reconnaissance of peri-domestic habitats. This determined species specific breeding preference. Sibling species of *An. culicifacies* and susceptibility of vector species were determined. Spatial and temporal trend of malaria in a sentinel area (Rapar Taluka, Kutchh district) during 2000 to 2003 was studied to assess the risk of malaria. Correlation of rainfall and malaria in Kutchh district was studied. Malaria prevalence based on mass blood survey was found to range from 4.4–5.4% during October 2003 to March 2004. A mosaic pattern of use of insecticides indoors in various districts in Gujarat suggested the need for a rationale planning

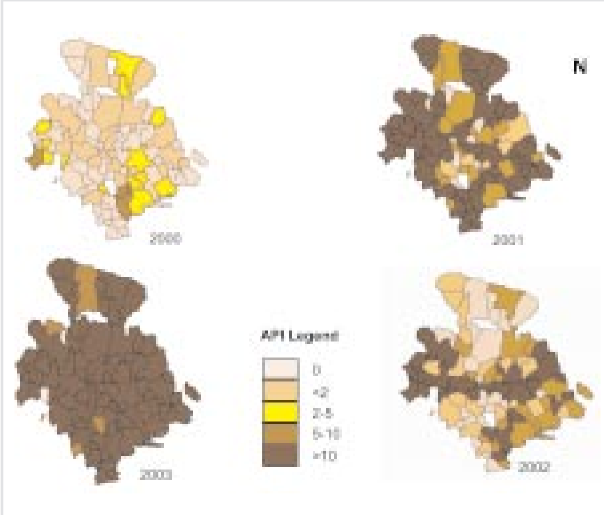

Fig. 13: Spatial and temporal trend of malaria in Rapar taluka, Kutchh district

and use of insecticides. Prevalence of dengue was assessed. Results of the study were disseminated in a state level dissemination workshop in Anand and in a national workshop in Bengaluru.

As an outcome of the study, an evidence-based integrated strategy for control of malaria and dengue vectors in semi-arid zone of Gujarat was developed. The important components of the strategy are: assessment of the risk of disease by stratification (Fig. 13), developing a management information system and epidemic containment, strengthening dengue surveillance, increasing access and coverage to diagnosis and treatment, strengthening laboratory and diagnostic services, drug resistance monitoring, vector management need assessment and implementation, advocacy, inter-sectoral cooperation and legislation. In order to strengthen the proposed strategy operational research, capacity strengthening and monitoring of programme are necessary.

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