THE USE OF SPECIES SANITATION AND INSECTICIDES FOR MALARIA CONTROL IN COASTAL AREAS OF JAVA

Soeroto Atmosoedjono[*], P.R. Arbani[**], and Michael J. Bangs[*]

ABSTRAK

Aktivitas pengendalian penyakit malaria dimulai sejak awal abad ke-20. Beberapa peneliti malaria terkemuka memulai karirnya di pulau Jawa, dan banyak pakar lain memperoleh keuntungan dari berbagai pengalaman dalam aktivitas pengendalian malaria di Indonesia. Salah satu peristiwa terpenting yang telah terjadi adalah suksesnya pengendalian di sebagian besar daerah di pulau Jawa, yang merupakan salah satu daerah terpadat penduduknya di dunia. Alasan-alasan yang sebenarnya dari keberhasilan dan kegagalan dalam pengendalian malaria di Jawa sering dikemukakan dalam literatur dan jarang mendapat perhatian sepenuhnya. Informasi yang disajikan di sini mengulas tentang faktor-faktor penting ekologi malaria di sepanjang pantai pulau Jawa, dan terutama menyangkut usaha-usaha pengendalian terhadap vektor utama, yaitu nyamuk Anopheles sundaicus. *Penggunaan insektisida secara tepat dan bijaksana, perbaikan lingkungan untuk mengurangi habitat perkembangan larva, dan kebiasaan masyarakat yang menyangkut pengaturan/ pengolahan tanah dan tambak merupakan faktor-faktor penting untuk mencapai keberhasilan yang cukup tinggi. Usaha-usaha pemberantasan terhadap* An. sundaicus *dapat berhasil dengan adanya pemahaman biologi vektor dan ekologi pantai muara yang dipadukan dengan perubahan cara hidup dan pengendalian populasi dalam masyarakat. Meskipun pengendalian vektor sepanjang pantai utara pulau Jawa telah tercapai, akan tetapi ketidakmampuan untuk mengatasi kendala-kendala teknis dan lingkungan telah menghalangi keberhasilan usaha-usaha pengendalian* An. sundaicus *di sepanjang pantai selatan pulau Jawa.*

A Brief History of the Malaria Program in Indonesia

Environmental management for malaria control was extensively undertaken in Indonesia by the Netherlands-Indies Medical and Sanitary Services before World War II.[1,2,3,4,5,6,7] Swellengrebel and others had success in controlling malaria using ecological methods with special emphasis on the method coined "species sanitation". This method is defined as naturalistic control directed against the main vectors and dependent upon modification of habitat in such a way as to discourage their establishment and proliferation.[8] Figure 1 depicts the decrease in spleen rate between 1925-1932 along Java's coasts as the result of antilarval measures using environmental management in reducing malaria. With the advent of effective antimalarial drug and

[*]   US NAMRU-2, Jakarta
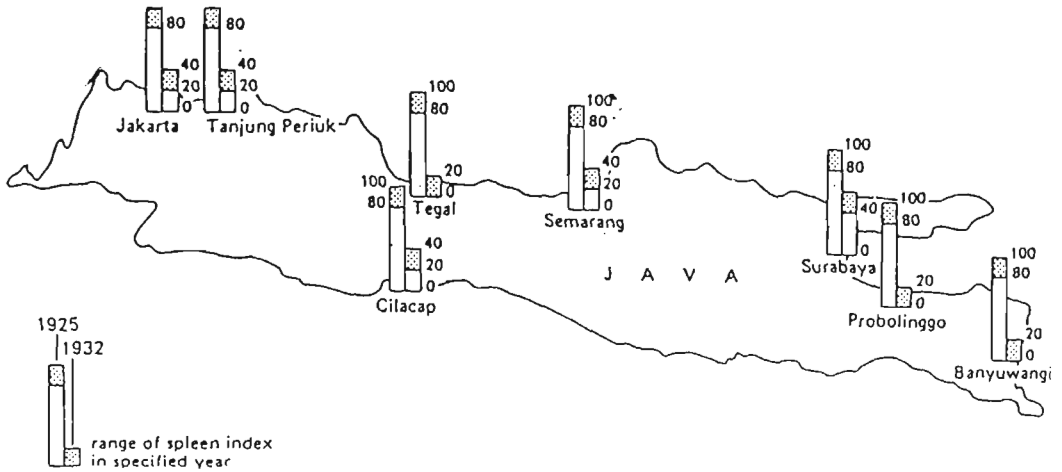[**] Directorate General CDC & EH, MOH.

Figure 1. **Decrease of spleen index in seaports and coastal towns of Java in the period 1925-1932. (6,7).**

modern synthetic insecticides during the period 1945-1965, emphasis shifted from environmental management of vector populations to insecticide-based campaigns aimed at eradication.These events dramatically changed the face of malaria control in Indonesia and throughout the world. Environmental management and naturalistic control was nearly abandoned as a practical means of malaria abatement.

In 1950 the Indonesian Ministry of Health considered malaria one of its most pressing health problems and initiated a small scale control program in Java. Agreements were signed between the Malaria Institute in Jakarta and the U.S. International Cooperation Administration (ICA, currently USAID) and the World Health Organization (WHO) to begin a malaria pilot project in Cilacap, Central Java.

After successful trials, DDT house spraying routinely implemented from 1952 onwards in Java and other islands experiencing high malaria rates. In 1955, a five year plan was conceived and the malaria control program was accelerated. During this time it was discovered that *Anopheles sundaicus* had developed physiological resistance to DDT and Dieldrin was introduced to overcome the problem. At the peak of this program an estimated 117 million persons had been protected and a marked decrease in malaria incidence was reported, especially in Java. Subsequently, the WHO Expert Committee on Malaria concluded in June 1956, that country-wide malaria eradication was not only feasible but in most cases more economical than a continuous program of control. A tri-partite agreement between WHO, ICA and the Government of

Indonesia was signed in December 1957 that converted the objective of this program to the eradication of malaria. The eradication program was approved by the cabinet in September 1958, and was begun in January 1959. Under the new agenda malaria eradication in Java was expected to be achieved by 1970. Operationally, the country was divided into 66 divisions, each with an average population of 1.4 million people at risk. In each division the program was to go through three phases :[9]

1. Pre-operational (one year)
2. Attack (three years)
3. Surveillance/Consolidation (three years)

Much of 1959 was devoted to finance, planning and organization.
During the transition from control to eradication objectives, indoor residual spraying (IRS) was temporarily halted and shortly after a malaria outbreak occurred in Semarang, Central Java. Population density of *An. sundaicus* in Semarang was very high during 1960 with human-biting rates of 160 and 250 mosquitoes/man/night recorded frpm indoor and outdoor colllections, respectively[10,11]. No DTT or dieldrin resistance was detected and dieldrin IRS successfully brought the outbreak under control. Prior to this outbreak *An. sundaicus* populations in Semarang had apparently been suppressed by enviromental control methods.

The Indonesian National Malaria Eradication Service (NMES) was established in March, 1959. Soon after it was transferred from the National Malaria Institute and placed under the directorship of the Minister of Health. The NMES was composed of four division : 1) Evaluation and intelligence, 2) operations and training, 3) personnel, and 4) logistics and finance. Most importantly, provincial directors

of public health were given an active part in their respective malaria programs.

Within the first year reevaluation of the NMES program was necessary. It was decided to concentrate on training and staffing the central organization during 1960 and to confine operations to Java, South Sumatera and Bali. The shift in program emphasis did not alter the ultimate target goal of achieving malaria eradication by 1970. However, the date for completion of maximum attack effort was set back by three years and scheduled for 1964. The NMES or KOPEM (Komando Operasi Pembasmian Malaria = National Malaria Eradication Command) reported that all 42 malaria control divisions in Java were brought into attack phase during 1963, thus giving protection by spray coverage to an estimated 64.5 million people. Surveillance operations had also expanded to cover an estimated 57 million people in 33 division. The goal of malaria eradication seemed attainable at that point. Based upon an NMES assessment team's evaluation of the malaria situation and efficiency of surveillance activities in the control divisions, it was anticipated that in 1964 spraying could be discontinued in 13 divisions and that post-control assessment could be expanded to other divisions that had entered the surveillance phase. However, there were growing technical problems : Vector resistance to DDT and dieldrin had developed in certain areas and there was increasing movement of human populations from unsprayed or malaria-endemic areas into areas that had been sprayed or were generally free of malaria tranmission. For the most part these setbacks failed reestablished permanent transmission in the control areas. However, with such a vast

programme, and with operational and technical problems developing in many different locations, hope of achieving malaria eradication weakened. Political instability and withdrawal of foreign support in 1965 caused further deterioration of the eradication program and by 1969, the national program had reverted back to malaria control.

Malaria remains a serious problem for the development and improvement of human health in Indonesia, but modern malaria control strategies are tempered with greater awareness of ecological balance and pesticide safety. As new insecticide based control methods become increasingly more expensive and demonstrate limited effect, renewed interest has been sparked in the "old" methods of environmental management and personal protection[12].

Because significant success has achieved in Java and Bali, the control policy today emphasizes prevention of malaria resurgence through the control of persistent foci, selective house spraying and early case detection and treatment. The immediate goal for the outer Islands is to reduce disease incidence primarily through passive case detection and indoor residual spraying.[4].

COASTAL MALARIA

The principal vector of coastal malaria in Java, *An. sundaicus*, breeds in sunlit brackish waters with abundant floating algae. For decades coastal marine fishponds have been associated with malaria because man-made impoundments can produce ideal breeding conditions for this vector[1,3,13.] This was the common situation prior to 1960, but a series of fortuitous and deliberate vector control

measures has practically eliminated *An. sundaicus*, from Java's northern coast. Suppression of *An. sundaicus* appears to have been accomplished primarily through the use of dieldrin, which was selected for indoor residual house spray (IRS) when the species developed physiological resistance against DDT.[14,15]

As mosquito vector densities declined, malaria transmission on the northern coastal strip gradually disappeared. The net reproduction rate of malaria (i.e. "the number of secondary malaria infections transmitted within a susceptible population from a single non-immune individual")[16] had plummeted to a non-sustainable level due to critically low vector densities. Reintroduction of malaria by persistent importation of human cases has not appeared to renew transmission in these low permissive areas. The whole north coast of Java now appears safe and essentially free from endemic malaria. This condition has been maintained during the past 30 years despite the continued existence of *An. sundaicus* on nearby small islands in the Java Sea within known flight range to the coast. Prevalent offshore winds and lower relative humidity above seawater possibly limit their ability to reach the mainland. Along the southern coast of Java; however, *An. sundaicus* is still common and involved in focal malaria outbreaks. The behavior of this species on the south coast is markedly different from its northern relative in that they generally avoid human dwellings and rest in vegetation. Although dieldrin IRS was very effective in reducing populations of north coast *An.*

sundaicus, this type of control has little impact on south coast populations. The reason for the behavioral difference is uncertain, and may imply existence of sibling species within an *An. sundaicus* complex. The high toxicity and low irritation properties of dieldrin does not repel or excite mosquitoes and appears not to have generated avoidance behavior or behavioral resistance in vector populations.

Extensive environmental changes along the north coast appear to have contributed to the sustained absence of *An. sundaicus*. Extensive land clearance, filling, and levelling and the elimination of fish impoundments for housing and industrial development has inadvertently destroyed many larval habitals. In north Jakarta, for example, the brackish, low-land areas around Ancol was previously a hunting ground for feral monkeys, pigs, and rabbits. This area was levelled, filled with sea-sand, and has now become a prime site for development of recreation and tourist resorts. During 1933, in Kelapa Gading, North Jakarta, *An. sundaicus* was common and frequently found to be infected with malaria sporozoites. The people of nearby Mangga Dua presented a set spleen index of 50%.[6] Fishponds in the villages of Marunda and Cilincing in East Jakarta were drained and filled to make way for various industrial projects. The development of Soekarno-Hatta International Airport and adjoining facilities in Cengkareng, west of Jakarta, has also altered these previously malarious locations. The remarkable changes in these environments have very effectively stopped malaria transmission and today, most of the younger generation residing in Jakarta has little or no appreciation of the disease. Their parents however, can still remember the fever, chill, and nausea caused by malaria and the resultant bitter taste of the quinine or chloroquine they took for its treatment.

Shortly after the introduction of DDT spraying in 1950, dramatic reductions in coastal malaria transmission became apparent in Java. Concurrent population growth pressured the Forestry Department to clear more coastal mangrove for fishponds (tambak) and agriculture, but the attention of health services was necessarily focused on the expanding insecticide program. Consequently, their role in monitoring new environmental changes and managing fishpond breeding of malaria vectors declined and various other sanitation projects also were neglected. Fortunately, the Forestry Department realized that extensive damage was being done to the mangrove ecosystem by unregulated fish and prawn cultivation on the north coast and development control policies were instituted. This was, in fact, a blessing for the Departement of Health and the Malaria Control Service, and helps to maintain marine productivity by preserving the fragile mangrove ecology of the coast. Today, approximately 63.000 hectares (ha) of mangrove forest remains along the entire north coast.[17] In West Java, about 48% of the 32.000 ha coast line can be considered mangrove, 6% being natural forest and 42% cultivated mangrove. The remaining 52% of the coastal area is used for fishponds, rice cultivation, water channels and settlements.

To overcome the problem of continued mangrove deforestation along the northern coast, legal and conservation efforts have attempted to regulate the intensive tambak fishery practices and provide environmentally

sound, technically simple quidance for local fish farmers.[18,19] "Silvo-fishery" is for the present time considered the best technical approach (tambak-forest system + tambak empang parit), as it benefits both fish culture and mangrove ecology.[20] Figure 2 illustrates conventional and silvo-fishery system of fishpond management. This method has been fostered primarily through the Forest Farmer Community Development Program (Kelompok Tani Hutan), and promotes general welfare of the indigenous people.

Anopheles sundaicus, a sunloving (heliophilic) species, generally deposits her eggs in sunlit water with luxuriant algae growth (*Enteromorpha*, *Cladophora*, and *Chaetomorpha spp.*), an environment rich in diatome and plankton populatations, on which larvae feed.[1,13,16,21,22] *Haplochilus panchax* or "ikan kepala timah," a larvivorous fish also

thrives in the algae environment; however, floating algae generally protect larvae from this predator fish. Algae helps to conceal larvae and serves as a physical barrier as well.[7] Proper fishpond management and the presence of shade trees along the banks of impoundments generally discourages algae formation and high density anopheline breeding.

Fish commonly cultured in marine fishponds are *Chanos chanos* Forsk or "ikan bandeng". a vegetarian species that feeds on bottom algae, (*Cyanophyceae sp.*). Floating algae is controlled by draining ponds completely once each month and exposing the drying algae to sun. Two or three days of sunlit drying are usually sufficient to reduce algae to a powdered mass. During this drying phase, fish congregate in water-filled depressions purposely made along the edge of the pond. This simple method was found to be more acceptable than mechanical clearing of algae because it requires
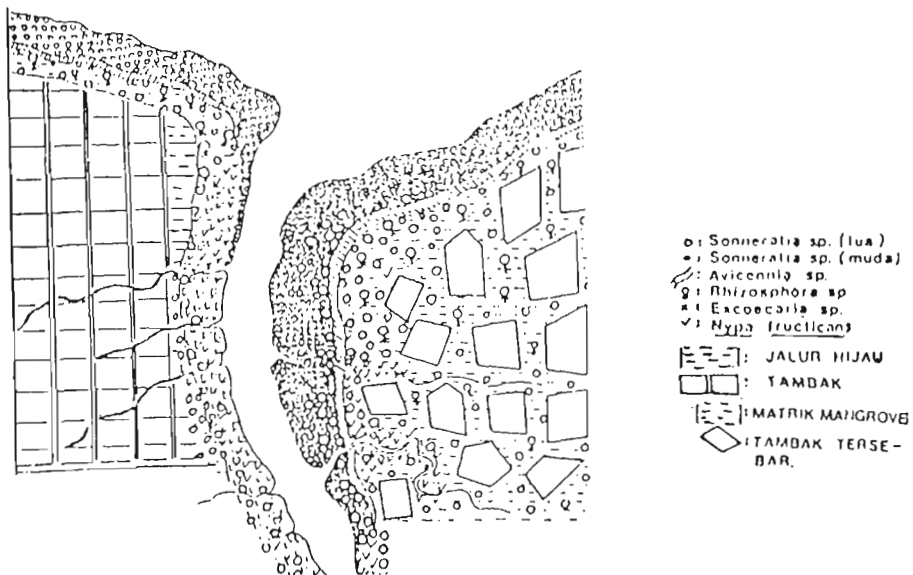

Figure 2. **Conventional monocultural fishpond management compared to a silvo-fishery system with fishponds interspersed in an intact natural mangrove forest (20)**

much less labor. The entire community benefits from its impact on *An. sundaicus* populations. *Anopheles sundaicus* is considered strongly anthropophilic over most of its geographic range.[1] Human blood indices (HBIs) of 86% or greater are typical.[23] Normal flight range for this species is estimated to be 1-3 km from breeding sites. Population densities generally peak during the drier period of the year, followed one to two months later by outbreaks of malaria.[24] This species often has high *Plasmodium* infection rates in nature.[3,13,21] Along the northern Java coast *An. sundaicus* prefers to rest inside houses, while the south coast population appears to have no preference, resting equally both indoors and outdoors. Because of this facultative behavior, south coast populations developed first a behavioral resistance to DDT then a physiological resistance to dieldrin, the replacement chemical

that became intensively for IRS at the time.[10] Vector behavior modification from endophily to exophily has been observed with some anopheline species as possibly a response to sublethal exposure to DDT.[22] In contrast, north coast populations rapidly developed physiological resistance to DDT but did not develop dieldrin resistance. Table 1 depicts the chronological development of DDT and dieldrin resistance in selected coastal localities in Java. The timely switch to dieldrin combined with the strong endophilic character of the vector population to achieve rapid and lasting reductions. The impact of dieldrin alone may have been sufficient to overcome the potential development of resistance, and eventual resurgence of the vector, but concurrent species sanitation and habitat management activities may have contributed to suppress *An. sundaicus* beyond any chance of recovery in the north.[4]

Tabel 1.   Development of DDT and dieldrin resistance in *An. sundaicus* Rodenwaldt.

Year	Zone	DDT	Dieldrin
	North coast of Java		
1954	Jakarta	X	---
	Cirebon	X	---
1955	Semarang	X	---
	Surabaya	X	---
	South coast of Java		
1959	Purworejo	---	X
	Yogyakarta	---	X
1961	Cilacap	---	X
1962	Garut	---	X
	Rangkasbitung	---	X
	Jember	---	X
1963	Tulungagung	X	X
	Malang	---	X

Adapted from Soerono (1965)

SOUTH COAST OF JAVA

Along coastal Java, lagoon formation is a natural oceanographic/geologic consequence of the dry season, and occurs predominantly along the south coast. The shallower Java Sea exerts a milder tidal influence upon the noreline, while the greater tides and strong wave action of the Indian Ocean contribute significantly to lagoon formation along the south coast. Considerably more sand is formed and deposited along the shoreline by the increased wave action. During the dry season river outflow is low and too weak to break through these sand banks. Eventually the sluggish river flows parallel the beach and lagoons. High tides periodically supply sea water to these lagoons and brackish conditions result. With surface algae growth these brackish lagoons become ideal anopheline breeding habitats. Within six to eight weeks of the lagoon's formation, anopheline densities can reach peak levels, and the stage becomes set for potential malaria outbreaks. Heavy monsoon rains swell the rivers, eventually open the sand barries, and drain the lagoons, thus bringing an end to brackish conditions and anopheline vector breeding. This process of lagoon formation and destruction is repeated annually and governs the seasonality of malaria outbreaks. During drought periods, ocean tidewaters follow river beds for inland and extend anopheline breeding to interior areas that do not normally experience this type of seasonal malaria transmission. The following three examples illustrate the changing picture of coastal malaria in Java.

LAGOONS

Pameungpeuk lagoons : Endemic malaria among villages in Pameungpeuk subdistrict, Garut Regency, West Java Province, was vectored by *An. sundaicus* and *An. aconitus*, which breed in brackish water lagoons and post-harvest wet rice fields, respectively. Three rivers, the Ciawi, Biera, and Cibarebeg, each having large estuaries, were routinely impounded during fry seasons, forming near-permanent lagoons of 2.0-4.5 ha^2 (Fig. 3). Periodic surface applications to impounded waters and habitat modification by plating shade trees along the river banks discouraged some breeding by heliophilic *An. sundaicus*, but results were unsatisfactory. Villages situated near to the Cibera lagoon continued to suffer heavily and spleen rates of 80-100 percent were recorded. From June to August 1982, weekly applications of a new liquid formation of *Bacillus thuringiensis* H-14 achieved good suppression of anopheline larvae and showed that such applications could ultimately reduce anopheline biting rates in nearby hamlets. Weekly larviciding with this agent, during the high transmission period of July to October was considered more effective than residual insecticidal house spraying. (Kirnowardoyo, personal communication).

Glagah lagoon : "Anophelism without Malaria" characterized the situation in Glagah, Temon subdistrict, Yogyakarta. This phenomenon has been attributed to a unique behavioral change in the local population of *An. sundaicus*. Elsewhere along the south coast of Java this species commonly rests outdoors and enters houses only to feed on humans.[24,25] However, in this particular area the species tends to feed more on cattle than on humans. The feeding preference of this local population has possibly been reinforced or selected for by past DDT and dieldrin control program but the continued presence of numerous domesticated animals has also helped to promote this "protective" zoophilic behavior. Larval populations of *An. sundaicus* were formerly prolitic in Glagah lagoon, (Fig. 4) but the lagoon habitat has undergone considerable

change over the past 40 years. Public works projects have constructed embankments and water gates to prevent mixing of sea and river water, and brackish habitats required for vector breeding have been eliminated. Since 1987, the most dramatic change has been the use of the Glagah lagoon as a recreating site for swimming. Adjoining canals and overflow control mechanisms help to manage seasonal changes in water volume and velocity that formerly broke through the banks and allowed formation of brackish water breeding habitats.

Segara Anakan Estuary

A malaria epidemic with many associated deaths took place in early 1984 in three neighboring villages, Kleces, Ujung Alang and Ujung Gagak, (Kampung Laut) in the Segara
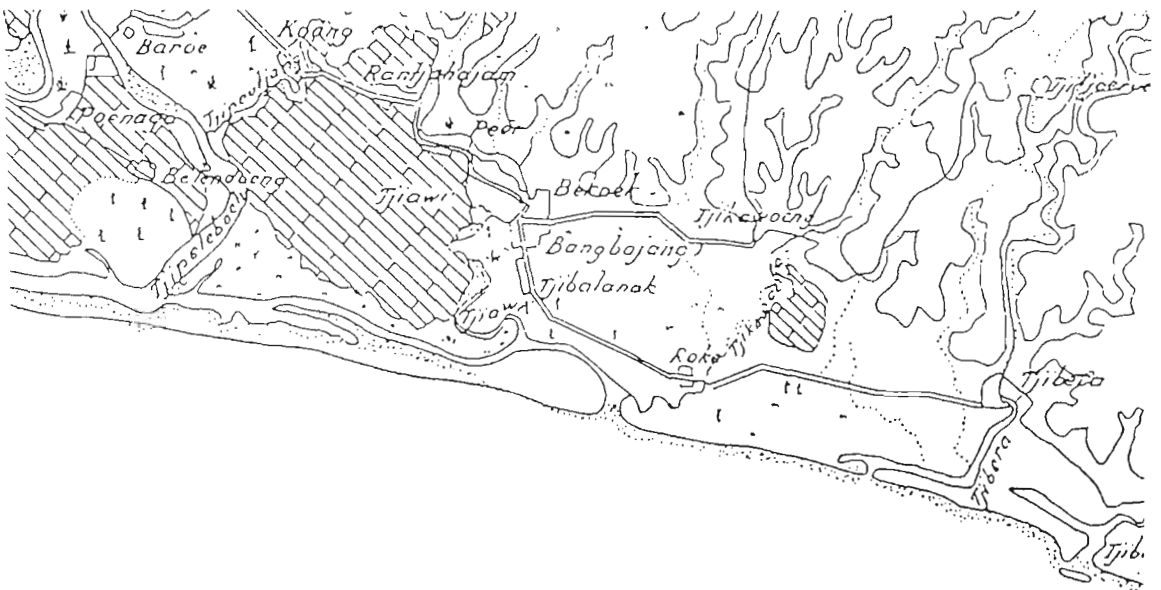

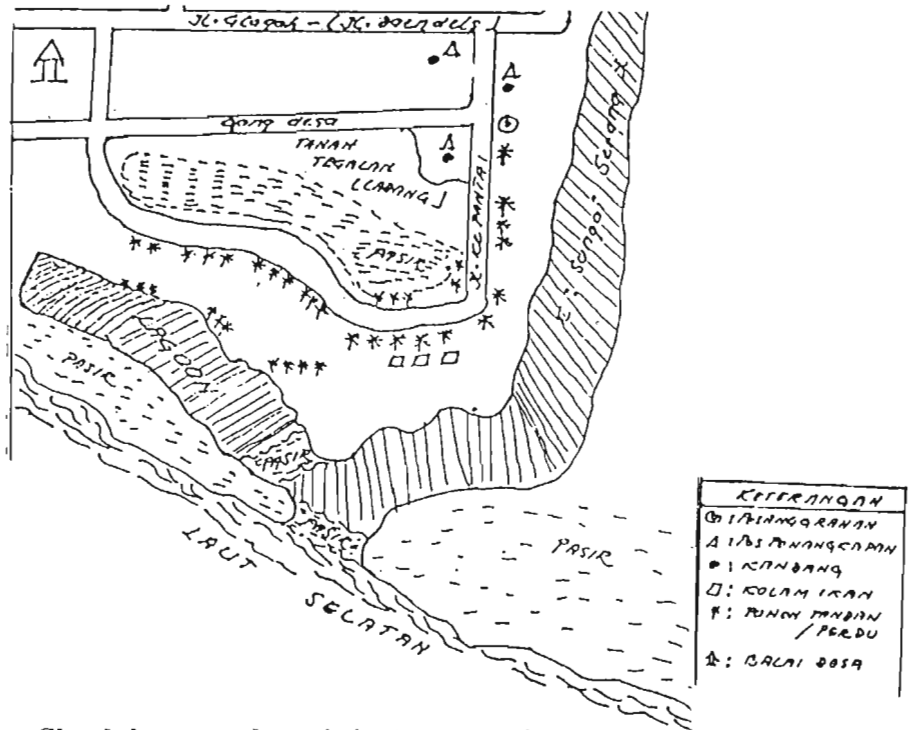Figure 3.   Pameungpeuk estuaries and coastal lagoon formation.

Figure 4. Glagah lagoon and proximity to community.

Anakan estuary of coastal Cilacap Regency. This event quickly drew the attention of the Ministry Health because Segara Anakan had no recent malaria history.[26]

Traditional-style house in this estuary region are elevated above high tide level permitting canoes to traverse an east-west gap on their way to the open sea. Due to years of natural sedimentation, the Segara Anakan has gradually become silted in as illustrated in Figures 5 and 6. Water surface area has been reduced from 51 km^2 in 1943, to only 27.5 km^2 in 1980. Many of the streams and rivers that culminate in the Segara Anakan estuary originate at Gunung Cakrabuana (1,721 m) in West Java. The largest of these, the Citandui, forms a natural border between West and Central Java in the South and passes through foot hills of high, dry plains in the West Java regencies of Tasikmalaya and Ciamis. Most of these hilly areas are deforested and top soil erosion has been measured at a rate of 2.9 mm per year. An estimated 9.5 million cubic meters of soil and organic material are lost into the Citandui river basin each year. The Cimuntur and Cibeureun rivers, which also feed into Segara Anakan, have a similarly high annual sedimentation rate. During 40 years of deforestation, soil erosion and sedimentation the Kampung Laut area has increased from 3.2 km^2 to 65.0 km^2. Although agricultural land area has increased to the benefit of many, the local fishermen's way of life has changed for the worse.

Figure 5.   Segara Anakan, 1917. An estuary virtually free of islands.
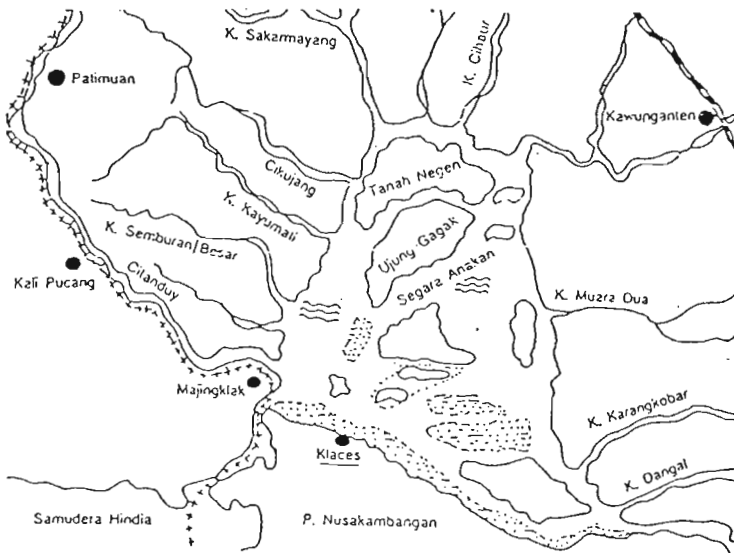

Figure 6.   Segara Anakan, 1984. Progressive effect of sedimentation and island formation.

In 1976 the response of local government to their plight was resettlement to South Kalimantan transmigration sites. When a second attempt was made in 1980 to relocate the population, more than 70% refused to leave. The issue of mangrove forest destruction and unregulated rice paddy expansion was also taken up by the local government.

The Departement of Fisheries and a local non-government organization (NGO) joined the local administration of Cilacap Regency to introduce marine fishpond culture into the local economy. The local health authority and other agencies in Cilacap were unaware of the potential impact that extensive mangrove destruction and fishpond culture would have upon malaria transmission. The normal construction of these impoundments prevented water movement and circulation; this stagnation promoted the growth of floating algae. Algae growth and anopheline breeding were most evident in ponds that were not properly maintained and where salinity levels were not properly maintained and where salinity levels were not controlled.

Anopheles sundaicus rapidly took advantage of these open brackish habitats and oviposited on the nutrient-rich algae mats. Within two or three years this species had built up population densities to such levels that when gametocyte carriers were introduced into the area malaria outbreaks quickly followed (Table 2). Monthly death rates for this time rose to more than five times the normal crude death rate of the community and was attributed to severe malaria. Infants and children under 5 years of age were most affected[26]. Blood examination in November 1984 revealed a malaria infection rate of 57% (28/49). *Plasmodium falciparum* accounted for 60.7% of these infections with high gametocytemia (76.4%) present in most cases. Spleen rates of 46.4% and 86.6% were recorded in Ujung Gagak and Kleces, respectively. Entomological surveys during this period reported significant numbers of *An. sundaicus* from both indoor and outdoor human-landing collections.[27] Because susceptibility tests showed strong DDT resistance, control measures consisted of residual house spraying with fenitrothion and fogging with malathion.

In summary, the events that led to the malaria epidemic in Kampung Laut were as follows : Inland deforestation and agricultural

Tabel 2.   Monthly Malaria Examination Results, Segara Anakan, 1984.

Month	Exam	Pos.	SPR	Pf./Mx.	SFR
June	972	-	-	-	-
July	1156	25	2.1	7	0.6
August	1296	44	3.4	13	1.0
September	2963	394	13.3	143	4.8

practices caused erosion which fed increasing volumes of soil into the streams and rivers. At the confluence of many of these rivers, the Segara Anakan estuary became more clogged with sediment each year. The extent to which tidal sea water could freely circulate through the mangrove forest was reduced, and parts of this forest began to die. Deliberate destruction of the mangroves for land use as settlements, rice paddies, and fish ponds, hastened deforestation. The loss of sea water circulation and mangrove shade resulted in shallow, sunlit brackish waters. Surface algae growth made the habitat suitable for *An. sundaicus* breeding, and populations which were formerly kept at low density rose sharply. Supported by these conditions *An.sundaicus* populations became established in the newly formed delta island groups, and for want of other blood sources, fed almost exclusively on humans. This set the stage for malaria transmission as outbreak cases began to spill over to neighboring villages of Segara Anakan.

Today, much of the south coast of Java remains underdeveloped. Malaria endures at low levels while sporadic outbreaks among these southern coastal villages is still being reported annually. As evident in the three previous examples of lagoon/estuary malaria, localities experiencing recurring outbreaks will need to be individually assessed and remedial action formulated to each particular situation. It hoped that the lessons of the past can be imparted to present malaria workers to assist in the development of sound integrated approaches towards sustainable malaria control in the future.

SUMMARY

1. *An. sundaicus* has been essentially eliminated from the north coast of Java. Its decline began in the early 1960's and was achieved by integrated control efforts: habitat reduction, proper fishpond management, and accurate targeting of effective insecticides.

2. *An. sundaicus* still exists along the south coast of Java despite massive efforts to achieve eradication. Its success presumably stems from the combined effects of physiological resistance to dieldrin, behavioral resistance to DDT, and insurmountable environmental conditions that foster prolific larval breeding. Malaria outbreaks still occur along the southern coast.

3. The elimination of native mangrove and the introduction of marine fishponds in Ciamis and Cilacap Regencies, West Java created ideal breeding habitats for *An. sundaicus*. Proper fishpond management and the use of shade trees to prevent floating algae growth prevent *An. sundaicus* from attaining levels of vectorial capacity.

4. Because of the different geophysical character of the south central coast of Java (strong tides, wave action, sand formation), brackish lagoons are created during dry season months. These temporary lagoons become ideal breeding habitats for *An. sundaicus* and are responsible for seasonal outbreaks of malaria. Malaria transmission by *An. sundaicus* is also governed by feeding preference (zoophagic vs. anthropophagic) and the availability of non-human blood sources.

5. Environmental changes and their ecological impact on human disease transmission must be carefully considered when planning development projects in coastal areas.

6. There is need for further development of biological methods for control of anopheline larvae. The commercial benefit and control effectiveness of stocking fishponds with non competitive algae consuming and larvirorous fish species should be evaluated. Use of water plants (i.e. *Eichornia crassipes*) to provide shade in potential breeding sites should also be evaluated.[28]

Acknowledgment

References

1. Boyd, M.F. (1949) **Malariology**. A comprehensive survey of all aspects of this group of diseases from a global standpoint. Vol.I and II, Philadelphia, Saunders Co. 1643 p.

2. Gandahusada, S.L., and Soemarlan (1978) Malaria in Indonesia, a review of literature, National Institute of Health Research and Development, Ministry of Health, Jakarta. 57 p.

3. Overbeek, J.G., and Stroker, W.J. (1938) Malaria in Nerderlandsh-Indie en hare bestrijding. Mededeelingen vanden Dienst der Volksgezondheid in Nederlandsch-Indie 28 : 183-205.

4. Soemarlan and Gandahusada, S. (1990) The fight against malaria in Indonesia : A historical review and future outlook. NIHRD/MOH, Jakarta 63 p.

5. Strickland, C. (1936) Papers on malaria in Malaya. Mededeelingen van den Dienst der Volksgezondeid in Nederlandsch-Indie. 25: 331-340.

6. Takken, W., Snellen, W.B., Verhave, J.P. Knois, B.G.J. and Atmosoedjono, S. (1990) Environmental Measures for Malaria Control in Indonesia - an historical review on species sanitation. Wageningen University Papers : 167 p.

7. Walch, E.W., and Soesilo, R. (1935) Malaria Control in the Netherlands Indies Mededeelingen van den Dienst der Volksgezondheid in Nederlandsch - Indie 24: 86-94.

8. Watson, M. (1911) The prevention of malaria in the Federated Malay States. Liverpool School of Tropical Medicine : 139 p.

9. Black, R.H. (1968) Manual of Epidemiology and Epidemiological Services in Malaria programmes. WHO, Geneva. 223 p.

10. Muir, D.A (1963) Observations on the development of and trend of insecticide resistance in two important malaria vectors in Indonesia. (unpublished document WHO/vector control/54.

11. Soerono, M. (1965) Pembasmian malaria di Indonesia, Research di Indonesia 1945-1965. Bidang Kesehatan Departemen Urusan Research National Republik Indonesia : 1 487-531.

12. WHO, (1982) Manual on environmental management for mosquito control with special emphasis on malaria vectors. WHO publication No. 66, Geneva, Wld. Hlth. org. 283 p.

13. Sundararaman, S., Soeroto, R.M. and Siran, M. (1957) Vector of malaria in mid-Java. Indian J. Malariology 11 · 321-338.

14. Chow, C.Y. and Soeparmo, H.T (1956) DDT resistance of **Anopheles sundaicus** in Java. Bull. Wld. Hlth. Org. 15 : 785-786.

15. Crandell, H.A. (1954) Resistance of **Anopheles sundaicus** to DDT. Mosq. News. 14 : 194

16. Bruce-Chwatt, L.J. (1985) **Essential Malariology**. Second Edition, London, wm. Heinemann Medical Books. 425 p.

17. Bratamiharja, M. (1990) Pengelolaan hutan payau di pantai utara Pulau Jawa. Prosiding Seminar IV Ekosistem Mangrove, Bandar Lampung, 7-9 Agustus 1990 : 59-63.

18. Naamin, N. (1990) Penggunaan lahan mangrove untuk Budidaya Tambak, Keuntungan dan kerugiannya. Prosiding Seminar IV Ekosistem Mangrove, Bandar Lampung, 7-9 Agustus 1990 : 49-57.

19. Wartaputra, S. (1990) Kebijaksanaan Pengelolaan Mangrove ditinjau dari sudut Konservasi. Prosiding Seminar IV Ekosistem Mangrove, Bandar Lampung, 7-9 Agustus : 17-24.

20. Sutopo G.N, Setiawan, A., Harianto, S.P. (1990) "Coupled Ecosystem Silvo-Fishery" Bentuk pengelolaan hutan mangrove - tambak yang saling mendukung dan melindungi. Prosiding Seminar IV Ekosistem Mangrove, Bandar Lampung, 7-9 Agustus . 69-72.

21. Scuffner, W., Swellengrebel, N.H., Swellengrebel-de Graaf, J.M.H., and Mochtar, A. (1919) On biology of **M. ludlowi** in Sumatra. Mededeelingen van den Burgerlijken Geneeskundigen Dienst voor Nederlandsch-Indie 3 : 65-88.

22. Chow, C.Y. (1970) Bionomic of malaria vector in the Western Pacific Region. Southeas Asian J. Trop. Med. Pub. Hlth. 1 : 40-57.

23. Walch, E.W. (1932) Het verband tussen de voorkeur van Nederlandsch Indische Anophelinen voor menschen-of dierenbloed en haar gevaarlijheid (tweede mededeeling). Geneeskundig Tijdschrift voor Nederlandsch - Indie 72 : 682-709.

24. Sundararaman, S. (1958) The behavior of **A. sudaicus** Rodenwaldt in relation to the application of residual insecticides in Tjilatjap, Indonesia. Indian J. Malariology 12 : 129-156

25. Kirnowardoyo, S. (1988) Anopheles malaria vector and control measures applied in Indonesia. Southeast Asian J. Trop. Med. Pub. Hlth. 9 : 713-716.

26. Jung, R.K. (1984) Tour Note on field visit to Central Java 10-15 Desember 1984. (unpublished document) Wld. Hlth. Org. 12 p.

27. Kirnowardoyo, S., and Yoga. G.P. (1987) Entomological investigations of an outbreak of malaria in Cilacap on south coast of Central Java, Indonesia during 1985. J. Com. Dis. 19 : 121-127.

28. Iyengar, M.O.T. (1946) Naturalistic control of the breeding of **Anopheles sundaicus** by means of **Eichhornia**-cover. J. Malaria Inst. India 6 : 309-310.