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CRITICAL REVIEW OF *AEDES AEGYPTI* CONTROL PROGRAMS IN THE CARIBBEAN AND SELECTED NEIGHBORING COUNTRIES

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ABSTRACT. In recent years the region of the Americas has experienced increasing dengue activity with circulation of multiple virus serotypes. Associated with this trend has been the occurrence of sporadic dengue hemorrhagic fever (DHF) cases and of DHF epidemics in both the Caribbean and Latin America. High vector infestation levels persist even though most countries in the Caribbean conduct national *Aedes aegypti* control programs and despite the fact that in some instances, expenditures exceed US$5 per capita per annum. This paper critically reviews the resources and vector control strategies employed in the region and in selected neighboring countries. Reasons for the lack of progress include continued overreliance on eradication-style larviciding routines and the passive role of communities in addressing the problem. A policy of health promotion aimed at improving environmental health practices at the household and community levels has been endorsed by the governments of the region but as yet has not been widely adopted.

INTRODUCTION

By 1962 the hemispheric campaign to eradicate *Aedes aegypti* (Linn.) had eliminated the vector of dengue and yellow fever from 18 continental countries of the Americas. The Caribbean islands were less successful and only a minority of them achieved this goal. There was progressive erosion of these gains as program resources dwindled, and over the next 25 years all but a handful of countries became reinfested. By 1991 only Costa Rica, Uruguay, Chile, Bermuda and the Cayman Islands continued to report vector-free status. The substantial increase of dengue activity in the region during the same period can be attributed primarily to this geographic resurgence of *Ae. aegypti* and to dengue virus dissemination resulting from the rapid growth of international and inter-regional air travel (Gubler and Casta-Valez 1991). Increasing and often unplanned urbanization has further contributed to the disease trend.

Sequential infection with different serotypes is considered to enhance the risk of clinical presentation of dengue hemorrhagic fever (DHF) (Bravo et al. 1987, Halstead 1989). Dengue virus serotypes 1, 2 and 4 have been circulating concurrently in the Americas for over 10 years while the reappearance of dengue 3, absent since the late 1970s, seems inevitable. Epidemic DHF occurred for the first time in this hemisphere in Cuba in 1981 (Kouri et al. 1983) and another epidemic followed in Venezuela in 1989–90 (PAHO 1990). Over the same period sporadic cases of DHF have been reported with increasing frequency in other countries, notably Puerto Rico, Brazil, El Salvador and Colombia (Pinheiro 1989).

In the absence of a vaccine, vector control remains the only option for preventing or reducing dengue transmission. This paper reports on the status of *Ae. aegypti* control programs in the Caribbean and in selected neighboring countries and considers the reasons for lack of progress in reducing vector densities. The information was gathered by PAHO/WHO during the course of its technical cooperation program with the countries.

REPORTED *AEDES AEGYPTI* INFESTATION LEVELS

The levels of *Ae. aegypti* infestation reported by governments of 24 countries or territories are shown in Table 1. The most recent information is for the year 1990, and where available, comparisons are made with reported indices from the periods 1982–83 and 1984–85 to indicate trends over time. For 1990 reported house indices (the percentage of houses with larval infestations of *Ae. aegypti*) ranged from 0% (Cayman Islands and Bermuda) to 34%, while Breteau indices (number of larval foci of *Ae. aegypti* per 100 houses) reported for 12 of these countries ranged from 0 to 77. These data indicate an apparent improvement over the prevailing conditions of the early 1980s although a general deterioration of the situation is suggested in more recent years: among 17 countries for which comparative figures are available, ten had house indices higher than those reported 5–6 years earlier; of the remainder, 2 continued to report

Table 1. *Aedes aegypti* larval indices in the Caribbean and selected neighboring countries.

	Government reported indices[a]			
Year	1982–83	1984–85	1990	
Country or territory	House index %	House index %	House index %	Breteau index
Anguilla	22.5	7.3	11.4	n.a.
Antigua/Barbuda	14.2	12.4	12.9	n.a.
Aruba	n.a.	20.1	13.9	26.0
Bahamas NP	60.0	17.6	7.6	9.7
Barbados	2–4	1.4	2.1	2.9
Belize	20–30	n.a.	5.0	8.0
Bermuda	n.a.	0.0	0.0	0.0
Bonaire	7.9	11.7	21.2	40.3
Br. Virgin Is.	22.0	3.7	4.9	5.3
Cayman Is.	n.a.	0.0	0.0	0.0
Dominica	60–65	23.0	23.5	26.0
Dominican Rep.	n.a.	n.a.	27.6	59.0
Grenada	3–4	3.4	15.4	29.0
Jamaica	35–50	43.3	n.a.	n.a.
Martinique	n.a.	n.a.	0–34	0–77
Montserrat	9–46	11.8	16.0	n.a.
St. Kitts	58.0	26.6	3.0	n.a.
St. Lucia	4–50	2.4	10.5	n.a.
St. Maarten	n.a.	21.8	n.a.	n.a.
St. Vincent	3.9	5.9	13.5	n.a.
Suriname	24.7	17.5	17.2	1.6
Tobago	n.a.	n.a.	1.5	n.a.
Trinidad	5.6	7.2	7.2	9.8
Turks and Caicos	n.a.	n.a.	10.8	n.a.

[a] Government reports to PAHO/WHO; and Knudsen (1983).
NP = New Providence Island only.
n.a. = Information not available.

zero infestations, one remained unchanged and only 4 reported a decrease.

During recent years, periodic visits to the English-speaking territories of the region have enabled technical advisers from PAHO/WHO to conduct "spot check" surveys in collaboration with national staff (Knudsen 1983, Nathan and Knudsen 1991). These surveys have invariably resulted in the observation of much higher infestation levels than officially reported figures. This discrepancy can be attributed in part to the routine, repetitive nature of surveys, which frequently leads to boredom and loss of motivation among field workers and the development of a less than meticulous approach toward the search for and control of larval foci.

PROGRAM STATUS—1990

Demographic data, staffing levels and budget expenditure on *Ae. aegypti* control are shown in Table 2 for 25 reporting countries or islands. Although the countries are no longer conducting time-limited eradication programs, the legacy of vertically organized program structures, established during the era of hemispheric eradication, can still be seen in contemporary control programs. With few exceptions they operate with a "top down" centralized management structure, functioning autonomously within the general environmental health program; the small numbers of staff working part-time in the programs are a reflection of this approach. The idea that vector control can be applied as part of the Primary Health Care strategy remains for the majority of countries more of a concept than a reality.

Expenditure on *Ae. aegypti* control often cannot be determined because costs are incorporated within the budget of the entire environmental health program. However, for 17 countries from which data are available, annual per capita expenditure, summarized in Table 2, ranged from US$0.14 to US$8.49, with emoluments representing 51–96% of the total.

Despite the economic austerity measures facing most Caribbean governments, comparison of the manpower:house ratio in 1990 with that reported by Tonn et al. (1979) for 12 countries in 1978 shows that the median ratio has only increased by 25%, from 1:690 to 1:860. Moreover, in many countries the increase can be attributed to expansion of the housing stock

Table 2. Demographic data, and *Aedes aegypti* program budgets and staffing, 1990.

Country or territory	Area (km^2)	Population (×1,000)	Approx. no. houses (×1,000)	Full-time and part-time staff	Budget US$ (×1,000)	Per capita expenditure US$
Anguilla	88	7.0	4.5	4 (1)	37.5	5.36
Antigua/Barbuda	442	75.0	23.5	40	n.a.	n.a.
Aruba	190	67.5	20.5	32	432.4	6.41
Bahamas NP	381	171.5	80.0	18	178.4	1.04
Barbados	430	250.0	96.0	79	886.1	3.54
Belize	22,963	183.2	28.4	31	79.2	0.43
Bermuda	75	56.0	n.a.	(24)	n.a.	n.a.
Bonaire	112	11.0	4.4	8 (4)	62.2	5.65
Br. Virgin Is.	151	12.2	5.8	6 (1)	80.8	6.62
Cayman Is.	263	26.4	8.3	4 (3)	n.a.	n.a.
Dominica	771	80.0	19.0	5	44.8	0.56
Dominican Rep.	48,698	7,169.8	1,125.8	29 (1)	n.a.	n.a.
Grenada	344	90.0	32.0	45	160.7	1.79
Jamaica	10,991	2,392.0	508.7	76 (1)	n.a.	n.a.
Martinique	1,018	350.0	110.0	50	1,940.0	5.54
Montserrat	102	12.0	5.0	10 (1)	3.7	0.31
Puerto Rico	8,960	3.500.0	700.0	160	2,500.0	0.71
St. Kitts	176	34.5	6.0	3 (8)	4.8	0.14
St. Lucia	619	140.0	28.0	32	187.6	1.34
St. Maarten	41	25.0	8.0	4 (1)	82.7	3.31
St. Vincent	388	120.0	28.1	33	101.3	0.84
Suriname	163,820	400.0	50.0	34	n.a.	n.a.
Trinidad	4,769	1,234.4	329.8	787	4,084.5	3.31
Tobago	300	49.0	15.0	62	416.0	8.49
Turks and Caicos	430	12.4	2.0	7 (19)	n.a.	n.a.

( ) = Part-time staff.
n.a. = Information not available.
NP = New Providence Island only.

rather than a reduction of the work force. Some programs have nevertheless experienced difficulties in maintaining adequate transportation, field supplies and an uninterrupted supply of insecticides.

STRATEGIES FOR CONTROL OF THE VECTOR

Of the 25 respondent countries and territories, all but 3 relied mainly on the periodic application of residual insecticides as focal treatments to larval habitats (Table 3). Ten of them used this technique in combination with perifocal spraying of the surfaces of discarded containers. One program routinely applied insecticides only as space sprays against the adults. Forty percent used kerosene or diesel oil to supplement the use of larvicides and to reduce insecticide costs. Larvivorous fish were used in 52% of programs, mostly for stocking large domestic water storage vessels such as rainwater cisterns. Source reduction measures were reportedly undertaken by 84% of programs. An integrated approach to control, combining residual chemical, biological and source reduction strategies, was reported by 44% of programs.

Insecticides: The residual insecticide temephos, formulated as 1% sand core granules, is the mainstay of most programs and is routinely applied to larval habitats including those used for storage of potable water. Although there is some evidence of decreased susceptibility of Caribbean *Ae. aegypti* populations to this insecticide (Georghiou et al. 1987, Mekuria et al. 1991), its operational failure has yet to be demonstrated. The advent of slow-release formulations of *B.t.i.* and methoprene, and the recent approval of permethrin for use in drinking water at a concentration of 15 μg/liter (WHO 1991), provide alternatives but have not been extensively used presumably because of the continued efficacy of temephos and its lower application costs.

Regardless of the choice of larvicide, repeated treatment of indoor and outdoor larval habitats with sufficient frequency and geographic coverage to sustain effective control is beyond the operational capacity of many programs. Only 8 of them (32%) achieved 100% geographic coverage in 1990, each with no more than 4 completed cycles during the year. Many programs have reduced their coverage and even then are unable to attain an adequate time interval be-

Table 3. Routine antilarval measures undertaken by *Aedes aegypti* control programs, 1990.

Country or territory	Population coverage %	Cycles per year	Routine interventions					
			Focal	Perifocal	Fish	Kerosene/diesel	Source reduction	No. of interventions
Anguilla	100	1	Yes	No	Yes	No	Yes	3
Antigua/Barbuda	100	4	No	No	Yes	Yes	Yes	3
Aruba	100	2	Yes	Yes	Yes	Yes	No	4
Bahamas NP	16	0	Yes	Yes	No	No	Yes	3
Barbados	100	2–3	Yes	Yes	Yes	Yes	Yes	5
Belize	n.a.	3	Yes	No	No	Yes	Yes	3
Bermuda	n.a.	None	No	No	Yes	No	Yes	2
Bonaire	80	1	Yes	No	Yes	Yes	Yes	4
Br. Virgin Is.	100	4	Yes	No	Yes	No	Yes	3
Cayman Is.	25	2–4	Yes	No	No	No	No	1
Dominica	90	1	Yes	Yes	Yes	Yes	Yes	5
Dominican Rep.	2	1	Yes	Yes	No	No	No	2
Grenada	100	1	Yes	Yes	Yes	No	Yes	4
Jamaica	n.a.	None	Yes	No	Yes	No	Yes	3
Martinique	100	4	Yes	No	No	No	Yes	2
Montserrat	60	<1	Yes	No	No	Yes	Yes	3
Puerto Rico	n.a.	None	No	No	No	Yes	Yes	2
St. Kitts	<1	None	Yes	No	No	Yes	Yes	3
St. Lucia	33	n.a.	Yes	Yes	No	No	Yes	3
St. Maarten	6	4	Yes	No	Yes	No	Yes	3
St. Vincent	100	3	Yes	Yes	Yes	No	Yes	4
Suriname	5	3	Yes	Yes	No	No	No	2
Trinidad	84	4	Yes	Yes	No	No	Yes	3
Tobago	75	1	Yes	Yes	No	No	Yes	3
Turks and Caicos	75	2	Yes	No	Yes	Yes	Yes	4

n.a. = Information not available.
NP = New Providence Island only.

tween applications; nine countries failed to complete more than one cycle of treatment over a 12 month period. Given that the anticipated 6–8 week duration of effective chemical control is often reduced because containers, especially those used for storing water, are emptied, cleaned or flushed out (sometimes deliberately, following treatment) with resultant loss of insecticide, the rationale for continued over-reliance on this strategy must be questioned.

Increasingly in Caribbean societies, economic circumstances are determining the need for more than one breadwinner per household. Consequently closed houses have become a major hindrance to door-to-door strategies of insecticide application. In Trinidad, for example, Chadee (1988) found almost one third of houses closed in an urban development during weekly visits over a 12-month period. He attributed control failure to the survival of *Ae. aegypti* in larval habitats in those houses which were inaccessible during each cycle of inspection and insecticidal treatment. Moreover, few ministries of health afford sufficient priority to vector control to offer financial or other benefits, or the flexibility of conditions of service to accommodate the sustained working of unorthodox hours by their staff in order to overcome these difficulties. Inadequate supervision, training, motivation and rapid staff turnover further reduce the impact of these measures.

Residual insecticides were routinely applied as perifocal sprays by the former eradication programs, but the technique has now been discontinued by most control programs in order to reduce costs. In 1990, where the practice continued, fenthion, fenitrothion or malathion were applied as wettable powder formulations.

Space sprays: More than half the programs maintain vehicle-mounted ULV sprayers. Many also use portable thermal foggers. With the exception of only 4 countries, where synthetic pyrethroids were applied, malathion was used for space spray applications (for thermal fogging a 5% formulation in diesel is normally used). The equipment is used in response to a variety of circumstances, e.g., in areas with high *Ae. aegypti* infestation levels; at times when there is an increased risk of dengue introduction from neighboring countries; in localities where there are reported cases of dengue; or following complaints by the general public about biting nuisance from other mosquito species, typically *Culex quinquefasciatus* Say and *Aedes taeniorhynchus* (Wied.). Because space spraying increases selection pressure for insecticide resistance and

does not provide effective and sustainable control, PAHO policy discourages its *routine* use; however, several programs also continue to apply adulticides as space sprays on a routine basis, often for political rather than for technical reasons.

Biological control: Larvivorous fish were used in 13 countries. *Poecilia reticulata*, indigenous to most of the islands, and *Gambusia affinis*, an introduced species, were the 2 most frequently used. Their most widespread application is in household concrete cisterns and drums on islands where there is a lack of community water supply and there is heavy dependence on collection and storage of roof catchment rainwater. Derived benefits include the total prevention of adult mosquito emergence, often for months or years, thus obviating the need for regular treatment with large amounts of temephos. Intensive pisciculture is not undertaken; in most cases adequate supplies are obtained by collection from natural breeding sites on the islands. Stocks are then maintained, usually in concrete holding tanks, until they are distributed to target sites by the field staff or are supplied on request to the general public.

In several countries larvivorous fish are also being used in ground water habitats such as roadside ditches and brackish water ponds for control of *Anopheles albimanus* Wied. and *Anopheles aquasalis* Curry, but there has been no attempt to evaluate their impact.

Source reduction: For most countries source reduction measures include the overturning, emptying or destruction of discarded containers during house to house visits by field workers. Clean-up campaigns are also carried out in several of them, usually by community service groups in collaboration with public and private sector sanitation or trucking services. In the organization of such campaigns, adequate consideration is often not given to the larval ecology of the vector in a given community. Without focusing on discarded items that constitute important larval habitats, these labor-intensive efforts sometimes have only marginal impact on vector densities although the removal of bulky items such as old household appliances, car wrecks, old mattresses and beds, etc., may be more beneficial from a general sanitation standpoint and may indeed be perceived as being of greater benefit by the community itself. When small discarded containers, e.g., tin cans, jars and small plastic food containers, are removed in the exercise, any resultant reduction in larval indices is likely to be only temporary unless efforts are made to prevent the rapid reaccumulation of freshly discarded household debris (Windeguth et al. 1969, Nathan and Knudsen 1991). The sociological significance of the container site must also be considered when selecting an appropriate source reduction or container management strategy. Nathan and Knudsen (1991) noted that the 3 commonest larval habitats in the Caribbean are water storage drums, house plants and buckets, all of which may be regarded as "useful" or "essential" by the householder and therefore inappropriate for destruction or removal.

Education: A range of health education and community-oriented activities are undertaken by the countries. In descending frequency of utilization, the following components were reported in 1990: a) use of printed materials such as pamphlets and posters; b) talks, lectures to schoolchildren and public gatherings; c) radio messages, health programs, interviews etc.; d) use of the print media; e) TV; and f) community-based source reduction initiatives as outlined above. While these educational activities are designed to increase public awareness of the health risks associated with peridomestic mosquito breeding, and to elicit changes of behavior at the household level, socio-behavioral studies relating to peridomestic mosquitoes and their control are generally lacking in the West Indies and evaluation of these interventions has not been systematically undertaken.

Most programs also report that health education activities are carried out at the household level during routine visits by field staff either during the process of seeking permission to carry out control measures and larval inspections or in reporting their findings to the householder upon completion of the tasks. However, training of field workers in communication and interpersonal skills is seldom given and didactic materials are generally lacking. In practice, the primary objective of most field workers is for them to seek the consent of the householder to carry out the assigned tasks rather than to encourage the latter to undertake appropriate actions themselves.

DISCUSSION

Unless more effective vector control measures are implemented, the epidemiological trend of increasingly frequent epidemics of dengue and DHF, and in the larger population centers, of endemic dengue transmission, will impose a serious burden not only on the health status of Caribbean populations, but also on their economies. Although few studies on the economic impact of dengue have been made, the 1981 DHF epidemic in Cuba was estimated to have cost US$103 million (Kouri et al. 1989); of this total US$43 million was for the direct initial costs of

the *Ae. aegypti* control program, US$41 million was for medical care and the remainder was for lost production and salaries paid to adult patients. The 1977 epidemic in Puerto Rico is estimated to have cost between US$6 and $16 million in medical services and lost work due to absenteeism (Von Allmen et al. 1979). McIntyre (1988) pointed out that the Caribbean as a whole constitutes the largest regional supplier of tourism among the developing countries. Given the highly competitive nature of this service industry, epidemics of dengue are likely to divert tourists to other market destinations thereby contributing to significant losses of revenue.

Substantial amounts of money have been and continue to be allocated to Caribbean vector control programs, largely in the employment of semi-skilled field workers. The preoccupation of these workers is the systematic, cyclical application of larvicides to an abundance of water-filled receptacles in and around the household environment. As a sustainable, long-term and major strategy of vector suppression, it has been largely a failure. The weaknesses of program delivery, in terms of management, continuity and coverage are reflected in the inability of governments to sustain low vector densities since the unofficial abandonment of the eradication objective in the 1970s. In this period of global economic recession, with frequent implementation of structural adjustment programs, it is unreasonable to expect the allocation of substantially greater budgetary resources for vector control except as supplemental emergency support during dengue epidemics. It seems unlikely that the operational shortcomings of insecticidal programs can be rectified. Moreover, in the industrialized nations there has been an increasing public awareness and groundswell of opposition to the widespread use of pesticides. These concerns about environmental impact invariably influence the decision-making processes in disease-endemic developing countries as well; since the distinction between agricultural and public health applications are unlikely to be made, these influences seem destined to further erode public support for insecticide-based vector control strategies.

The strengthening of environmental management strategies incorporating source reduction, container management and biological control methods, combined with long-term goals of improving community water supplies, solid waste services and sanitation, appear more likely to achieve sustainable gains than the continuation of insecticide-dominant approaches to vector control. Fundamental to the success of these strategies is the need to increase public awareness of the benefits to be derived from maintaining a healthy environment, and to identify ways and means for motivating behavioral change in individuals and communities that will lead to improvements in sanitation. These goals are more likely to be attained through broad-based, intersectoral primary health care programs than through the continuation of specialized, single disease or vector-specific community-passive programs such as those presently employed against *Ae. aegypti*.

In an effort to address some of these issues a three-year project, funded by the Government of Italy and managed by PAHO/WHO, has recently begun in 15 countries and territories of the Caribbean. The project seeks to promote the further development of integrated vector control strategies and the mobilization of communities to share the responsibility for improving the standards of environmental sanitation in the region.

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