SYMPOSIUM VI

Economic Impact of Insects in the Tropics

CONTENTS

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VECTOR-BORNE DISEASES OF MAN AND THEIR SOCIO-ECONOMIC IMPACT

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Abstract—Vector-borne diseases such as malaria, lymphatic filariases, schistosomiasis, leishmaniasis, onchocerciasis, trypanosomiasis, dengue and dengue haemorrhagic fever (DHF), yellow fever and Japanese encephalitis, globally account for suffering amongst more than one billion people, mostly from the developing world. Geographical distribution and prevalence of these diseases have been discussed. In addition to the mortality caused by these diseases, millions of people lead a hopeless life and are socially unable to achieve self-realization and be economically productive, as a result of these diseases. Examples of such economic impact and the costs of these diseases and methods of control have been given. Economic benefits of control of some of these diseases have been discussed. These concepts are of utility when resource allocation for control of these diseases is under consideration.

Key Words: Vectors, vector-borne diseases, geographical distribution, socio-economic impact

Résumé—Les maladies transmises par des vecteurs telles que le paludisme, la filariose lymphatique, la schistosomiase, la leishmaniose, l'onchocercose, la trypanosomiase, la dengue et la dengue hémorragique, la fièvre jaune et l'encéphalite japonaise affectent au total plus d'un milliard de personnes dans le monde, principalement dans les pays en développement. La question de la répartition géographique et de la prévalence de ces maladies a été examinée. Outre qu'elles sont des causes importantes de mortalité, elles sont directement responsables du fait que des millions de personnes mènent une vie sans espoir et sont socialement incapables de s'assumer et d'être économiquement productives. Des exemples de l'impact économique et du coût de ses maladies et des méthodes de lutte pertinentes ont été fournis. Les avantages économiques découlant de la maîtrise de certaines de ces maladies ont aussi été passés en revue. Ces concepts sont utiles lorsqu'on examine l'allocation des ressources pour la lutte contre ces maladies.

MAGNITUDE OF THE PROBLEM

Vector-borne* diseases globally account for suffering amongst more than one billion people, the majority of whom belong to the developing countries. These same countries also are the scene of other socio-economic and developmental phenomena, some of which adversely affect health. Natural disasters, such as drought, and man-made political crises, such as the threat of war, problem of refugees, compounded with growth of population, growing urbanization and other trends have created significant socio-economic disparities in vast areas of the developing world. Absolute poverty, traps almost 1000 m people. This is reflected in the life expectancy at birth (significantly lower in the developing countries, as compared to the developed countries) and infant mortality rates (50–100 or more per 1000 live births in many developing countries, and below 50 in most of the developed countries). Infectious and parasitic diseases (which include the vector-borne diseases) cause 40% of the total deaths in the developing countries, compared to 8% in the developed countries. Major vector-borne diseases are malaria, lymphatic filariases, schistosomiasis, leishmaniasis, onchocerciasis, trypanosomiasis (both African and American), dengue and dengue haemorrhagic fever (DHF), yellow fever and Japanese encephalitis. In addition, plague continues to persist in scattered foci in many countries, as well as louse-borne relapsing fever, tick-borne rickettsiosis, typhus and viral haemorrhagic fevers constituting important health problems locally. Leptotrombidium and other mites called "chiggers" are also important in some areas of the world.

Table 1 shows the recent status of different vector-borne diseases globally and Figs 1–9 present their distribution. In addition to the data presented on seven vector/reservoir-borne diseases, dengue/DHF is reported to have caused hospitalization of about 750,000 people and 20,000 deaths during the past 25 years in only a few countries of South Asia; and Japanese encephalitis has caused high case fatality rates during outbreaks.

Dracunculiasis disease transmitted by ingestion of infected cyclops is widely distributed in the Western part of India and in about 17 countries of Africa.

In addition to the diseases that they transmit, many arthropods contribute to human misery through sheer numbers, annoyance, allergies and discomfort which they cause. Flies, bed-bugs, cerapatogonidae

*The term vector has been used in a broad sense and includes primary and intermediate vertebrate and invertebrate hosts and animal reservoirs of human diseases.

Table 1. Estimated global status of vector-borne diseases (Global population estimated at 4.75 billion)

Disease	Population at risk (millions)	No. of clinical cases (thousands)	Areas specifically affected	Remarks
Malaria	2,209	97,978	Fig. 1	Major public health problem globally. Important cause of child mortality in Africa
Lymphatic filariases	905	90,200	Fig. 2	Acute cases cause much suffering, although not a killing disease
Schistosomiasis	600	200,000	Fig. 3	Chronic debilitating disease closely related to water development projects
Onchocerciasis	85	17,000 (No. of blind people estimated at 336,000)	Fig. 4	Disease results in blindness and causes severe socio-economic problems
African trypanosomiasis	50	(20,000 new cases/year)	Fig. 5	Endemic in 36 countries of Africa, south of Sahara
Chagas' disease	65	10,000 to 20,000	Fig. 6	Disease exclusive to Americas. Disease associated with poverty
Leishmaniases	No estimates available		Figs 7 and 8	
Dracunculiasis	63	50	Fig. 9	Disease exclusive to W India, Pakistan and Central and Western parts of Africa

and cockroaches are some of the examples, and large amounts of money are spent on controlling these pests. Urban pest problems are another aspect of the importance of vectors and vector control. In a survey carried out by WHO, it was estimated that in 1980 roughly $800 m were spent on urban vector control. In north-eastern United States of America alone, roughly $400 million are spent on cockroach control.

With the rapidly developing air and sea transportation services, and the epidemiological problems related to the transportation of vectors, disinfection of aircraft and vessels is assuming more importance.

Status of vector control

The above is rather a grim situation and now we will briefly review what is actually being done globally as far as control of vectors of the above diseases are concerned. Control of malaria vectors is still primarily carried out using chemical insecticides as residual sprays. DDT is still used to a large extent in rural areas where the vector(s) is susceptible because of comparatively low cost and safety record to man when used indoors. With the onset of resistance, organophosphate (OP) compounds, such as malathion, fenitrothion, pirimiphosmethyl and carbamates, such as propoxur and bendiocarb, are used. Other insecticides, which have given satisfactory results are chlorphoxim and pyrethroids such as permethrin and deltamethrin. However, some of these compounds have still been used only experimentally. Larvicides, such as temephos, and larvicidal oils for the control of exophilic/endophilic mosquitoes where the larval habitats are restricted and readily accessible, such as urban or periurban areas, sometimes in conjunction with ULV applications, as supplementary measures, have also been employed. Bacterial pathogens have been tried but not used on an extensive scale, e.g., *B.t.* H-14, one exception being the Onchocerciasis Control Programme in West Africa where *B.t.* H-14 is used operationally. Much attention is now being given to the use of fish. For example, larvivorous fish, *Gambusia affinis* and *Poecilia reticulata* are being used on a relatively large scale for the control of *Anopheles stephensi* in urban areas of India. Environmental measures, such as source reduction, sanitation and water management, are presently limited to very few areas as a malaria vector control measure.

An effective drug is available for filariasis control (Diethyl carbamazine) and this approach, within the context of primary health care, is currently being used in several countries, but appropriate vector control methodology, such as source reduction, source modification, drainage, canalization of marshes and swamps, use of larvivorous fish, afforestation together with the use of chemical larvicides, such as fenthion or chlorpyrifos in polluted waters, have been used in some programmes. Herbicides have been used for controlling host plants of *Mansonia* and use of temephos for reducing populations of *Aedes polynesiensis* is being made. For filariasis control, vector control through community participation has been demonstrated as a successful approach in limited urban areas.

The primary urban vector of dengue and DHF, and other diseases like yellow fever, *A. aegypti* breeds in man-made habitats; and theoretically it should be possible to eliminate or reduce vector populations. A vaccine is available against yellow fever and is used during emergencies.

A vaccine is not yet available against dengue/DHF, and vector control remains the mainstay for prevention and control. Source reduction and elimination, with the exception of Singapore, has not been universally successful. Use of temephos (1 mg/l) or, in some cases, methoprene as a larvicide to treat the water containers has often been done with success. During the outbreaks, application of ultra low volume (ULV) insecticides, such as malathion, fenitrothion, from ground or air or using thermal fogs (malathion or pirimiphos methyl in oil), have been used with success. This, however, is not a long-term solution of this problem.

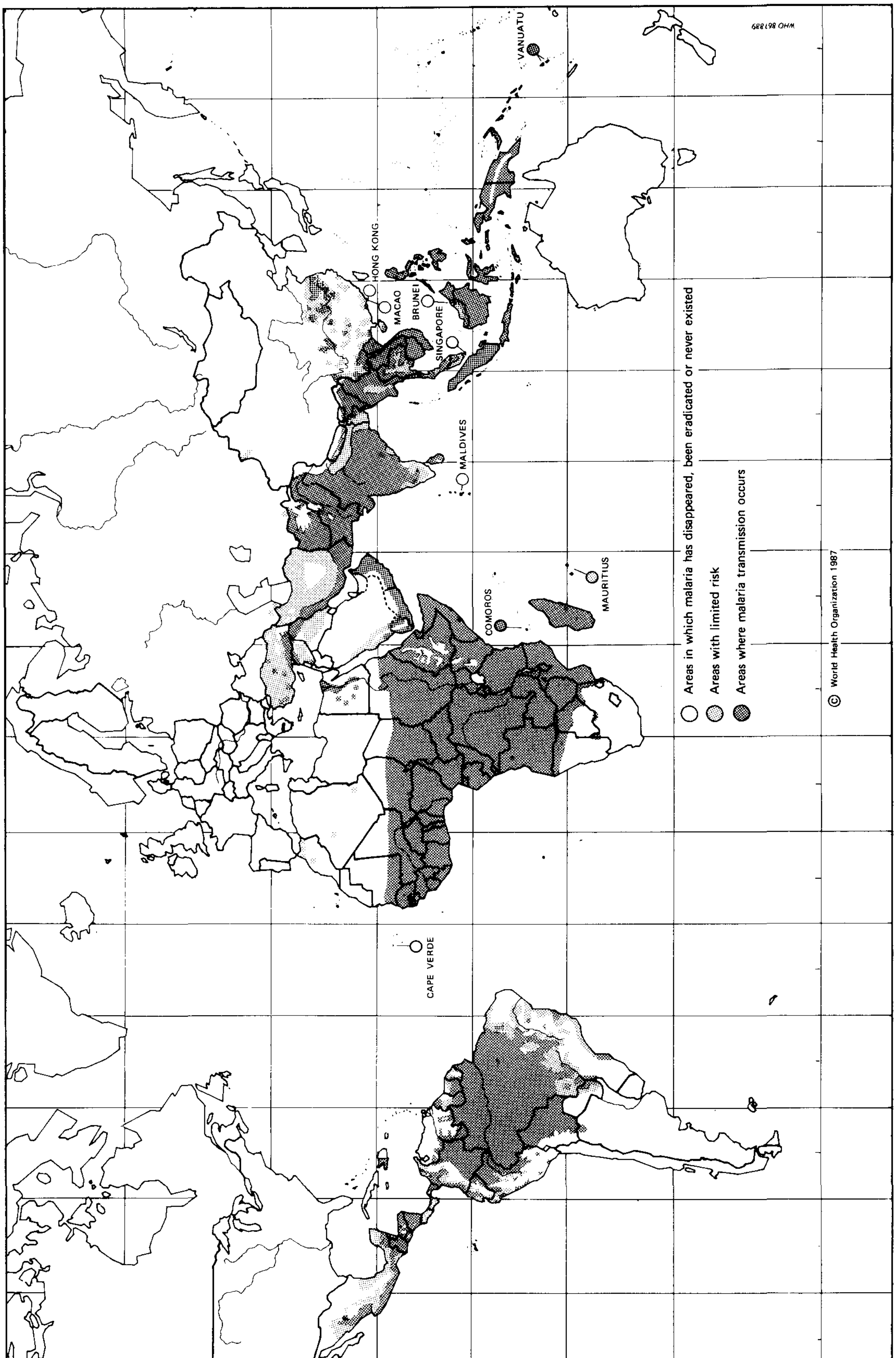

Fig. 1. Epidemiological assessment of status of malaria (1985).

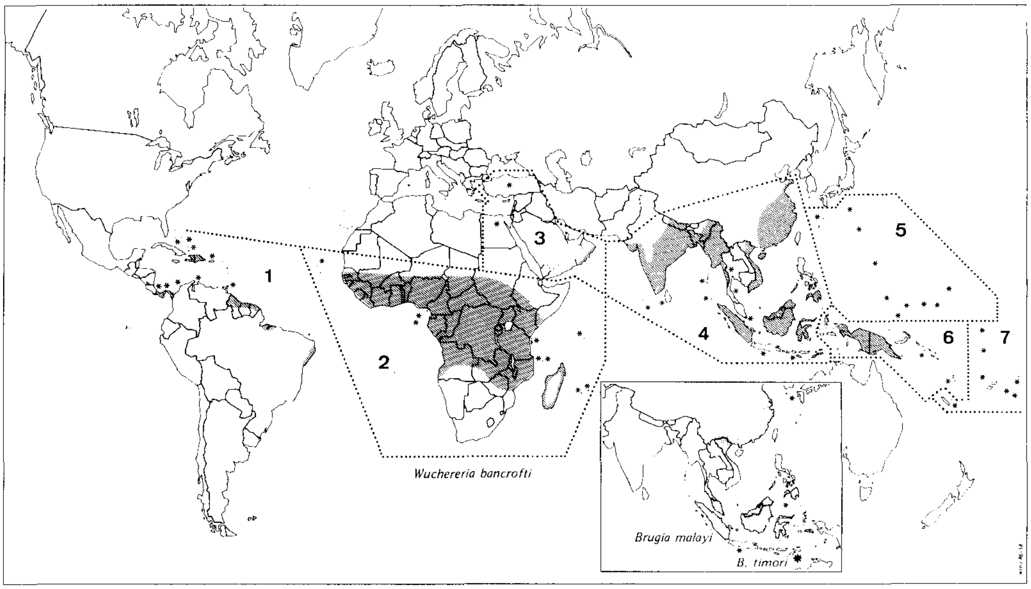

Fig. 2. Distribution of the lymphatic filariases and vector zones (WHO, 1984b).

Vectors of viruses causing encephalitis, such as Japanese encephalitis, breed in such extensive areas that larviciding is neither feasible nor cost-effective. For outbreaks, malathion, fenitrothion, propoxur, naled, chlorpyrifos, bioresmethrin, permethrin or deltamethrin have been employed as ULV applications, either from ground or air.

For onchocerciasis vector control, the treatment of choice is the larval control by aerial applications to the river systems using temephos or, where resistance in blackflies has developed, chlorphoxim or *B.t.* H-14 at weekly intervals. The largest vector control programme in Africa and probably in the world, the Onchocerciasis Control Programme in the Volta River Basin area of West Africa involves weekly spraying of almost 14,000 km of river.

Against tsetse, insecticidal sprays have employed endosulfan, DDT, dieldrin and deltamethrin. Recently, traps and screens impregnated with insecticides have been developed and found successful against certain species of riverine tsetse.

American trypanosomiasis or Chagas' disease vectors are largely controlled using residual insecticides such as HCH and dieldrin. Resistance to dieldrin has been recorded in a small area of Venezuela.

Dracunculiasis has been controlled by using temephos against cyclops species, improvement of the design of wells to avoid contact of infected people

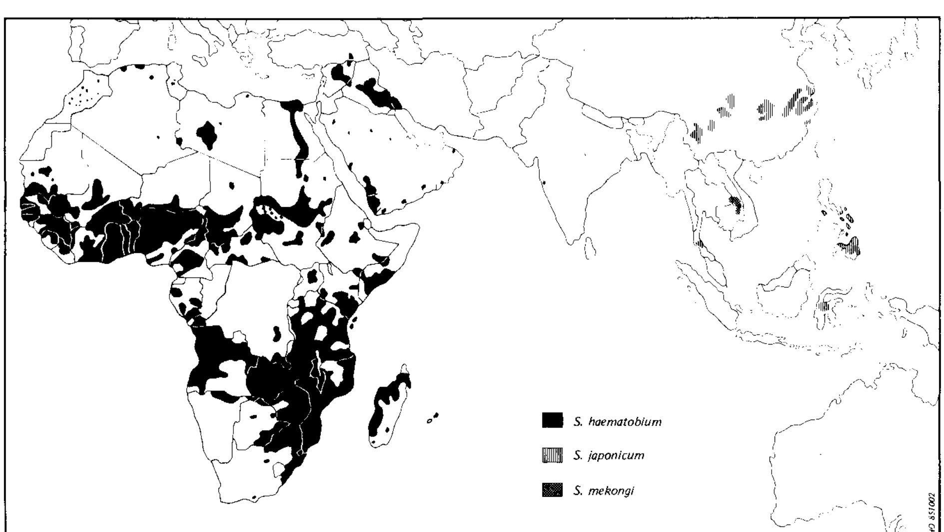

Fig. 3a. Global distribution of schistosomiasis due to Schistosoma *haemtobium*, *S. japonicum* and *S. mekongi*.

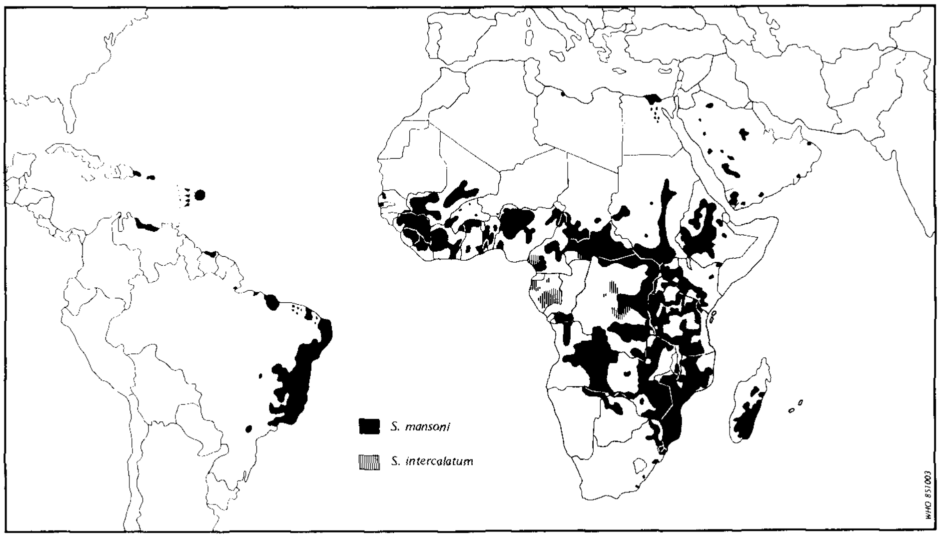

Fig. 3b. Global distribution of schistosomiasis due to Schistosoma mansoni and *S. intercalatum* (WHO, 1985).

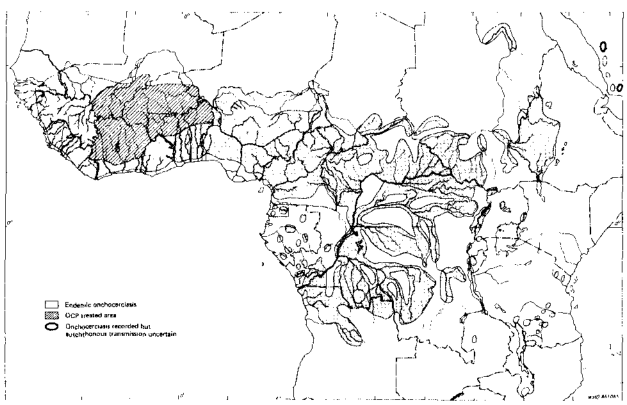

Fig. 4. Distribution of onchocerciasis in Africa (WHO, 1987c).

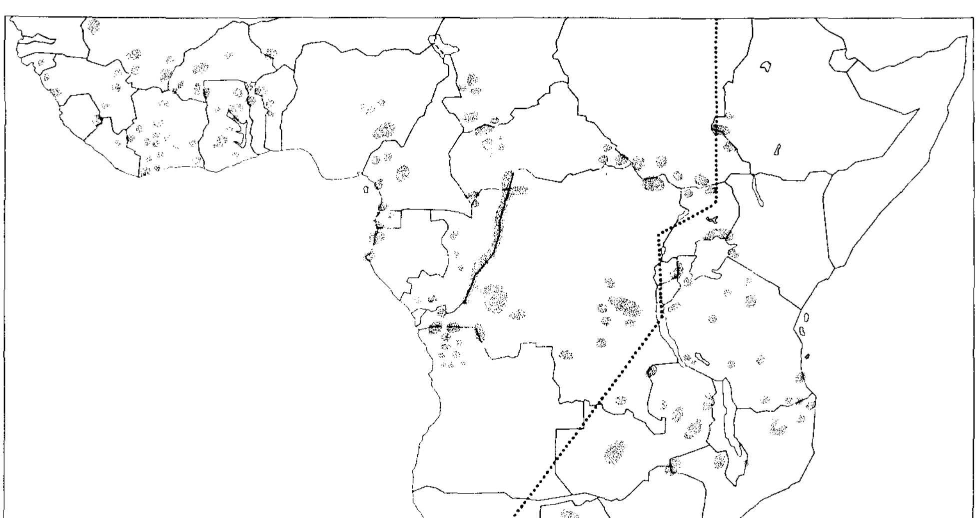

Fig. 5. Distribution of sleeping sickness foci in Africa, *T.b. gambiense* areas of distribution to the left of dotted line in West and Central Africa, *T.b. rhodesiense* to the right of line in Eastern and S. Africa (WHO, 1987b).

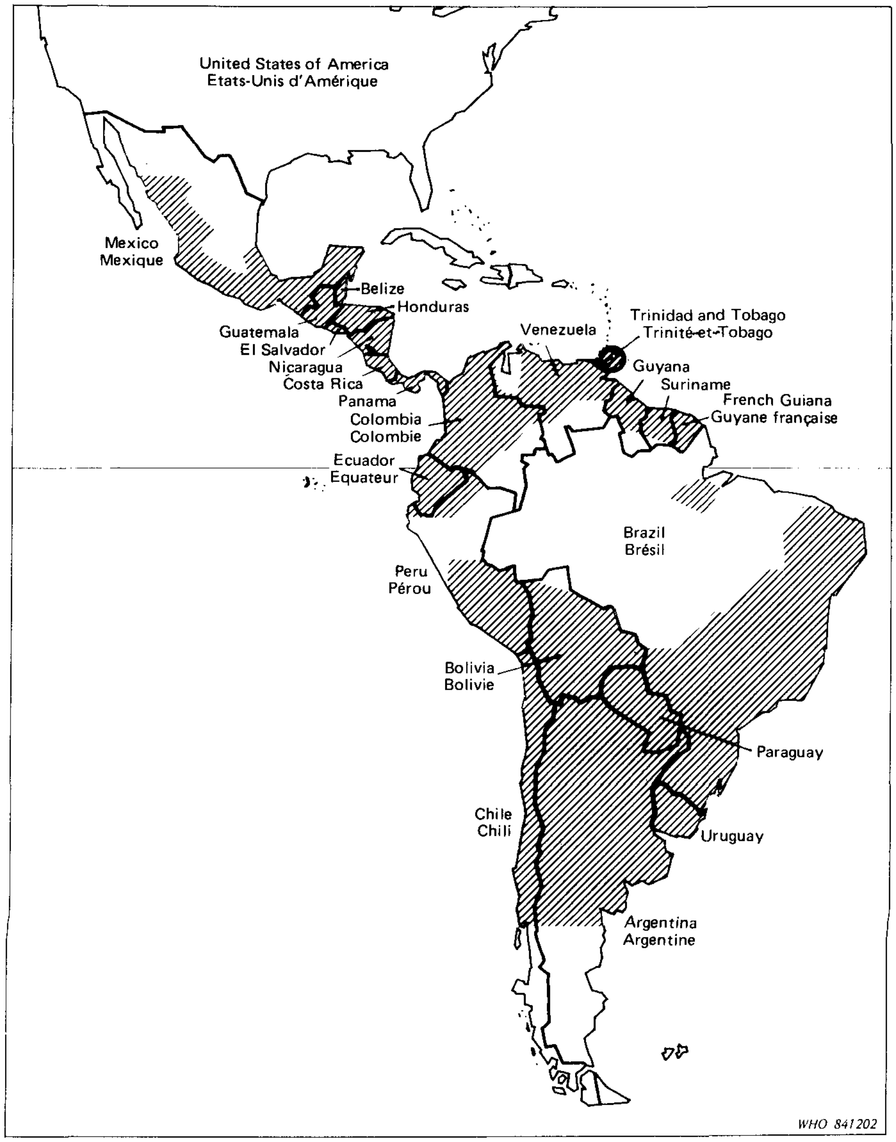

Fig. 6. Approximate distribution of Chagas' disease in the region of the Americas (WHO, 1985).

with water, and use of filters for drinking water. India has embarked on the eradication of this disease using the above strategy for control.

Other nuisance insects and vectors, such as synanthropic flies, fleas, bedbugs, lice and cockroaches are generally controlled using sanitary measures and insecticides for example, for houseflies and cockroaches environmental sanitation. Proper garbage disposal and use of screens, traps, and insecticides have been used and recommended. Similar measures are being applied to the control of bedbugs and lice. A series of acaricides and insecticides are available for the control of ticks and mites.

I have not commented much on the control of nuisance causing species in the developed countries but, since many of these are not involved in the transmission of disease organisms, these have not the same priority. Importance of these is, however, recognized.

Socio-economic impact of vector-borne diseases

It is difficult to measure the socio-economic impact of vector-borne diseases, because the actual cost of illness, value of life, quality of life, and losses to the family of the person when death occurs are impossible to measure in a quantifiable term. "There are those who die and that is sad enough, but there are those who lead a hopeless life, the forgotten ones, these women and men who are socially unable to achieve self-realization and to be economically productive" (Halfdan Mahler, Unpublished). Health conditions affect the pace of development and the developmental processes by an improved standard of life ameliorate health. How then do we go about measuring socio-economic impact of vector-borne diseases? Economists have thus devised different approaches and among these the following deserve mention:

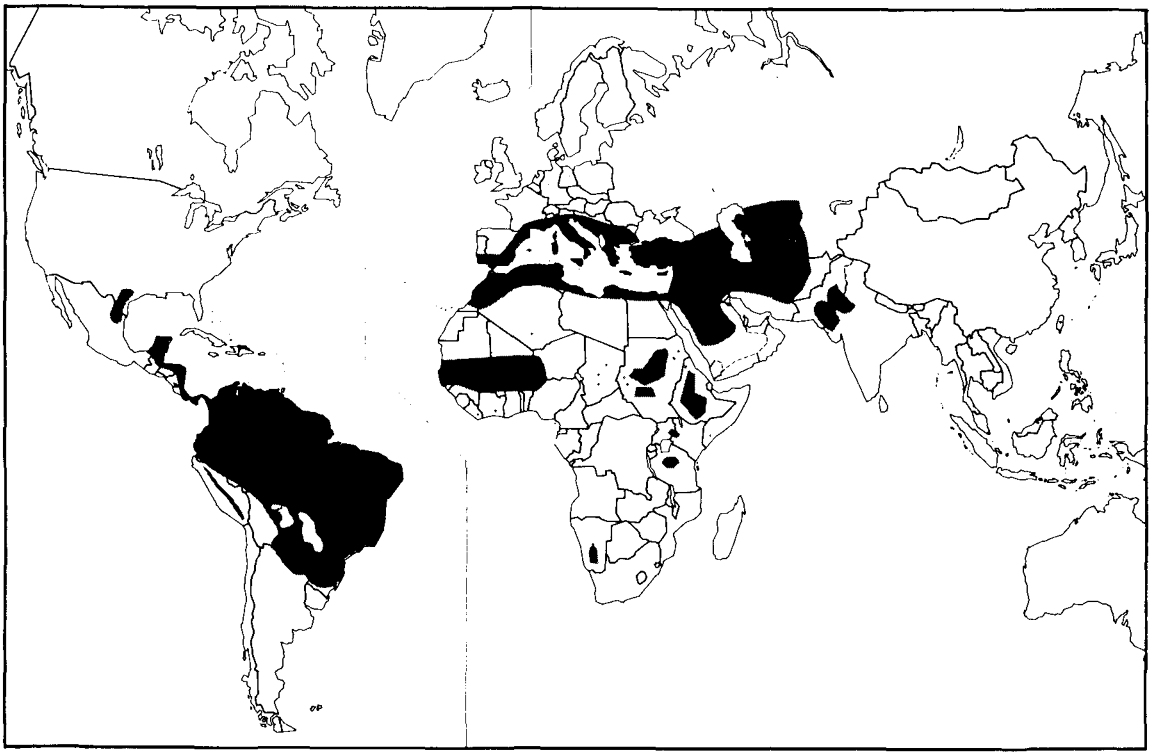

Fig. 7. The distribution of cutaneous and mucocutaneous leishmaniasis in the world (shaded areas = endemic areas; dots = sporadic cases) (WHO, 1984).

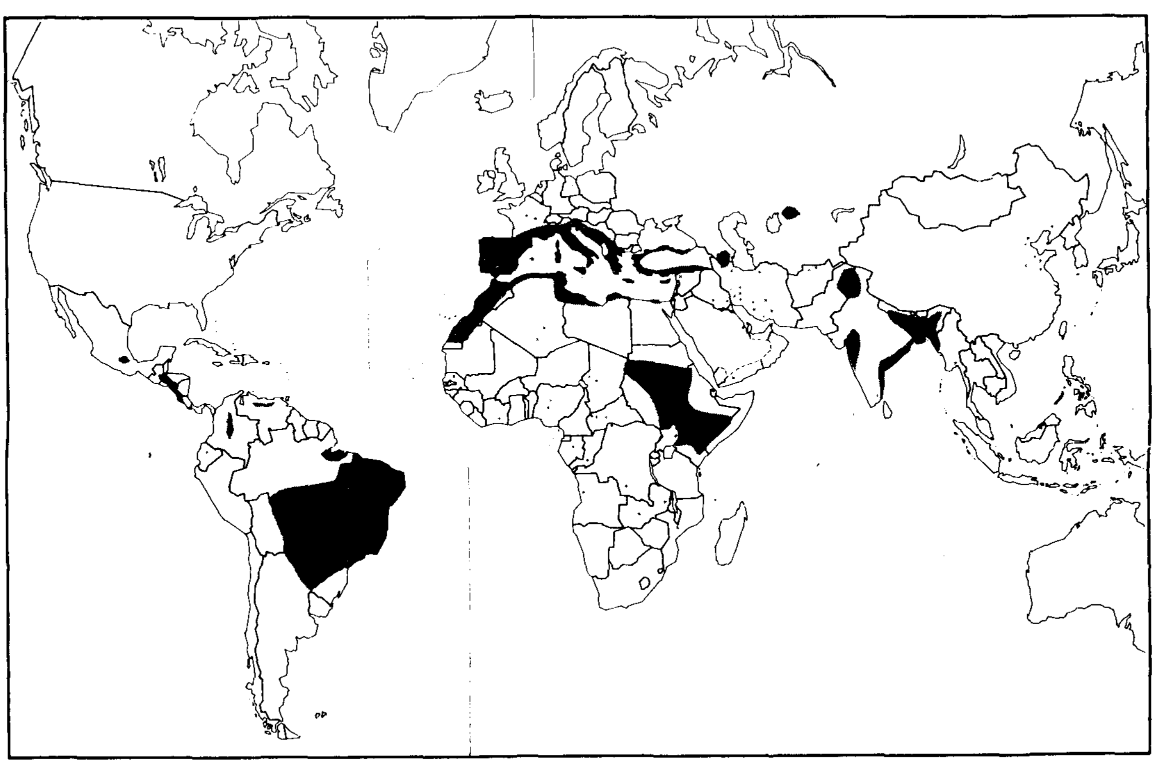

Fig. 8. The distribution of visceral leishmaniasis in the world (shaded areas = endemic areas; dots = sporadic cases) (WHO, 1984).

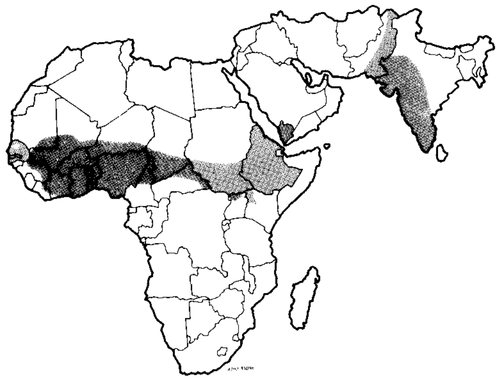

Fig. 9. Areas in which dracunculiasis is reported or probably exists (WHO, 1982).

(a) Cost effectiveness in terms of cost per person protected, per case-year prevented, per death averted and per healthy year gained. Of these, cost per case year prevented and cost per healthy year gained are the most useful concepts (Barlow and Grobar, 1986).

(b) Cost of the control programmes per unit of population.

(c) Cost of alternative method, such as change of the insecticide used.

(d) Morbidity and debility, work days lost and effect on developmental activities, and

(e) Benefits of control.

Some aspects of socio-economic impact of malaria and its control

Sinton (1935) wrote on what malaria costs India and calculated the financial losses to the community in terms of lost wages alone as Indian rupees 123 m (100 m people suffered from malaria annually, of this one-third were of the adult productive group, and lost 15 days per year due to malaria). This sum would be equivalent to $40 m then and a lot more now. This type of analysis has several shortcomings and the present day economists do not accept these findings as very sound, because there are several flaws in this analysis. Many of those who are sick are not employed in any case, but the cost of medical attendance, loss to industry and other fields and amelioration of the situation after control can be noteworthy. A good example of this is the gain in the agricultural activity and production in the Terai area in the north of India as well as Kunduz area in Afghanistan. This area was dreaded by settlers prior to the introduction of the control programme in the early fifties. Once malaria was brought under control, there has been a phenomenal agricultural growth in the area and what was once malarious marshes has been transformed to a prosperous green belt. No doubt agricultural technology development and other infrastructures played a big role here, but it would not have been possible if the area was still malarious. As Pampana (1963) pointed out, the value of land that cannot be cultivated or developed due to malaria can only be appreciated when it has been eradicated or controlled.

Some argue that improved "health" will no doubt increase production (both agricultural as well as industrial), but because of the population growth there will be more mouths to feed and, hence the gains achieved by disease control will not be productive economically. Again this argument is fallacious because social gains achieved by disease control have to be looked at in a much broader sense and developments generate employment and productivity.

There has also been a debate whether control of malaria with the reduction of deaths during infancy and increasing of the expectation of life does not bring about population explosion. It should be pointed out that there are many other contributing factors, such as improved health care, modern medicines, etc. It has also been shown that the acceptance of family welfare programmes is high when infant mortality is no longer a looming danger. After all, the rate of growth of population is least in highly developed societies where the infant mortality rates are lowest and the expectation of life longest. Power, irrigation, railway constructions, etc. can also suffer when the mosquitogenic conditions of the sites worsen and non-immune labour force is introduced into the area. Harrison (1978) has recounted how the control of malaria and yellow fever contributed to the successful construction of the Panama Canal.

Prescott (Unpublished data) and Rosenfield *et al.* (1980) analysed the economic consequences of diseases and concluded that economic consequences, including damages which can be quantified and losses which cannot be easily valued can probably be better measured in terms of benefits its control will generate. Social impacts of vector-borne diseases have yet to be carefully studied. The stresses resulting from chronic non-infectious diseases have been analysed in terms of resulting psychological disorders and behavioural changes. This may also result in the reduced ability to participate fully in family or community life. Such effects are again difficult to measure quantitatively.

Le Berre *et al.* (1977) considered that onchocerciasis has the gravest socio-economic repercussions in the Savannah countries of Africa where the main issue is desertion of the villages. Economy of these countries is essentially based on agriculture and the utilization of these areas which are fertile, depends on the situation *vis-a-vis* onchocerciasis. Large-scale emigration from the infected areas makes agricultural development difficult. Blindness, the major complication of onchocerciasis, makes this disease a major public health problem in W Africa for it strikes mainly at economically active adults in the prime of their life. This may directly cause substantial excess mortality and indirectly stagnation or decline in the human population. Eventually it leads to abandonment of the villages. Blindness rates in some villages may rise to 15% of the local population and 40% of the adult male workforce. Life expectancy of the blind is shortened. Although blind persons may not be idle and may be occupied in basket-making, drawing water from wells, etc., they do become a burden to the society. Onchocerciasis-infected villages are poor and this leads the younger population to emigrate and thus the population becomes imbal-

Table 2. Costs and benefits of controlling vector-borne diseases (costs of vector control)

Nature of cost	Malaria	Filariases	Onchocerciasis	African trypanosomiasis	Schistosomiasis
Annual cost per person protected in 1984 ($)	1.57–4.85 (Indonesia) 6.64 (Liberia) Drugs and insecticides	0.59 (India) Vector control 1.31 (Kenya) Chemotherapy	12 (OCP area) Vector control —	2.40 (Ivory Coast) —	0.44 (Sudan) Drugs and vector control 2.23 (Tanzania) Vector control only 16.91 (Brazil) Vector control
Cost per case year prevented in 1984($)	1.88 (India) Vector control 75.00 (Indonesia) Vector control 233.15 (Nigeria) Vector control and	5.71 (Kenya) Chemotherapy 11.79–51.96 (India)	20.00 (OCP area) —	— —	2.52 (Iran) Drugs and vector control 13.99–63.02 (St Lucia)
Cost per death averted ($)	Drugs 69.95 (Sri Lanka)	—	—	—	—
Cost per healthy year gained	—	—	($)239.61	—	—

Table 3. Cost implications of insecticide resistance in malaria-vector control*

Country	Base year	Latest year	Change in insecticide	Percentage increase of costs (compared with 1959 costs)	
Nicaragua	1959 DDT	1964	Malathion, $0.40/house	82%	*A. albimanus*
		1973	Propoxur and malathion, $0.90/house	264%	
		1983	DDT, chlorphoxim and deltamethrin, $1.90/house	764%	
Sri Lanka	1970–1975 DDT	1978–1983	Malathion	800%	*A. culicifacies*
India	1985 hypothetical DDT only	1985	BHC, malathion, DDT	64%	*A. culicifacies*

*Adapted from Smith A. (1985, pers. commun.).

anced and the villages are occupied by old and blind people.

Economic benefits of control of onchocerciasis

The beneficial changes are already noticeable in the Onchocerciasis Control Project (OCP) in W Africa, where available manpower has already increased and improvements in productivity are apparent. New land freed from disease is already being exploited. Thus onchocerciasis control is considered to be a cost-effective programme.

Cost of control

Noguer (1977) analysed the cost of vector-borne disease control programmes with particular reference to malaria. Due to fluctuations in the cost of insecticides from year to year and variations in the cost of labour from country to country and frequent changes in the insecticide used, whose costs vary within very wide margins, it is not possible to give precise figures which may be correct within space and time. He estimated that in a zone of 1 m population using DDT as the primary weapon, these costs would have amounted to US $1.7 m (much more now). The cost per capita of a programme of 8 years' duration would be approximately US $8.00. Another way of looking at it is the percentage of health budget which is allocated to disease control. Cost of programmes often represent a very important part of national income. In 1974–1975, the Government of India authorized 75% of the development budget for health for malaria control activities. In Pakistan the 5-year crash programme against malaria was more than twice the total budget for health in 1975. In the Sudan (Gezira Province), the estimated cost of an 8-year malaria control programme (1976–1984) has been estimated to be US $17 per capita. In Pakistan, a 5-year crash programme using mostly malathion (because of widespread DDT-resistance) is $10 per capita. The OCP programme in Volta River Basin area was estimated to cost US $120 m for the period 1974–1993. The investment of control programme is the equivalent of US $12 per capita. McCullough (Unpublished) estimated that the cost of control programmes (mollusciciding and chemotherapy) in Tanzania in 1973 was approximately US $4.11 per person at risk. Rosenfield *et al.* (1977) estimated that, in Iran, chemotherapy cost only $2.46 per case year prevented, as compared to $9.29 when mollusciciding was used. This has been a trend of findings elsewhere as well and the strategy of morbidity control for schistosomiasis by use of drugs is now considered more cost effective as compared to the schistosomiasis control by use of molluscicides (WHO, 1985b).

Costs and benefits of control

Barlow and Grobar (1986) have reviewed most comprehensively the available literature on the costs and benefits of controlling parasitic diseases. Table 2 gives some of the data presented. In view of the importance of resource allocation for disease/vector control, the economists feel that costs and benefits of a control programme is a more balanced presentation than costs alone.

Global pesticide requirements and costs for vector control programmes in developing countries

Prices of insecticides vary greatly, being influenced by many factors. Smith and Lossev (Unpublished) carried out an analysis based on a questionnaire sent to 103 developing countries. On the basis of this survey, the total cost of insecticides, solely for national vector control programmes, would have been no less than $100 m in 1984 and the figure would be about $255 m when other expenses are added. Most of our information in this respect comes from the control of malaria vectors.

Except where resistance to DDT occurs in the vectors, DDT accounts for a major part of the expenditure on insecticides. Due to an acceptable level of control achieved, DDT continues to be used and is the mainstay of many antimalaria programmes. When DDT has to be replaced by other insecticides, the cost increases profoundly. In global terms, the direct and indirect effects of DDT-resistance on malaria vectors were to promote a considerable shift to other compounds or methods of vector control. Table 3 gives some data showing the increases due to replacement of DDT by other insecticides.

Thus insecticide resistance has been extremely costly as far as malaria control is concerned and may have cost several billion dollars over the last two decades.

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