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Environmental measures for malaria control in Indonesia -an historical review on species sanitation

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Contents

Preface

This review is the result of discussions held at the 1987 annual meeting of the WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control (PEEM). PEEM was set up as an advisory and policy-making body to promote the application of environmental management techniques for the control of disease vectors. Recent information on the use of such techniques for the control of malaria is scarce, because since the discovery and large scale application of DDT, malaria control throughout the world has relied heavily on chemical insecticides. In view of that scarcity, and in the collaborative framework between PEEM and the International Institute for Land Reclamation and Improvement (ILRI), this institute began collecting and reviewing information on the environmental measures that were used to control malaria in the former Netherlands Indies. The main objective was to compile a list of measures for malaria control, along with their working principles, applicability, and (cost) effectiveness. It soon appeared that making such a list required a proper understanding of the technique of 'species sanitation'. This technique, which is the subject of this review, aims to control malaria through the elimination or alteration of the habitat of the most important vector species.

ILRI, as a land and water development institute, did not have the specialized knowledge to deal with the entomological, parasitological and medical aspects of species sanitation so that the review became a collaborative project of several institutions. The Department of Entomology of the Wageningen Agricultural University studied the ecological and entomological aspects of malaria control. A chapter on Dr. Swellengrebel, the man who recognized and developed the unique aspects of species sanitation, was written by the Department of Microbiology of the Nijmegen University. ILRI studied the anti-malaria measures from Indonesia before World War II to evaluate which lessons can be learnt from that experience. Finally, the Ministry of Health in Indonesia provided the information that was required to bridge the pre-World War II data with the present day situation.

Writing an historical review unavoidably presents difficulties concerning geographical names. This is especially so in a country that went from a colonial era to independence, in the process of which many names of islands, provinces and towns were changed. We have chosen to use the present-day names whenever possible. Previous names are indicated in square brackets in order to present the text more clearly. A list of present day geographical names, together with their historical names, is presented as a reference in the introductory pages of this review.

Recent developments in insect taxonomy have made it possible to study the extent of 'species complexes' of anophelines. As a result of these studies the number of species of the genus *Anopheles* is likely to increase as differences become known. This is particularly true for anophelines of the South East Asian region. Being well aware of these developments, we have chosen to use the generally accepted nomenclature as described by Knight & Stone (1977). Type localities for the different species were also taken from these authors. Any changes which may have occurred since this publication have not been considered.

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List of modern and historical geographical names

	modern name	historical name[1]
islands		
	Jawa (Java)	Java
	Sumatera (Sumatra)	Sumatra
	Kalimantan	Borneo
	Sulawesi	Celebes
	Irian Jaya	New Guinea
mountains		
	Gunung Arjuno	Mount Ardjoeno (E. Java)
towns and villages		
on Jawa:		
	Bandung	Bandoeng
	Banjar	Bandjar (W. Java)
	Banyuwangi	Banjoewangi
		Brengkok*[2]
	Cianjur	Tjiandjoer
	Cihea	Tjihea
	Cilacap	Tjilatjap
	Jakarta	Batavia
	Pasuruan	Pasoeroean
	Probolingo	Probolinggo
	Solo (Surakarta)	Solo
	Sukabumi	Soekaboemi
	Surabaya	Soerabaja
	Tanjung Periuk	Tandjong Priok
on Sumatera:		
	Lampung	Lampoeng
		Mandailing*
		Soendatar*
		Soengei Baleh*
	Tapanuli	Tapanoeli

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[1] Source: *Atlas van Tropisch Nederland* (1938). Koninklijk Nederlandsch Aardrijkskundig Genootschap in samenwerking met de Topographischen Dienst in Nederlandsch-Indië, Batavia/Amsterdam.

[2] The current names of these locations were not found.

Chapter 1

Introduction

W. Takken

Of the many parasitic diseases of man in the tropics, malaria remains at the top of the list in terms of importance because of the very large number of people which contract the disease annually and the high death rate it causes among young children (WHO, 1987). For this reason, malaria control continues to receive high priority in health programmes. However, the way to achieve this goal is proving increasingly difficult. Apart from chronic shortages of funding for health programmes in many developing countries, the increasing occurrence of drug resistance as well as insecticide resistance are serious obstacles for malaria control.

Indonesia is one of the countries experiencing malaria at a relatively high incidence. The country consists of several large islands and thousands of smaller islands (Figure 1.1) and at least 18 mosquito species have been confirmed as malaria vectors, distributed over the entire archipelago (Kirnowardoyo, 1988). Despite great efforts to control the disease, effective control is achieved in limited areas and malaria is still widespread (Harinasuta *et al.*, 1982; Bang, 1985). New methods to improve this situation are highly desirable. During the colonial days the Dutch authorities experimented successfully with environmental methods of malaria control which since then seem to have been forgotten. In recent years these measures have been 'rediscovered' (Service, 1989). This prompted us to

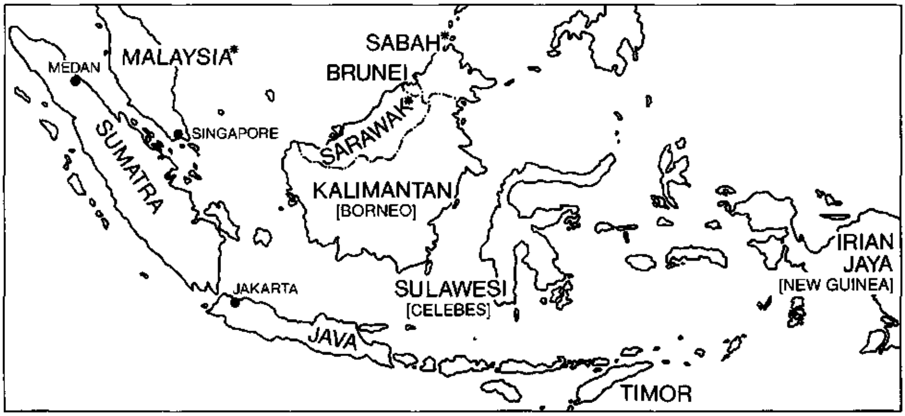

Fig. 1.1 Map of Indonesia and surrounding countries. (Areas indicated with * belong to the Federation of Malaysia).

review the pre-independence anti-malaria control strategies from Indonesia in order to assess their value for present-day malaria control.

Until recently, malaria control was based on the principles of killing the parasites inside the human body with drugs and attacking the vectors with insecticides. These methods are becoming increasingly unsuitable because, firstly, in many countries malaria parasites have become resistant against drugs and, secondly, mosquitoes have developed a high degree of insecticide resistance so that their use had to be discontinued (Najera, 1989). Several encouraging developments in the field of vector control occurred in recent years, which have led to the introduction of the term 'environmental management'. This means that it is envisaged to control or reduce vector populations by taking environmental measures which are disadvantageous for the target species, without damaging other organisms in that environment. One example of this is the periodic drainage of irrigated rice fields in China, which kills the anopheline larvae without affecting other important elements of the rice field habitat. Environmental management for malaria control was widely practiced in Indonesia (formerly: the Netherlands Indies) before World War II. The advent of modern synthetic insecticides such as DDT and dieldrin led to the abandonment of the aforementioned ecological methods of vector control. To-day environmental management is only used on a limited scale throughout the world, although the potential of this method appears to be large (IRRI, 1988).

The present study was undertaken to review the pre-World War II literature about vector control measures developed in Indonesia. It was expected that the experience gained in those days might be useful for the development of alternative control strategies required to-day. Environmental management of aquatic anopheline habitats was the focus of our study, with special emphasis on the method called *species sanitation*. In order to utilize the existing data properly, it proved necessary to review the taxonomy and bionomics of the most important malaria vectors of the Indonesian archipelago. We used these data to evaluate

The malaria cycle

Malaria is a parasitic disease caused by protozoa (*Plasmodium* spp.) which are circulating in the blood stream. Four species of *Plasmodium* affect man: *P. vivax*, *P. falciparum*, *P. malariae* and *P. ovale*. The infection begins when parasites (*sporozoites*) enter the human body through the bite of an infected mosquito. Only mosquitoes of the genus *Anopheles* can carry the human malaria parasites. After rapid asexual multiplication in the human liver and blood cells, the parasites develop sexual stages (*gametocytes*). These are ingested by the mosquito during a blood meal. Inside the mosquito the gametes fuse and develop into oöcysts, which are attached to the mosquito's stomach wall. Upon maturation, the oöcysts burst and release large numbers of sporozoites which migrate to the salivary glands, from where they enter the human body during the next blood meal. Thus, whereas man is the definite host of the malaria parasites, anopheline mosquitoes are required for the continuation of parasite transmission. In this process certain anopheline mosquitoes function as *vectors* of the disease. The malaria cycle is being maintained as long as uninfected mosquitoes bite gametocyte carriers and, after an incubation time of 9-20 days, transmit the parasites to hitherto uninfected persons.

several vector control programmes conducted between the years 1916 and 1938. A mathematical model developed by Kuipers (1937a) to predict the effect of environmental factors on mosquito population dynamics in Indonesia is described. It is shown how this model could have been used in vector control programmes. Recent information on malaria and malaria control operations in Indonesia are described in a separate chapter. The consequences of the environmental management methods used in the past are then discussed with reference to present day malaria situations. Since the work of one scientist, Swellengrebel, appeared to have been overwhelmingly important in the development of malaria control in the Netherlands Indies, a special chapter has been included to describe his work. Many of the works reviewed in this paper were written in Dutch which hindered their distribution given the limited size of the Dutch language area. We hope that this review will be helpful to gain access to the papers mentioned, particularly since we found that many of these are highly relevant for modern day entomologists and health personnel and those engaged in land and water management.

Chapter 2

Species sanitation

W. Takken

When in 1897 Ross published his findings on the development of *Plasmodium* inside the mosquito, and it was subsequently demonstrated that mosquitoes of the genus *Anopheles* were responsible for the transmission of malaria, it was soon realized that changing the aquatic habitat of the vectors would automatically lead to interruption of malaria transmission. The most well known example of this method is the drainage of the marshes near Rome, Italy (for a detailed description see: Bruce-Chwatt, 1985). Malaria control through habitat modification was at that time also attempted in Indonesia by filling small water bodies with soil, especially close to areas of human habitation (Hulshoff Pol & Betz, 1908; Salm, 1915). In Malaysia, Watson (1911) experimented with the selective elimination of one species, *Anopheles umbrosus*, which had been incriminated as the principal malaria vector in a lowland area. Watson had previously found that not all the anopheline species in the area were responsible for malaria transmission and he had also found that these mosquitoes were often restricted to a specialised breeding habitat (the same would be discovered by Jennings in Central America in 1912). Through the selective clearing of wooded habitat, the shade loving *An. umbrosus* was being exposed to the sun and subsequently disappeared. The previously widely present malaria went with it. This proved to be an economical method of malaria control: by identifying the most important vector and the subsequent study of its biology and ecology, malaria control had been achieved without having to eliminate all anopheline species present.

Watson discussed his findings with Swellengrebel on Sumatra (Indonesia) in 1913. The latter became deeply interested in this method and called it *species sanitation*. This is the term with which we still identify the method to-day. In this review we define species sanitation as '**a naturalistic approach of vector control, directed against the main vectors, through modification of the habitat in such a way that the vectors avoid these areas**' (Bruce-Chwatt, 1985, after Watson, 1911). The method requires a study of the characteristic breeding habits of the main vectors and of the type of water in which they lay their eggs. Control is mostly directed against larval stages, but sometimes adults can be included as well. Species sanitation has the advantage above general sanitation, that often only one of a complex of several *Anopheles* species need to be attacked.

Swellengrebel realized that in order to use species sanitation in Indonesia, a thorough knowledge of the taxonomy and bionomics of the local vectors would be required (Swellengrebel, 1916). He therefore encouraged health personnel, responsible for malaria control, to undertake a study of the vectors and describe as accurately as possible the number of species present, their habitat and habits.

At that time knowledge on Indonesian anophelines was scarce. By 1919 several studies had been published, which gave detailed descriptions of anopheline species and their habitats from different regions on Java and Sumatra (Van Breemen, 1919; van Driel, 1919; Mangkoewinoto, 1919; Swellengrebel & Swellengrebel-de Graaf, 1919). Swellengrebel & Swellengrebel-de Graaf (1919) divided the anophelines into three groups, according to the breeding sites: (1) ubiquitoes (unspecialised) species, (2) hill species and (3) specialised species. According to these authors species sanitation could only be applied for the last group. They especially mentioned *An. sundaicus* [*An. ludlowi*], which was present in specific habitats along the northern coast of Java.

In 1920 Swellengrebel published an overview of malaria control in Indonesia and its future prospects (Swellengrebel, 1920). Of the 20 malaria vectors known at that time, *An. sundaicus*, *An. aconitus* and *An. maculatus* were incriminated as important malaria vectors. Of these, *An. sundaicus* could be controlled through species sanitation. The author concluded that 'provided detailed vector studies were included in malaria control programmes, species sanitation was a potentially effective method of malaria control in Indonesia' (Swellengrebel & Swellengrebel-de Graaf, 1920).

Between 1920 and 1935 species sanitation, along with general sanitation, was widely applied throughout the Indonesian archipelago. Of these, the sanitations of Mandailing (Sumatra), Tandjong Priok (Java), Alor, Batavia and Tegor, all against *An. sundaicus*, and of Tandjong Pinang (Sumatra) against *An. maculatus* and of the Tjihea plains (E. Java) against *An. aconitus* should be mentioned. These control programmes have been described by Rodenwaldt (1924; 1928), Essed (1928; 1932a; 1932b) and Hulshoff (1933). Walch & Soesilo (1935) summarized the achievements of malaria control in the Netherlands Indies, in which they emphasize the control of aquatic stages. In particular the sanitation of the coastal fish ponds in Java is described in detail. Soesilo (1936) reviewed the sanitation programmes that were known up to that time and mentions that of the 40 known anopheline species, 11 species should be considered dangerous. In 1937 Swellengrebel writes 'the principle of species control remains unshaken, but some of the so-called anopheline species which had revealed themselves as dangerous malaria-carriers in one country and as harmless mosquitoes in another, were proved to be groups of two or more species, very much resembling each other in shape and design, but differing in their habits to such an extent as to render one an efficient malaria-carrier and another quite harmless'. With this statement he laid down the basis for the 'species-complex' principle which is widely accepted to-day (Service, 1988). This theory emphasizes the potential usefulness of species sanitation because by detailed studies of the local malaria vectors, which morphologically may be indifferent, malaria control can be directed against the vector species only. An example of this is the control of an indoor-biting species without affecting an outdoor-biting sibling species, or the control of a shade-loving species while leaving a sun-loving sibling.

Swellengrebel had based his statement on species sanitation on the discovery in the Netherlands that the local *An. maculipennis* consisted of two distinct sibling species, *An. atroparvus* and *An. messeae*, each with different bionomics. Only *An. atroparvus* was a malaria vector and *An. messeae* was quite harmless (Van Thiel, 1936). These findings convinced Swellengrebel that future prospects for species sanitation were positive.

Although by 1938 several malaria control programmes had failed to achieve the desired results, Overbeek & Stoker (1938) nevertheless published an overview 'Malaria control in the Netherlands Indies' in which they strongly supported the principle of species sanitation.

In conclusion, species sanitation has been widely applied for malaria control in the Netherlands Indies. The method requires detailed biological and ecological studies on the local malaria vectors, before anti-mosquito measures can be taken. On the basis of these pre-control studies it should be decided whether species sanitation is feasible. Chapter 5 discusses several examples of species sanitation, and why they were successful or failed.

Chapter 3

A taxonomic and bionomic review of the malaria vectors of Indonesia.

W. Takken and B.G.J. Knols

3A – Taxonomy

In this section an outline of the taxonomic development of the genus *Anopheles* in Indonesia is presented. An important consideration in undertaking this review was that a detailed study of the anophelines would be the only reliable basis for the interpretation of results of the malaria control operations from the past, in particular those with emphasis on species sanitation.

For a long time it was thought that the taxonomic study of anophelines was purely of biological interest to entomologists. It was even sometimes referred to as being an 'affectation' (Swellengrebel, 1934). Many authors however noticed the importance of taxonomic studies and the names of Swellengrebel, Schüffner, Walch and Rodenwaldt, amongst others, must be mentioned in this respect (Schüffner & Swellengrebel, 1914; Fischer, 1917; Swellengrebel 1921, Swellengrebel & Rodenwaldt 1932).

For this review we consulted Swellengrebel (1921), Swellengrebel & Rodenwaldt (1932), Bonne-Webster & Swellengrebel (1953) and Knight & Stone (1977). These taxonomic works were studied in order to extract lists of anopheline species known throughout the history of Indonesia. This resulted in Tables 3.1, 3.2 and 3.3, in which the anophelines from the Indo-Australian region as they were known in 1921, 1932 and 1953, respectively, are presented.

An accurate description of all Indonesian anopheline species and their names

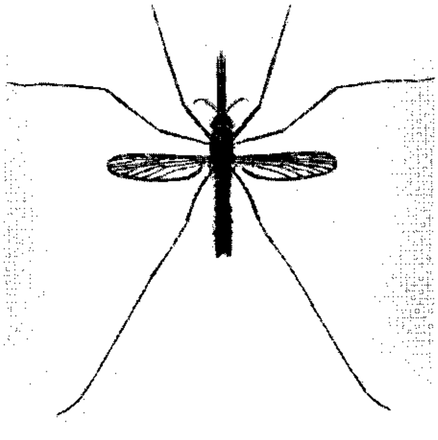

Photo 1 *Myzomyia ludlowi* (= *Anopheles sundaicus*). (Source: Swellengrebel, 1916).

Table 3.1 Systematic index of the anophelines of Indonesia (after Swellengrebel, 1921).

I.	**ROSSI-group.**	
1.	*Myzomyia vaga*	Dönitz, 1902.
2.	*Myzomyia ludlowi*	Theobald, 1903.
3.	*Myzomyia ludlowi var. flavescens*	nov.var., 1921.
4.	*Myzomyia rossii*	Giles, 1899.
5.	*Myzomyia immaculata*	James, 1902.
II.	**ACONITA-group.**	
6.	*Myzomyia aconita*	Dönitz, 1902.
7.	*Myzomyia minima*	Theobald, 1901.
III.	**PUNCTULATA-group.**	
8.	*Neomyzomyia punctulata*	Dönitz, 1901.
9.	*Nyssorhynchus annulipes var. moluccensis*	Swellengrebel-Swellengrebel de Graaf, 1920.
10.	*Neomyzomyia leucosphyra*	Dönitz, 1901.
11.	*Cellia kochii*	Dönitz, 1901.
IV.	**NYSSORHYNCHUS-group.**	
12.	*Nyssorhynchus fuliginosus*	Giles, 1900.
13.	*Nyssorhynchus fuliginosus var. nivipes*	Theobald, 1903.
14.	*Nyssorhynchus schuffneri*	Stanton, 1915.
15.	*Nyssorhynchus maculatus*	Theobald, 1901.
16.	*Nyssorhynchus karwari*	James, 1903.
17.	*Nyssorhynchus jamesi*	Theobald, 1901.
V.	**MYZORHYNCHUS-group.**	
18.	*Myzorhynchus sinensis*	Wiedemann, 1828.
19.	*Myzorhynchus sinensis var. vanus*	Theobald, ?.
20.	*Myzorhynchus sinensis var. separatus*	Leicester, 1908.
21.	*Myzorhynchus sinensis var. argyropus*	Swellengrebel, 1914.
22.	*Myzorhynchus barbirostris*	v.d. Wulp, 1884.
23.	*Myzorhynchus barbirostris var. pallidus*	Swellengrebel-Swellengrebel de Graaf, 1919.
24.	*Myzorhynchus albotaeniatus*	Theobald, 1903.
25.	*Myzorhynchus umbrosus*	Theobald, 1903.
26.	*Myzorhynchus gigas*	Giles, 1901.
VI.	**STETHOMYIA-group.**	
27.	*Stethomyia aitkenii*	James, 1903.
28.	*Stethomyia aitkenii var. insulae florum*	Swellengrebel-Swellengrebel de Graaf, 1919.
29.	*Stethomyia aitkenii var. papuae*	

in the past is needed to answer several important questions:
- Has the name of a certain species (type or variety) remained constant since its first description?
- Why were certain species divided into lower taxa (morphology, epidemiology, geographic distribution etc.)?
- What is known about the breeding places of the anophelines, and how do descriptions of them vary over time?
- How did the description of the bionomics of a certain species vary over time?
- What is known about the epidemiological importance of each species?

Once these factors for all the species are known, sanitation works as they were executed before W.W.II can be evaluated. From the data it is obvious that the number of described anopheline species increased rapidly after the first taxonomic studies were published, resulting in more than 116 different species by 1953 (Table 3.3). Of these, not all species were described as malaria vectors in Indonesia and in fact only a few had been the subject of species sanitation. We therefore selected those species that were definitely present in Sumatra, Java, Kalimantan [Borneo] and Sulawesi [Celebes] and for which the following information was available:
- geographical distribution
- confirmed role as a malaria vector
- bionomics of aquatic and terrestrial stages

This selection resulted in a list of 24 anopheline species which were considered important malaria vectors in Indonesia. The history of the taxonomic status of these 24 species is shown in Table 3.4, to which the scientific names as they are in use to-day (Knight & Stone, 1977) have been added. Throughout the remainder of this review these latter names will be used, which for easier reference are shown separately in Table 3.5. The geographic distribution of these species across the major islands of Indonesia is presented in Table 3.6. These data were derived from Bonne-Wepster & Swellengrebel (1953).

When studying the anophelines of South West Asia, it is interesting to notice the number of species that were originally described from Indonesia, as confirmed by the type locality for each species. Out of the 24 species mentioned in Table 3.5, seven were originally collected in and described from Indonesia (Java, Sumatra, Celebes), demonstrating the important geographical position this region played in the study of anophelines.

In recent years several species complexes of the genus *Anopheles* have been described (Service, 1988; White, 1989), of which the *An. balabacencis* complex, the *An. punctulatus* complex and the *An. maculatus* complex are present in the Indonesian region. Much research in this field is still required in order to elucidate the nature of ecological and behavioural variation within species, which are known to breed in different habitats. For instance *An. sundaicus*, which is known to breed in fresh as well as in brackish water, may exist of a sibling complex of which the individual species have distinct ecological requirements.

Table 3.2 Systematic index of the anophelines of Indonesia (after: Swellengrebel and Rodenwaldt, 1932).

I. Subgenus: *Brugella* (Edwards).

1.	*Anopheles travestitus*	Brug, 1928.

II. Subgenus: *Bironella* (Theobald).

2.	*Anopheles bironelli*	Christophers, 1924.

species: *Anopheles papuae* (Sw. and Sw.-d Gr.):

3.	*A. papuae typicus*	Sw. & Sw.-d Gr., 1920 (*).
4.	*A. papuae typicus var. brugi*	Soesilo & v. Slooten, 1931.
5.	*A. papuae derooki*	Soesilo & v. Slooten, 1931.
6.	*A. papuae soesiloi*	Soesilo & v. Slooten, 1931.

III. Subgenus: *Anopheles sensu strictiori* (Meigen).

A. Myzorhynchus - group.

species: *Anopheles hyrcanus* (Pallas):

7.	*A. hyrcanus typicus var. sinensis*	Wiedemann, 1828.
8.	*A. hyrcanus typicus var. nigerrima*	Giles, 1900.
9.	*A. hyrcanus typicus var. pseudopicta*	Grassi, 1899.
10.	*A. hyrcanus separatus*	Leicester, 1908.
11.	*A. hyrcanus hunteri*	Strickland, 1916.
12.	*A. hyrcanus peditaeniatus*	Leicester, 1908.
13.	*A. gigas var. sumatrana*	nov. var., 1932.

species: *Anopheles barbirostris* (v.d. Wulp):

14.	*A. barbirostris typicus*	v.d. Wulp, 1884.
15.	*A. barbirostris typicus, var. barbumbrosa*	Strickland & Chowdhury, 1927.
16.	*A. barbirostris bancrofti*	Giles, 1902.
17.	*A. barbirostris bancrofti var. pseudobarbirostris*	Ludlow, 1902.
18.	*A. albotaeniatus*	Theobald, 1903.
19.	*A. albotaeniatus var. montana*	Stanton & Hacker, 1917.
20.	*A. umbrosus*	Theobald, 1903.
21.	*A. umbrosus var. novumbrosa*	Strickland, 1916.
22.	*A. umbrosus var. similissima*	Strickland & Chowdhury,1927.

B. Mennemyia - group.

23.	*Anopheles brevipalpis*	Roper, 1914.

C. Lophoscelomyia - group.

24.	*Anopheles annandalei var. djajasanensis*	Brug, 1926.

D. Stethomyia - group.

species: *Anopheles aitkenii* (James):

25.	*A. aitkenii typicus*	James, 1903.
26.	*A. aitkenii typicus var. bengalensis*	Puri, 1930.
27.	*A. aitkenii typicus var. insulae florum*	Sw. & Sw.-d Gr., 1920.
28.	*A. aitkenii palmatus*	Rodenwaldt, 1927.

Table 3.2 Continued

IV. Subgenus: *Paleomyzomyia* (Nov. Subg.).

29.	*Anopheles parangensis*	Ludlow, 1914.

V. Subgenus: *Pseudomyzomyia* (Theobald).

30.	*A. ludlowi var. sundaica*	Rodenwaldt, 1926.
31.	*A. ludlowi (type)*	Theobald, 1903.
32.	*A. vagus*	Dönitz, 1902.
33.	*A. subpictus*	Grassi, 1899.
34.	*A. subpictus var. malayensis*	Hacker, 1921.

VI. Subgenus: *Myzomyia* (Blanchard).

35.	*A. aconitus*	Dönitz, 1902.
36.	*A. minimus*	Theobald, 1901.
37.	*A. minimus var. varuna*	Iyengar, 1924.

VII. Subgenus: *Neocellia* (Theobald).

species: *Anopheles fuliginosus* (Giles):

38.	*A. fuliginosus typicus*	Giles, 1900.
39.	*A. fuliginosus philippinensis*	Ludlow, 1902.
40.	*A. fuliginosus pallidus*	Theobald, 1901.

41.	*A. ramsayi*	Covell, 1927.
42.	*A. schuffneri*	Stanton, 1915.
43.	*A. maculatus*	Theobald, 1901.
44.	*A. karwari*	James, 1903.

VIII. Subgenus: *Cellia* (Theobald).

45.	*A. errabundus*	Swellengrebel, 1925.
46.	*A. incognitus*	Brug, 1931.

IX. Subgenus: *Neomyzomyia* (Theobald).

A. Punctulatus - group.

47.	*A. leucosphyrus*	Dönitz, 1901.
48.	*A. leucosphyrus var. hackeri*	Edwards, 1921.
49.	*A. amictus*	Edwards, 1921.

species: *Anopheles punctulatus* (Dönitz):

50.	*A. punctulatus typicus*	Dönitz, 1901.
51.	*A. punctulatus typicus var. moluccensis*	Sw. & Sw.-d Gr., 1920.
52.	*A. punctulatus longirostris*	Brug, 1928.
53.	*A. punctulatus longirostris var. annulata*	Brug, 1930.
54.	*A. punctulatus tesselatus*	Theobald, 1901.
55.	*A. punctulatus tesselatus var. orientalis*	Sw. & Sw.-d Gr., 1920.

B. Kochi - group.

56.	*Anopheles kochi*	Dönitz, 1901.

(*) Sw. & Sw.-d Gr.: Swellengrebel and Swellengrebel-de Graaf.

Table 3.3 Systematic index of the anophelines of the Indo-Australian region (after: Bonne-Wepster and Swellengrebel, 1953.)

I. Genus: *Bironella* (Theobald).

Subgenus: *Bironella* (Theobald).

1. *B. gracilis*	Theobald, 1905.	1b;2.
2. *B. confusa*	Bonne-Wepster, 1951.	1a,b,c;2.
3. *B. occulta*	Bonne-Wepster, 1951.	1a,b,c;2.
4. *B. papuae*	Sw. & Sw.-d Gr., 1920.	1b,c;2.
5. *B. papuae* var. *brugi*	Soe. & Van Sloo., 1931.	1a,b,c;2;4.
6. *B. soesiloi*	Strickl. & Chowdhury, 1931.	1b,c;2.

Subgenus: *Brugella* (Edwards).

7. *B. hollandi*	Taylor, 1934.	1b;2.
8. *B. travestita*	Brug, 1928.	1b;2;4.
9. *B. walchi*(?)	Soesilo, 1932.	1b,c;2;4.

II. Genus: *Anopheles* (Meigen).

Subgenus: *Anopheles* (Meigen).
Group : *Anopheles* (Root).
series : *Anopheles* (Edwards).

10. *A. aitkeni*	James, 1903.	(*)
11. *A. aitkeni*	James, aberrant form.	1b,c;4.
12. *A. aitkeni* var. *bengalensis*	Puri, 1930.	1b.
13. *A. aitkeni* var. *borneensis*	McArthur, 1949.	1b;4.
14. *A. insulaeflorum*	Sw. & Sw.-d Gr., 1919.	1b.
15. *A. palmatus*	Rodenwaldt, 1926.	1b.
16. *A. alongensis*	Venhuis, 1940.	1b;3.
17. *A. atratipes*	Skusse, 1889.	2.
18. *A. powelli*	Lee, 1944.	1b;2.
19. *A. stigmaticus*	Skusse, 1889.	2.
20. *A. brevipalpis*	Roper, 1914.	1b.
21. *A. lindesayi*	Giles, 1900.	3.
22. *A. lindesayi* var. *benguetensis*	King, 1931.	1b;3.
23. *A. lindesayi* var. *cameronensis*	Edwards, 1929.	1b;3.
24. *A. bulkleyi*	Causey, 1937.	1b;3.
25. *A. gigas*	Giles, 1901.	1b.
26. *A. gigas* var. *formosus*	Ludlow, 1909.	1b;3.
27. *A. gigas* var. *baileyi*	Edwards, 1929.	1b;3.
28. *A. gigas* var. *danaubento*	Moch. & Waland., 1934.	1b;4.
29. *A. gigas* var. *oedjalikalahensis*	Naiggolan, 1939.	1b;4.
30. *A. gigas* var. *sumatranus*	Swell. & Rodenw., 1932.	1b;4.
31. *A. wellingtonianus*	Alcock, 1912.	1b;4.

series: Lophoscelomyia (Edwards).

32. *A. annandalei*	Baini Prashad, 1918.	1b.
33. *A. annandalei* var. *interruptus*	Puri, 1929.	1b,c;3.
34. *A. asiaticus*	Leicester, 1904.	1b;3.

Table 3.3 Continued

series: Myzorhynchus (Edwards).

35. *A. albotaeniatus*	Theobald, 1903.	1b.
36. *A. montanus*	Stanton & Hacker, 1917.	1b;4.
37. *A. umbrosus*	Theobald, 1903.	(*)
38. *A. baezai*	Gater, 1933.	(*)
39. *A. letifer*	Gater, 1944.	(*)
40. *A. roperi*	Reid, 1950.	(*)
41. *A. brevirostris*	Reid, 1950.	1b,c;3.
42. *A. samarensis*	Rozeboom, 1951.	1b;3.
43. *A. separatus*	Leicester, 1908.	1b(?).
44. *A. hunteri*	Strickland, 1916.	1b(?).
45. *A. similissimus*	Strickl. & Chowdh., 1927.	1b,c.
46. *A. barbirostris*	Van der Wulp, 1884.	(*)
47. *A. vanus*	Walker, 1859.	(*)
48. *A. barbumbrosus*	Strickl. & Chowdh., 1927.	1b,c.
49. *A. bancrofti*	Giles, 1902.	(*)
50. *A. pseudobarbirostris*	Ludlow, 1902.	1b,3.
51. *A. bancrofti* var. *barbiventris*	Brug, 1938.	1b;4 .
52. *A. hyrcanus*	Pallas, 1771.	3.
53. *A. sinensis*	Wiedemann, 1828.	(*)
54. species near *sinensis*	Colless, 1948.	4.
55. *A. lesteri*	Baisas and Hu, 1936.	1b;3.
56. *A. pseudosinensis*	Baisas, 1935.	1b,3.
57. *A. nigerrimus*	Giles, 1900.	(*)
58. *A. venhuisi*	Bonne-Wepster, 1951.	5.
59. *A. indiensis*	Theobald, 1901.	1b,c.
60. *A. peditaeniatus*	Leicester, 1908.	1b.
61. *A. argyropus*	Swellengrebel, 1914.	1b,c.

Subgenus: *Myzomyia* (Blanchard).
group : Neomyzomyia (Christophers).

62. *A. aurirostris*	Watson, 1910.	1b;3.
63. *A. watsoni*	Leicester, 1908.	1b;3.
64. *A. kochi*	Dönitz, 1901.	(*)
65. *A. kolambuganensis*	Baisas, 1931.	1b;3.
66. *A. tesselatus*	Theobald, 1901.	(*)
67. *A tesselatus* var. *orientalis*	Swell. & S.-De Gr.	1b;4.
68. *A. leucosphyrus*	Dönitz, 1901.	(*)
69. *A. leucosphyrus* var. *pujutensis*	Colless, 1948.	1b.
70. *A. leucosphyrus* var. *riparis*	King & Baisas, 1936.	1b;4.
71. *A. balabacensis*	Baisas, 1936.	(*)
72. *A. hackeri*	Edwards, 1921.	1b.
73. *A. leucosphyrus* near *hackeri*	(Celebes form)	1a,b,c;4.
74. *A. cristatus*	King & Baisas, 1936.	1b;3;4.
75. *A. longirostris*	Brug, 1928.	1b;2;4.
76. *A. annulatus*	De Rook, 1930.	1b;2;4.
77. *A. lungae*	Belkin and Schlosser, 1944.	1b;2.
78. *A. meraukensis*	Venhuis, 1932.	1b;2.
79. *A. amictus*	Edwards, 1921.	2.
80. *A. amictus* var. *hilli*	Woodhill and Lee, 1944.	2.
81. *A. incognitus*	Brug, 1931.	1a,b,c;2;4.
82. *A. novaguinensis*	Venhuis, 1933.	1b;2.
83. *A. punctulatus*	Dönitz, 1901.	(*)
84. *A. farauti*	Laveran, 1902.	(*)
85. *A. koliensis*	Owen, 1945.	(*)
86. *A. clowi*	Rozeboom and Knight, 1946.	1a,b;2;4.
87. *A. annulipes*	Walker, 1856.	2.

Table 3.3 Continued

group: Myzomyia (Christophers).

88.	*A. aconitus*	Dönitz, 1902.	(*)
89.	*A. minimus*	Theobald, 1901.	(*)
90.	*A. minimus* var. *flavirostris*	Ludlow, 1914.	(*)
91.	*A. filipinae*	Manalang, 1930.	3.
92.	*A. mangyanus*	Banks, 1906.	3.
93.	*A. fluviatilis*	James, 1902.	3.
94.	*A. culicifacies*	Giles, 1901.	3.
95.	*A. jeyporiensis*	James, 1902.	3.
96.	*A. jeyporiensis* var. *candidiensis*	Koidzumi, 1924.	3.

group: Pseudomyzomyia (Christophers).

97.	*A. sundaicus*	Rodenwaldt, 1925.	(*)
98.	*A. litoralis*	King, 1932.	3.
99.	*A. ludlowi*	Theobald (?), 1903.	1b.
100.	*A. parangensis*	Ludlow, 1914.	1b.
101.	*A. subpictus*	Grassi, 1899.	(*)
102.	*A. subpictus* var. *indefinitus*	Ludlow, 1904.	1b;3.
103.	*A. subpictus* var. *malayensis*	Hacker, 1921.	1b;3?.
104.	*A. vagus*	Dönitz, 1902.	1b?.
105.	*A. vagus* var. *limosus*	King, 1932.	1b;3.

group: Neocellia (Christophers).

106.	*A. annularis*	Van der Wulp, 1884.	(*)
107.	*A. errabundus*	Swellengrebel, 1925.	1a,b,c;4.
108.	*A. philippinensis*	Ludlow, 1902.	3,4.
109.	*A. pallidus*	Theobald, 1901.	1b;4.
110.	*A. schuffneri*	Stanton, 1915.	1b.
111.	*A. maculatus*	Theobald, 1901.	(*)
112.	*A. maculatus* var. *dravidicus*	Christophers, 1924.	1b,c;3.
113.	*A. karwari*	James, 1903.	2.
114.	*A. jamesi*	Theobald, 1901.	1b;3.
115.	*A. ramsayi*	Covell, 1927.	1b,c.
116.	*A. splendidus*	Koidzumi, 1920.	3.

(*) : species is included in this report.
1a : geographical distribution unknown.
1b : no epidemiological data, or species considered not to be dangerous.
1c : no data on the bionomics of the species.
2 : species of the Australian region.
3 : species occuring north of Sumatra, Borneo, and Celebes.
4 : species known from very few places or small islands only.
5 : taxonomic status has changed.

Table 3.4 See page 18, 19

Table 3.5 Anopheline species considered to be important vectors of malaria in Indonesia in 1953 (after Tables 3.3 and 3.4). Scientific names according to Knight and Stone (1977).

	species	**author**	**type locality**
1.	*Anopheles aitkenii*	James, 1903.	Karwar, Bombay (near Goa Frontier), India.
2.	*Anopheles umbrosus*	Theobald, 1903.	[Pekan], Penhang, [Pahang], Malaya
3.	*Anopheles baezai*	Gater, 1933.	Pulau Langkawi,[Perlis], Malaya
4.	*Anopheles letifer*	Sandosham, 1944.	Malaya
5.	*Anopheles roperi*	Reid, 1950.	Kuala Kubu Bahru, Selangor, Malaya
6.	*Anopheles barbirostris*	Van der Wulp, 1884.	Mount Ardjoeno, Java
7.	*Anopheles vanus*	Walker, 1859.	Makassar, Celebes
8.	*Anopheles bancrofti*	Giles, 1902.	Burpengaly, Queensland, Australia
9.	*Anopheles sinensis*	Wiedemann, 1828.	[Canton], China
10.	*Anopheles nigerrimus*	Giles, 1900.	Calcutta, [West Bengal], India
11.	*Anopheles kochi*	Dönitz, 1901.	Padang, [Tapanuli], Sumatra
12.	*Anopheles tesselatus*	Theobald, 1901.	Taipang (=Taiping), Perak, Malaya
13.	*Anopheles leucosphyrus**	Dönitz, 1901.	Kajoe Tanam, north of Padan, [Tapanuli], Sumatra
14.	*Anopheles balabacensis**	Baisas, 1936.	Balabac, Balabac Island,[Palawan], Philippines
15.	*Anopheles punctulatus***	Dönitz, 1901.	Stephansort, New Guinea & Herbertshoehe, Bismarck Archipelago
16.	*Anopheles farauti***	Laveran, 1902.	Faureville, Vate(Efate), New Hebrides
17.	*Anopheles koliensis***	Owen, 1945.	Koli Area, Guadalcanal, Solomon Islands
18.	*Anopheles aconitus*	Dönitz, 1902.	Kajoe Tanam, north of Padang, [Tanapuli], Sumatra & Willem Island, Soekaboemi, Java
19.	*Anopheles minimus*	Theobald, 1901.	Pokfulam, Hong Kong
20.	*Anopheles flavirostris*	Ludlow, 1914.	Camp Wilhelm, Tayabas (= Quezon),[Luzon], Philippines
21.	*Anopheles sundaicus*	Rodenwaldt, 1925.	Indonesia
22.	*Anopheles subpictus*	Grassi, 1899.	India
23.	*Anopheles annularis*	Van der Wulp, 1884.	Mount Ardjoeno, Java
24.	*Anopheles maculatus****	Theobald, 1901.	Hong Kong, [China]

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* species belonging to the *A. balabacensis* complex.
** species belonging to the *A. punctulatus* complex.
*** species belonging to the *A. maculatus* complex.

Table 3.4 History of taxonomical status of important Indonesian malaria vectors from 1921 to 1977 (Authors see text).

Year	**1921** (Swellengrebel)	**1932** (Swellengrebel/Rodenwaldt)	**1953** (Bonne-W./Swellengr.)	**1977** (Knight and Stone)	species no. in this review
Group/Genus	Rossi-group	Pseudomyzomyia (Theob., 1907)	Myzomyia (Blanchard, 1902)	Cellia (Theobald, 1902)	
Species (Author)	*Myzomyia ludlowi* (Theobald, 1903)	*Anopheles ludlowi var. sundaica* (Rodenwaldt, 1925)	*Anopheles sundaicus* (Rodenwaldt, 1925)	*Anopheles sundaicus* (Rodenwaldt, 1925)	21
	M. rossi (Giles, 1899)	*A. subpictus* (Grassi, 1899)	*A. subpictus* (Grassi, 1899)	*A. subpictus* (Grassi, 1899)	22
Group/Genus	Aconita-group	Myzomyia (Blanchard, 1902)	Myzomyia (Blanchard, 1902)	Cellia (Theobald, 1902)	
Species (Author)	*Myzomyia aconita* (type) (Dönitz, 1902)	*Anopheles aconitus* (Dönitz, 1902)	*Anopheles aconitus* (Dönitz, 1902)	*Anopheles aconitus* (Dönitz, 1902)	18
	M. aconita (variation) (Dönitz, 1902)	*A. minimus var. varuna* (Iyengar, 1924)	*A. m. var. flavirostris* (Ludlow, 1914)	*A. flavirostris* (Ludlow, 1914)	20
	M. minima (Theobald, 1901)	*A. minimus* (Theobald, 1901)	*A. minimus* (Theobald, 1901)	*A. minimus* (Theobald, 1901)	19
Group/Genus	Punctulata-group	Neomyzomyia (Theob., 1910)	Myzomyia (Blanchard, 1902)	Cellia (Theobald, 1902)	
Species (Author)	*Neomyzomyia punctulata* (Dönitz, 1901)	*Anopheles punctulatus typicus* (Dönitz, 1901)	*Anopheles punctulatus* (Dönitz, 1901)	*A. punctulatus* (Dönitz, 1901)	15
	Nyssorhynchus annulipes var. moluccensis (Sw./Sw.-de Graaf, 1920)	*A. punctulatus typicus var. moluccensis* (Sw./Sw.- de Graaf, 1920)	*A. farauti* (Laveran, 1902)	*A. farauti* (Laveran, 1902)	16
		A. punctulatus tesselatus (Theobald, 1901)	*A. tesselatus* (Theobald, 1901)	*A. tesselatus* (Theobald, 1901)	12
	Neomyzomyia leucosphyra (Dönitz, 1901)	*A. leucosphyrus* (Dönitz, 1901)	*A. leucosphyrus* (Dönitz, 1901)	*A. leucosphyrus* (Dönitz, 1901)	13
	Cellia kochi (Dönitz, 1901)	*A. kochi* (Dönitz, 1901)	*A. kochi* (Dönitz, 1901)	*A. kochi* (Dönitz, 1901)	11
			A. balabacensis (Baisas, 1936)	*A. balabacensis* (Baisas, 1936)	14
			A. koliensis (Owen, 1945)	*A. koliensis* (Owen, 1945)	17

Group/Genus	Nyssorhynchus-group	Neocellia (Theob., 1907)	Myzomyia (Blanchard, 1902)	Cellia (Theobald, 1902)	
Species (Author)	*Nyssorhynchus fuliginosus* (Giles, 1900)	*Anopheles fuliginosus typicus* (Giles, 1900)	*Anopheles annularis* (Van der Wulp, 1884)	*Anopheles annularis* (Van der Wulp, 1884)	23
	N. maculatus (Theobald, 1901)	*A. maculatus* (Theobald, 1901)	*A. maculatus* (Theobald, 1901)	*A. maculatus* (Theobald, 1901)	24
			A. maculatus var. dravidicus (Christophers, 1924)	*A. maculatus* (Theobald, 1901)	24
Group/Genus	Myzorhynchus-group	Anopheles s.s. (Meigen, 1818)	Anopheles (Meigen, 1818)	Anopheles (Meigen, 1818)	
Species (Author)	*Myzorhynchus sinensis* (Wiedemann, 1828)	*Anopheles hyrcanus typicus var. sinensis* (Wiedemann, 1828)	*Anopheles sinensis* (Wiedemann, 1828)	*Anopheles sinensis* (Wiedemann, 1828)	9
	M. sinensis var. vanus (Theobald, ?)	*A. hyrcanus typicus var. nigerrima* (Giles, 1900)	*A. nigerrimus* (Giles, 1900)	*A. nigerrimus* (Giles, 1900)	10
	M. barbirostris (Van der Wulp, 1884)	*A. barbirostris typicus* (Van der Wulp, 1884)	*A. barbirostris* (Van der Wulp, 1884)	*A. barbirostris* (Van der Wulp, 1884)	6
		A. barbirostris bancrofti (Giles, 1902)	*A. bancrofti* (Giles, 1902)	*A. bancrofti* (Giles, 1902)	8
			A. bancrofti var. barbiventris (Brug, 1938)	*A. bancrofti* (Giles, 1902)	8
	M. umbrosus (Theobald, 1903)	*A. umbrosus* (Theobald, 1903)	*A. umbrosus* (Theobald, 1903)	*A. umbrosus* (Theobald, 1903)	2
		A. umbrosus var. novumbrosa (Strickland, 1916)	*A. umbrosus* (Theobald, 1903)	*A. umbrosus* Theobald,(1903)	2
			A. baezai (Gater, 1933)	*A. baezai* (Gater, 1933)	3
			A. letifer (Gater, 1944)	*A. letifer* (Sandosham, 1944)	4
			A. roperi (Reid, 1950)	*A. roperi* (Reid, 1950)	5
			A. vanus (Walker, 1859)	*A. vanus* (Walker, 1859)	7
			A. venhuisi (Bonne-Wepster, 1951)	*A. nigerrimus* (Giles, 1900)	10
			A. indiensis (Theobald, 1901)	*A. nigerrimus* (Giles, 1900)	10

Table 3.6 Geographical distribution of 24 important malaria vectors of Indonesia. (source: Bonne Wepster & Swellengrebel, 1953; Knight & Stone, 1977).

Faunistic region	Australian	Oriental			
Island	Irian Jaya	Java	Sumatra	Borneo	Celebes
A. aitkenii		○	○	○	○
A. umbrosus		○	○	●	○
A. beazai		○	○	●	○
A. letifer			○	○	
A. roperi			○	○	
A. barbirostris	○	○	●	○	○
A. vanus				○	●
A. bancrofti	●				
A. sinensis			●		
A. nigerrimus		○	●	○	○
A. kochi		○	●	○	○
A. tesselatus		●	○	○	○
A. leucosphyrus			●	○	
A. balabacensis		○		●	
A. punctulatus	●				
A. farauti	●				
A. koliensis	●				
A. aconitus		●	●	○	○
A. minimus		○	○	○	●
A. flavirostris		●	?	○	●
A. sundaicus		●	●	●	●
A. subpictus	○	●	●	○	●
A. annularis		○	●	○	○
A. maculatus		●	●	○	○

Explanation:

○ = species present in that part of Indonesia;

● = species has shown to play a role in malaria transmission in that part of Indonesia.

? = distribution and role as vector unknown in that area.

3B – The bionomics of aquatic stages of anophelines

Introduction

An understanding of the bionomics of the vector is of importance in connection with epidemiological studies and in relation to malaria control. This branch of biology, often referred to as ecology, has to do with the relation of organisms to their environment. It involves, in so far as mosquitoes are concerned, place and time of oviposition, factors controlling larval development and also mating, feeding, flight, and resting behaviour of adults, together with whatever tropisms are believed to govern the reaction of the insect to environmental change. The various stages of the life-cycle will be considered in the following sections, starting with the breeding habitats.

At some stages of their life-cycle mosquitoes require a water surface on which to deposit their eggs. Even under suitable climatological circumstances, areas free of any stagnant water are usually free of malaria. Based on these principles one can extract viable control methods (WHO, 1982):

- The application of chemical larvicides.
- The introduction of biological agents in the breeding habits.
- Environmental management works.

These methods can be used on a large scale and can be highly effective, as has been demonstrated by numerous examples elsewhere (Bruce-Chwatt, 1985). However, in the Dutch East Indies of pre-World War II, chemical larvicides (and also adulticides for that matter) were hardly available and larval control was mainly based on environmental management. For the purpose of this review we studied factors such as larval ecology, breeding habits and environmental factors (light, temperature, salinity etc.) in relation to the control methods used in Indonesia at that time, in particular *species sanitation.* We are particularly interested in differences in breeding habits that can be exploited for vector control to-day.

At the start of this century research in Indonesia was mainly focused on breeding sites. Hygienists considered malaria control at the larval or pupal stage as more important than any other control method developed so far. However, they faced many problems (De Raadt, 1918):

- There was no evidence that, once anophelines were eliminated in certain breeding places (e.g. fish-ponds), they could select other habitats (like rice fields). In other words, hygienists were unable to determine species as being 'specialised' or 'indifferent'.
- Nothing was known about the perniciousness of the anopheline species.
- For certain species it was not known whether they were able to transmit malaria (*An. argyropus*; *An. schuffneri*).
- In some areas a species transmits malaria, whereas in another area it is completely harmless.

Although De Raadt mentioned some species which could be controlled, he was not convinced that malaria control at the larval/pupal stage could be successful in Indonesia. This view changed later as fundamental research on vector bionomics and breeding habitats gave more insight to viable control of the aquatic stages. In the next section the breeding habits of the 24 species listed in Table 3.5 will be described. It must be stated that many of the descriptions found are not detailed, and apart from salinity estimations (mostly estimated by taste!) there are hardly any chemical (acidity, oxygen, nitrogen etc.), physical (temperature), meteorological (microclimatic) or ecological data given. Therefore it must be kept in mind that although species seem to be more or less indifferent, detailed studies of the breeding habits could determine whether species actually tolerate a broad spectrum of e.g. salt or organic matter (Williamson, 1927). This research could solve the question why for example *An. sundaicus* breeds extensively in certain marine fish-ponds but cannot be found in the same breeding places a few km further on; it might be caused by a small change in salinity (Balfour, 1922; Kuipers, 1937).

Characteristics of larval habitats

In Indonesia studies on larval habitats began soon after Ross's discovery of the transmission cycle in 1897. Many expeditions in the Archipelago (mainly on Sumatra and Java) resulted in fairly good descriptions of breeding sites and distribution maps of the anophelines so far known (Swellengrebel & Swellengrebel-de Graaf, 1919a; Schuurmans Stekhoven & Schuurmans Stekhoven-Meyer, 1922). Fischer (1917) describes 13 different factors which are of importance regarding anopheline breeding places. Schüffner (1916a; 1917) stressed the importance of knowing the exact breeding habitats in relation to the control of aquatic stages. Swellengrebel & Swellengrebel-de Graaf (1919a) describe breeding sites in great detail and list six general aspects required to attract a female that is ready to oviposit:

1. *Vegetation*: With few exceptions it can be said that Indonesian anophelines are found in breeding sites where vegetation is present. Some antagonism between certain larvae and plants (*An. sinensis* and *An. barbirostris* with *Pistia stratiotes*) is reported. On the other hand water completely covered by vegetation is free of anopheline larvae (Russell *et al.*, 1946) and some plants are thought to act as repellents to anophelines (Boyd, 1949).

2. *Size of the breeding place*: Authors noticed anophelines breeding in small pools but also in lakes. They state however that breeding in habitats without vegetation occurs only in covered small pools (protection against predators; optimal foraging. The conditions under which this occurs have not been described.

3. *Depth of the breeding place*: Larvae were mainly found in shallow water collections, and it was assumed that the way the larva feeds, and the frequency of breathing plays an important role with respect to water depth.

4. *Turbidity/pollution of the water*: Most of the anophelines avoid turbid or polluted water. Authors found *An. subpictus, An. kochi, An. punctulata*, and *An. sinensis* in turbid water, and *An. punctulata* in polluted water. Hill-species require clear water. Directly related to pollution is the oxygen content of the water, and larvae die rapidly when the oxygen concentration declines (Russell *et al.*, 1946).

5. *Absence of predacious fish species*: Russell *et al.* (1946) and others, report the relationship between larvivorous fish, their effectivity and the role of vegetation in which the larvae seek shelter.

6. *Sunlight and shade*: Russell *et al.* (1946) distinguish three groups as regards the relation of sunlight and shade to their typical breeding places: heliophilic (sunloving) species, like *An. maculatus*; heliophobic species like *An. umbrosus* and *An. leucosphyrus*; and indifferent species having well marked tendencies towards sun or shade (e.g. *An. culicifacies, An. albimanus, An. stephensi*).
Russell *et al.* (1946) add other important factors which determine breeding of anophelines (7-12):

7. *Water movement*: Some species show high preference for running water, (*An. aitkenii*) whereas others require standing water. Several authors (e.g. Rodenwaldt, 1925) mention that tidal movement of seawater keeps *An. sundaicus* out of mangrove forests, but Russell *et al.* (1946) disagree with this.

8. *Temperature*: Water temperature determines not only the development of larvae but also the distribution of the species. In general anophelines are less tolerant to low temperatures than culicines, a fact which may contribute to the more tropical distribution of the former.

9. *Surface tension*: Most mosquito larvae must remain at the surface in order to breathe, and so are dependent on surface tension. In Boyd (1949) an explanation for the orientation of larvae around vegetation and debris is given, based on surface tension.

10. *Hydrogen-ion concentration*: Though seen as unimportant by Russell *et al.* (assuming that anophelines tolerate a broad spectrum of pH values), Boyd (1949) states the value of pH-measurements.

11. *Mineral salts*: Most species can be readily classified as salt water, brackish water or fresh water forms.

12. *Larval food*: In nature all mosquito larvae probably depend directly or indirectly upon microscopic plant life for their nutrition. The type of microscopic plant life as influenced by pH and other factors may determine to some extent the species of mosquito present.

Boyd (1949) adds:

13. *Nitrates*: The impact of nitrogen on larvae can be considerable, inhibiting certain species to breed (Williamson, 1928).

Species-specific review of larval habitats

Using these criteria (1-13) details of the breeding habitats of the 24 selected anopheline species are listed below. From the many references cited it appears as if most species occupy a very wide range of breeding habitats. It should be mentioned, however, that on a local scale this is rare, and mostly one or two habitats are preferred. These habitats will be studied with a view to estimating for each species the level of danger related to malaria epidemiology and the potential for vector control. For easier reference, the data from this section are summarized in Table 3.7.

Whenever the years 1921, 1932, and 1953 are mentioned, they refer to the taxonomic works cited in section a of this chapter. Throughout the remaining chapters of this review, the nomenclature used was taken from Knight & Stone (1977).

1. *Anopheles aitkenii* (James, 1903).
Swellengrebel & Swellengrebel-de Graaf (1919a) classify *An. aitkenii* as a typical 'hill-species', they found the species in low hills up to 1500 m. Russell *et al.* (1946) denote *An. aitkenii* as an upland form, Boyd (1949) as a typical jungle form. In 1921, 1932, and 1953 the descriptions of the breeding places remain the same: the larva prefers shaded breeding places, particularly at the edges of swiftly running small streams, seepage springs; in jungle and forest, seldom in rice fields. It has been found in swamps, marshes, channels, rivers, and rock-pools, once at the mouth of a hill stream, where it reached the sea; the water was decidedly brackish. Although in 1953 the epidemiological importance of this species is neglected, Swellengrebel (1920a) gives records of malaria in which *An. aitkenii* played a role (though together with other more dangerous species like *An. aconitus*), and he found *An. aitkenii* for 97% in running small streams.

2. *Anopheles umbrosus* (Theobald, 1903).
De Raadt (1918) classified *An. umbrosus* as a specialised species. Of the three types of specialised species (1. forest species, 2. shade-demanding species and 3. running-water species) *An. umbrosus* belongs to the first type, breeding inside forests and depositing eggs in clear water. Swellengrebel & Swellengrebel-de Graaf (1919a) distinguish brackish and fresh water breeding places, and classify

Table 3.7 Breeding site characteristics and natural and man-made breeding sites of important malaria vectors in Indonesia.

BREEDING SITE CHARACTERISTICS		A. aitkenii	A. umbrosus	A. beazai	A. letifer	A. roperi	A. barbirostris	A. vanus	A. bancrofti	A. sinensis	A. nigerrimus	A. kochi	A. tesselatus	A. leucosphyrus	A. balabacensis	A. punctulatus	A. farauti	A. koliensis	A. aconitus	A. minimus	A. flavirostris	A. sundaicus	A. subpictus	A. annularis	A. maculatus
Light intensity	Heliophilic		●		●		●	●		*	*	●			●	*	●	*	*	●		*	*		*
	Heliophobic	*	*	*	*	*	*	*	*			●	*	*	*	●	●	●	●	*	*			*	
Salinity of the water	High (brackish)		●	*			●	●				●	●	●		●	●	●				*	*	●	
	Low (fresh)	*	●		*	*	*	*	*	*	*	*	●	*	*	*	●	●	*	*	*	●	●	*	*
Turbidity of the water	Clear	*	*	?	●	*	*	*	*	*	*	●	●	●	*	●	●	*	*	●	*	*	*	*	*
	Polluted		●	?	*	●						●	●	●		●	●	●		●		●	●		
Water movement	Stagnant		*	*	*	*	●	●		*	*	●	●	●	*	*	*	*	*	●	●	*	*	*	
	Running	*	●				●	●	*	●		●	●	●					●	*	*		●	●	*
Vegetation	Higher plants, algae etc.	*	?	?	*	*	*	*	*	*	*	●	*	●		●	●	●	*	*	*	*	●	*	
	No vegetation		?	?								●	●	●	*	●	●	●		●	●		●		*

* Common, most typical for the species concerned

● Rare

? No reference found

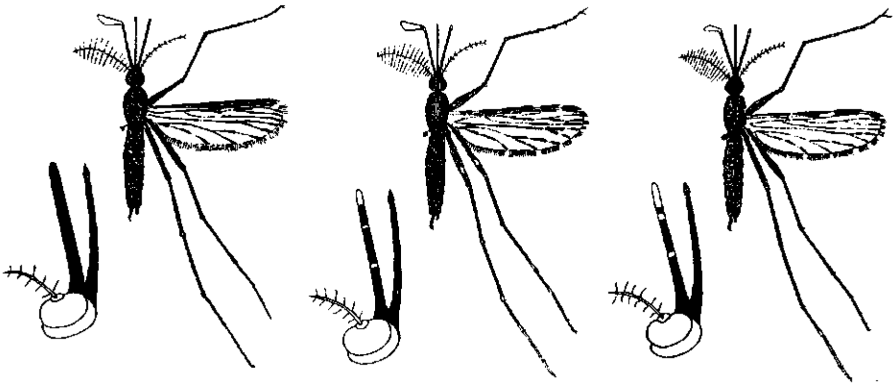
NATURAL AND MAN-MADE BREEDING SITES		A. aitkenii	A. umbrosus	A. beazai	A. letifer	A. roperi	A. barbirostris	A. vanus	A. bancrofti	A. sinensis	A. nigerrimus	A. kochi	A. tesselatus	A. leucosphyrus	A. balabacensis	A. punctulatus	A. farauti	A. koliensis	A. aconitus	A. minimus	A. flavirostris	A. sundaicus	A. subpictus	A. annularis	A. maculatus
Natural water collections (large)	Lagoons																	○				●	*		
	Lakes									*	*								○					○	○
	Marshes	*	●	●			○	○	●	*	*			*				○	*			*	*	*	
	Bogs									○															
	Slow flowing rivers	*					○	○	*	○											○				*
Man-made water collections (large)	Borrow pits (large)									*	*											○	○		
	Rice fields	○					●	●		●	●	○	●			○			●	○	○	*	●	●	○
	Fish ponds		*				*	*			○	○	*	*		○		○	●	*	○	●	●	●	
	Irrigation channels										*									○	○		○		
Natural water collections (small)	Small streams	●	*			●	*	*	*	*	○	○	○	*		○	*	●		●	●				●
	Seepage springs	●												*	*					○		○	○		○
	Pools	*	*	●	●					○		*	*	*	*	*	*	●			○				
	Wells						*	*													*	○	○		
	Depressions in ground													*	*										
Man-made water collections (small)	Overflow water					●									○						○				
	Irrigation ditches		*		●	*	○	○	*	*		*				○	*		*	●	○		*	○	*
	Borrow pits (small)																			○				○	
	Wheel ruts													*	○										
	Hoof prints											*	○	*		●						○	○		
	Puddles near rice fields															○	○	○					○		
Artificial sites	empty cans, shells etc.											○				*	*		○	○			○	○	

● Preferred habitat

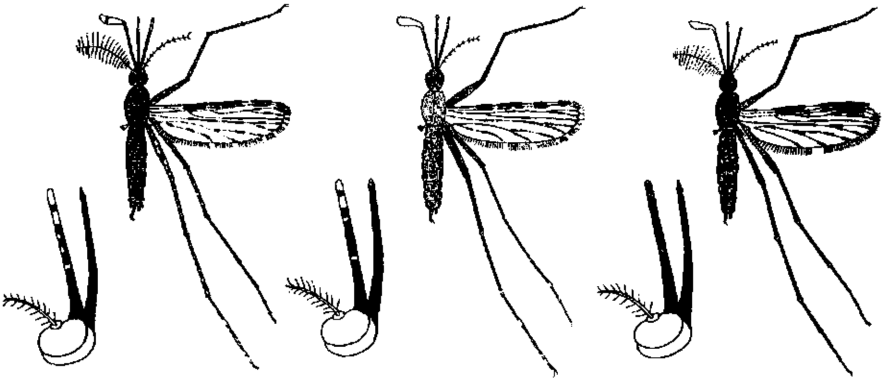
* Common habitat

○ Rare habitat

An. umbrosus as a shade-demanding species. In 1920, though, Swellengrebel also reports sunny habitats. Boyd (1949) and 1953: breeding places in the dense swampy jungle of the coastal plains, where the water is brown and peaty. They are seldom found outside the jungle and then only under heavy shade. The larvae have been found in small numbers in innumerable pools. Also in overgrown ditches in rubber plantations. It seems likely that they should also be looked for in pockets along the edges of small deep, slow moving water courses. Swellengrebel (1919) thought this species to be specialised, but the variety of places



Myzorhynchus Umbrosus (Theobald). *Nyssorhynchus Fuliginosus* (Giles). *Nyssorhynchus Schüffneri N. Sp.* (Stanton).



Nyssorhynchus Maculatus (Theobald). *Nyssorhynchus Karwari* (James). *Anopheles Gigas* (Giles).

Photo 2 Original drawings of *Anopheles* species from Indonesia. (source: Schüffner W. & H.N. Van der Heyden (1917) De anophelinen in Nederlands Indië, -*Medeelingen van den Burgerlijken Geneeskundigen Dienst in Nederlandsch-Indië* 4: 25-41)

suitable for breeding, a.o. mangrove swamps (Russel *et al.*, 1946), stagnant pools, swamps and ponds (Bruce-Chwatt, 1985), justify classification as an indifferent species. WHO (1982): pools, ponds, swamps, and sluggish streams, partially or heavily shaded water in forests or jungles. References to larvae in brackish water possibly refer to *An. baezai* (Horsefall, 1955).

3. *Anopheles baezai* (Gater, 1933).

This species very much resembles *An. umbrosus*. In 1953 the description is almost the same as that for the latter species: stagnant pools and swamps under shade (unlike *An. sundaicus* which favours sunlit breeding places) along the coast; as a brackish water breeder it easily finds favourable conditions along the extended coastline of the Malayan Archipelago; sometimes it breeds in water with a very high salt content. *An. baezai* tolerates a wide range of salinition from fresh water to water that is as salt as the sea (Horsefall, 1955). The species disappears with the exclusion of salt water.

4. *Anopheles letifer* (Sandosham, 1944).
Closely resembles *An. umbrosus* and *An. baezai.* 1953: abundant on the flat coastal plain, where the larvae are found in the many pools and stagnant agricultural drains of the Malay settlements and plantations. It has a preference for the dark brown water of peaty land that was formerly covered with jungle swamp, but it is found in many places along the coast where there is vegetation in or overhanging the water. *An. letifer* is intolerant of salt water; it was never found where there was contamination with more than 3% of sea water despite its presence in fresh water pools only a few yards away. It does not breed in the virgin swampy jungle of the coastal plain, while contrasting strongly with *An. umbrosus.* WHO (1982): shaded or partly sunlit pools, drains, especially with accumulations of decaying leaves and other vegetation.

5. *Anopheles roperi* (Reid, 1950).
1953: This species seems to be most common in low, rolling jungle country, where the land is mostly from 100 to 300 feet above sea level. The streams meander sluggishly through the jungle, and there are frequent shallow side channels, into which they overflow in wet weather. When such a stream subsides shallow pools are left in the storm-water channels, and decaying leaves soon collect in them. It is in these pools that *An. roperi* is principally found, though it sometimes appears in similar pools in shaded drains on rubber estates in this type of country. These temporary pools in the storm-water channels of jungle streams seem to be much favoured by the jungle-dwelling *Anopheles* spp. (*An. roperi, An. umbrosus*).

There is a general resemblance between the breeding places of the various species of the umbrosus-group, but each has its own preferred breeding places, and these preferences result in a characteristic zonation. *An. baezai* is confined to the brackish water zone; *An. letifer* and *An. umbrosus* follow on the flat coastal plains, one in the open country and the other in virgin jungle, while *An. roperi* appears in the foothills (Bonne-Wepster & Swellengrebel, 1953).

6. *Anopheles barbirostris* (Van der Wulp, 1884).
De Raadt (1918) classified *An. barbirostris* as a specified species, demanding shade (see also above under *An. umbrosus*). This is denied in 1932, where it is stated that there is no preference for shaded places. De Raadt (1918) also stated that this species could be found anywhere with the exception of brackish water, but Swellengrebel (1919), Russell *et al.* (1946) and Boyd (1949) report independently that the species is found in salt-water ponds and swamps. 1953: Breeding places usually in clear water (rice fields), slowly running streams, ponds (Swellengrebel & Swellengrebel-de Graaf (1919a) found 61% of 8739 larvae in fresh water

fish-ponds) and swamps, in ditches and wells; much vegetation and shade is preferred, though the larvae may also be found in sunny breeding places. The larva is found at lower or higher altitudes (Swellengrebel & Swellengrebel-de Graaf (1919a) mention 0-600 m).

7. *Anopheles vanus* (Walker, 1859).
This species resembles *An. barbirostris* closely and for a long time it was considered to be identical. This species though is more or less restricted to Sulawesi [Celebes] whereas *An. barbirostris* mainly occurs in Java and Sumatra. In 1953 Van Hell is cited, recording the breeding places as ubiquitous, even man-made.

8. *Anopheles bancrofti* (Giles, 1902).
This is a species which in earlier years was often taken for *An. barbirostris*. It appears that *An. bancrofti* breeds in the jungle, in old cut-off courses of the Digul River (Irian Jaya [New Guinea]), where coarse reeds, algae and *Azolla* combine to give shade and shelter. In Australia it is reported to have its breeding places in shaded swampy areas. Russell *et al.* (1946) report shallow, slow moving water, with much vegetation. WHO (1982): lowland grassy or weedy streams and irrigation ditches, running courses, clear fresh water, and direct sunlight demanded. Although this species should have been excluded because of its distribution, it is mentioned here because it is considered to be a very important vector of malaria (see next section).

9. *Anopheles sinensis* (Wiedemann, 1828).
De Raadt (1918) classifies *An. sinensis* as indifferent, though often found in rice fields. In 1921 Swellengrebel describes the breeding places of *An. sinensis* together with its allied forms; together with the description of 1932 these two vary from the 1953 version in that they report the demand for rich vegetation in the breeding places. Besides rice fields, the 1953 work mentions lakes, grassy pools, swamps, borrow-pits, edges of slowly moving water (grassy streams or ditches) as breeding sites; usually in unshaded water, though they have been recorded as breeding in shady pools; occasionally they have been reported breeding in brackish water. Boyd (1949) gives the same breeding places as for *An. nigerrimus*. WHO (1982): large bodies of fresh water in full or partial sunlight. Mentioned are: impoundments, lakes, pools, bays, large borrow pits, slow rivers, and pools in drying beds of rivers and major streams, marshes, bogs, swamps, and rice fields. Larvae occur in floating or emergent vegetation or floatage near the edges. Bruce-Chwatt (1985) adds to this the preference for cool water.

10. *Anopheles nigerrimus* (Giles,1900).
Resembles *An. sinensis*. In 1953 the same breeding places as for *An. sinensis* are given. Russell *et al.* (1946): rice fields, stagnant canals, borrow pits, lakes, slow streams, impounded water. Bruce-Chwatt (1985) adds deep ponds and swamps with much vegetation, and the preference for sunlight. The species originally described by Bonne-Wepster in 1951, *An. venhuisi* was later classified as

being *An. nigerrimus*. The description of the breeding habitat of *An. venhuisi* in 1953: closely resembles *An. sinensis* and *An. nigerrimus*. The breeding places of *An. venhuisi* are mostly rather deep swamps and swampy rice fields with much vegetation of *Azolla pinnata*, *Pista stratiotes* and *Jussieua repens*, *Hydrilla verticillata*, *Eichhornia crassipes* and *Spirodela polyrhiza*. Where this same vegetation is found in large borrow pits with stagnant water, larvae of this species are often present. The water in the breeding places is often clear, stagnant, fresh and not shaded. But *An. venhuisi* has also been found in brackish water.

11. *Anopheles kochi* (Dönitz, 1901).
Swellengrebel & Swellengrebel-de Graaf (1919a) denote *An. kochi* as being indifferent. This might be the reason for its wide distribution (Swellengrebel & Rodenwaldt, 1932). 1953: *An. kochi* breeds by preference in small, shallow, often muddy collections of water in the open, such as small pools, with or without grass, stagnant drains, buffalo-wallows, hoof-marks and collections in rice fields before planting commences; also along grassy banks of streams, in springs, sugar-cane fields and fresh water fish-ponds. It easily adjusts itself to the available breeding places. Russell *et al.* (1946) mentioned artificial containers and irrigation ditches as well, Boyd (1949) breeding in cut bamboos.

12. *Anopheles tesselatus* (Theobald, 1901).
1932, 1953: The larvae are usually found in rice fields; also in the shaded pools in the woods, now and then along grassy banks of running streams or in swamps. Other breeding places are fresh water fish-ponds and small pools with brackish water (Boyd (1949) reports breeding in hoofprints with strongly saline water). The larvae can stand a good deal of pollution.

13. *Anopheles leucosphyrus* (Dönitz, 1901).
This species only demands shade but could breed anywhere according to Swellengrebel & Swellengrebel-de Graaf (1919a) and Swellengrebel (1920b). In 1932 its avoidance for brackish water is reported though in 1953 brackish water habitats are mentioned, found in North Kalimantan [Borneo]. Russell *et al.* (1946), dividing *Anopheles* species into three groups as regards the relation of sunlight and shade to their typical breeding places mentioned *An. leucosphyrus* as generally found in well-shaded water. 1953: *An. leucosphyrus* has its breeding places in deep jungle and so they are difficult to detect: pools, well-shaded along streams. But on the other hand many records are there of *An. leucosphyrus* breeding in open jungle. The variety of breeding places of this elusive species is remarkable: pools with dead leaves; pools without vegetation in Nipah-forest; in springs, with or without vegetation; elephant foot-prints; bomb-craters, wheel ruts. Apparently the most universal feature of the species as a whole is the presence of a layer of leaves on the bottoms of the pools (Horsefall, 1955). WHO (1982): partially or heavily shaded water in forests or jungles: pools, ponds, swamps, sluggish streams, springs, shallow seepages and puddles on forest ground. To this Bruce-Chwatt (1985) adds hoof-prints.

14. *Anopheles balabacensis* (Baisas, 1936).
1953: The typical breeding place of *An. leucosphyrus* as recorded from other countries is in deeply shaded pools, under jungle cover. Although *An. balabacensis* was recorded on several occasions from such places, heavy larval concentrations were frequently found in open, lightly shaded or sunny situations, in bomb craters, wheel ruts and miscellaneous pools; these usually had a fine silt bottom and clear water, though it is stated that these might be atypical breeding sites due to abnormal conditions, possibly drying up of jungle seepages. WHO (1982): partially or heavily shaded water in forests or jungles: Springs, shallow seepages, and puddles on forest ground. Bruce-Chwatt (1985) adds to this that these habitats are often covered by thick undergrowth.

15. *Anopheles punctulatus* (Dönitz, 1901).
1953: This species breeds in open sunny water collections, whether these be natural ground pools filled with clear water or turbid water, temporary pools, footprints or artificial pools such as gutters or even pipes filled with water, barrels or puddles in light groves of sago palms. The margins of streams in exposed

Photo 3 Billiton: searching for breeding sites of malaria mosquitoes. (source: photo archives of Dr. Swellengrebel, private collection)

situations and pot holes in drying stream beds are also utilised occasionally, particularly during the dry season. Boyd (1949) describes its preference for small new pools in clay soil without vegetation and exposed to full sunlight. The pools in which this species occurs may be entirely free of vegetation and floatage or may have marginal herbaceous vegetation and dense algal growth. Though it has a very decided preference for breeding in sunlight, it is also found in partial shade. Eggs float in numerous meniscuses about emergent vegetation and often become stranded on the sides of vegetation as pools recede during periods of dryness (Horsefall, 1955). A small percentage of eggs withstood stranding on filter paper in a most chamber for 14 days at summer temperatures in a laboratory. In periods of dry weather it resorts to breeding in streams (Overbeek & Stoker, 1938, supposed it would not). After an occasional heavy rain it appears in large numbers in temporary pools. During the rainy season *An. punctulatus* extends its range into the coastal plain near the mouths of the river and utilises the same breeding places as *An. farauti* (see next section). Larvae are most numerous in small puddles with turbid water: a typical hoof print breeder. Although here it is said that the species never was found in brackish water, Swellengrebel & Swellengrebel-de Graaf (1919a) found numerous larvae in brackish water (foot prints) together with *An. sundaicus*. They furthermore refer to muddy breeding places, just like those described for *An. kochi*. Although it was originally assumed that anophelines were 'groundbreeders' (Schüffner, 1916a; 1917) here it is obvious that this is not true: *An. punctulatus* has been found breeding in tin cans, water barrels (Swellengrebel & Rodenwaldt, 1932), bilges of small boats (Russell *et al.*, 1946) and other man-made receptacles (Bruce-Chwatt, 1985). Though breeding in polluted water is given by Bruce-Chwatt (1985), the WHO (1982) reports breeding in muddy, but certainly not in polluted water. Swellengrebel & Swellengrebel-de Graaf (1919a) found a vertical distribution from 0-600 m, Russell *et al.* (1946) from coastal levels up to 2000 or even 3500 feet. Since this species is an important vector in Irian Jaya [New Guinea], it is included here for further study.

16. *Anopheles farauti* (Laveran, 1902).

In 1921 it was described as *Nyssorhynchus annulipes var. moluccensis* by Swellengrebel, and apart from cesspools this species was found in almost all sorts of breeding places (with or without vegetation, sun or shade, fresh or brackish water) (Swellengrebel, 1920a). In 1932 it was described as heliophilic, just like *An. maculatus*, and therefore important regarding man-made malaria. 1953: the larva breeds in any natural or artificial (even water collecting in native boats drawn ashore) water collection provided it is not shaded, Boyd (1949) reports breeding in metal drums, wooden kegs, tin cans, coconut shells, and holes in tree trunks. In coastal regions it even breeds in brackish water (a salinity of 4.6% is reported, though Russell *et al.* (1946) reports breeding in a salinity of 68% of that of sea water). Brooks, irrigation ditches, with or without marginal vegetation, and, in the interior, large streams with grassy banks and floating wood are good breeding places. WHO (1982): small collections of seepage water, stagnant and often muddy, full or partial sunlight. Vegetation present or absent. Russell *et al.* (1946) gives a vertical distribution from coast level up to 2000 feet, Bonne-Wepster & Swellengrebel 2250 m in Irian Jaya [New Guinea]. Considered to be a dangerous vector in Irian Jaya, and thus included.

17. *Anopheles koliensis* (Owen, 1945).
1953: The larvae of this species have been collected from temporary pools in grassland and in pools along the edge of jungle. They prefer water exposed to sunlight rather than dense jungle conditions. They have always been associated with *An. farauti* and in one locality were collected from the same water together with *An. farauti* and *An. punctulatus*. WHO (1982): like *An. farauti* but also breeding in brackish or saltwater marshes and lagoons; saltwater fish-ponds; full or partial sunlight. Bruce-Chwatt (1985): *An. koliensis* seems to prefer to breed in marshy pools at edges of forest streams.

18. *Anopheles aconitus* (Dönitz, 1902).
De Raadt (1918) reports *An. aconitus* solely from running water, he probably meant the variation form described by Swellengrebel (1921), later classified as *An. minimus* (see next section). Swellengrebel & Swellengrebel-de Graaf (1919a) found the type form in rice field (42%) and fish ponds (31%), and the variation type in running water (88%), hill streams etc., only 1.7% in rice fields. In 1920 Swellengrebel wrote: 'I found *An. aconitus* only in rice fields, and this shows a high preference for these breeding places, though in other places I found them in irrigation ditches, marshes, fish ponds, turbid water pools etc.' It is not clear why he did not mention the two forms here. In 1932 it has been found that in rice fields, especially shortly before the harvest, when the grass-blades touch the water surface, breeding of *An. aconitus* increases rapidly. Furthermore rice fields become fabulous breeding places if the irrigation water is not properly drained whenever there is no crop on the field (Mangkoewinoto, 1923). Russell *et al.* (1946) lists the following breeding places: Ponds, rice fields, swamps, irrigation ditches, creek and river beds, storm drains earth-bound reservoirs. Boyd (1949) adds breeding in tanks with grassy margins. The description given by Overbeek & Stoker (1938) and in 1953 are similar: the larva breeds in low country as well as at higher altitudes, most frequently in rice fields and fresh water ponds with grassy edges, not so often in running water. Swellengrebel & Swellengrebel-de Graaf (1919a) found *An. aconitus* up to 600 m, Russell *et al.* (1946) up to 2500 feet (see: Sundararaman *et al.*, 1957). WHO (1982): larval habitats such as rice fields, lakes, ponds, swamps, impoundments. Bruce-Chwatt (1985) reports heliophilic characteristics.

19. *Anopheles minimus* (Theobald, 1901).
Swellengrebel (1921) found the same breeding places as for the variation form of *An. aconitus*, later classified as being *An. flavirostris* : 88% running water breeding places, 1.7% rice fields and 10% fresh water fish ponds. In 1953 it is assumed that these breeding places bring them to a somewhat higher altitude

than where *An. aconitus* is usually found. Although being a running water species Russel *et al.* (1946) and Boyd (1949) report that *An. minimus* is unable to withstand a current having a greater velocity than 0.29 feet per second. Wave action is highly destructive to them and constant agitation by wind, or by man or beast may keep potential breeding places free from larvae. Russell *et al.* (1946) report that this species shows relatively little discrimination as to the character of the water on which it will deposit eggs; thus the species makes no distinction between water from its natural breeding areas and waters from widely different sources. Certain types of pollution, however, such as rotting leaves and stems of *Eupatorium*, repelled them, though tests showed that their larvae could develop in water with pollution thirty times as great. Evidently the tropisms of the adult female were not as closely attuned to the limits of larval tolerance as was expected. Boyd (1949) mentioned a thermal death point of 40 °C. WHO (1982) and Bruce-Chwatt (1985): flowing waters, such as foothill streams, springs, irrigation ditches, seepages, also rice fields and borrow pits. Prefers shaded areas of sunlit habitats. Larvae are found in margins of clear flowing water, where they cling to overhanging plant parts, especially roots (Horsefall, 1955). Only Boyd (1949) reported artificial breeding places (tanks).

20. *Anopheles flavirostris* (Ludlow, 1914).
Originally this species was described as being the variation form of *An. aconitus* (Swellengrebel, 1921). He reported as breeding places: 88% running water, 1.7% rice fields, and 10 % fresh water fish ponds. In 1953 the following description is given: Breeding in foothill streams along the shaded edges, especially among the bamboo roots. It is sometimes found at the edges of rivers, canals and irrigation ditches. It has been found in wells and occasionally in stagnant water pools, where presumably it had been carried by an overflow from its natural breeding place. Russell *et al.* (1946) figures *An. flavirostris* a most typical slow moving water breeder. It has seldom or in small quantities been found in typical stagnant water (fish pond, rice fields), in Bali (Boyd, 1949). The species has never been found at a higher altitude than 600 m (Swellengrebel & Swellengrebel-de Graaf, 1919a; Bonne-Wepster & Swellengrebel, 1953).

21. *Anopheles sundaicus* (Rodenwaldt, 1925).
Many authors consider this species to be the most dangerous malaria vector in Indonesia (Overbeek & Stoker, 1938). It is also the species of which an enormous amount of data have been collected of all the different life stages, breeding places, epidemiology etc. Lastly in connection with species-sanitation many of the works mainly involved the battle against *An. sundaicus*, and logically most of the literature found involves species-sanitation against *An. sundaicus*. Swellengrebel *et al.* (1919) describe two forms: the fresh water form and the brackish water form, and detailed descriptions of their breeding habits are listed in Schüffner *et al.* (1919):

1. *Coastal breeding sites*:
   a. Brackish water:
   - Coastal brackish water breeding habitats, fish ponds present:
     i. Breeding in the fish ponds;
     ii. Breeding in habitats outside the fish ponds (wells, hoofprints, lagoons etc.).
   - Coastal brackish water breeding habitats, fish ponds absent:
     i. Mangrove forest coastlines;
     ii. Sand coasts with lagoons.

   b. Fresh water.

2. *Inland breeding sites*:
   a. Fresh water fish ponds;
   b. Rice fields ('Sawahs').

Swellengrebel (1921) reports breeding in water up to 40% salinity, and a high preference for vegetation (algae). Other authors mentioned that *An. sundaicus* larvae require floating algae such as *Enteromorpha, Cladophora* and *Cyanophyseae*. Boyd (1949): larvae occur most frequently in seawater lagoons and swamps, collections of brackish water behind coastal embankments, borrow pits and hoof prints or any water collection in cleared mangrove. They will not breed in water subject to daily tides. From the wide range of optimum salinity (0.2 to 1.8%) recorded by various workers, it appears that salinity itself has practically no direct effect, but that it controls the breeding by its effect on the microflora and fauna on which the larva feeds. WHO (1982) and Bruce-Chwatt (1985): salt or brackish waters, lagoons, marshes, pools, seepages, especially with putrefying algae and aquatic weeds, mainly a coastal species, but found in fresh water inland pools in Java and Sumatra.

In fresh water, breeding in rice fields occurs only then, if these are free of vegetation, and become similar to the fish ponds (after harvesting, compare with similar situations concerning *An. aconitus*). In 1932 it is reported that *An. sundaicus* also can breed in heavily polluted water.

22. *Anopheles subpictus* (Grassi, 1899).
1932: Of this species, originally named *Myzomyia rossi*, the majority of breeding places are similar to those of *An. sundaicus*, but *An. subpictus* has got a much broader spectrum of those factors which determine the specialism of *An. sundaicus*: they have been found in fresh water, but also in salt pans (84.6% NaCl), they are not depending on vegetation in rice fields or fish ponds. Therefore *An. subpictus* often can be found in higher densities than *An. sundaicus* in breeding sites where the two species occur together. Rice fields yielded most larvae when the fields were fallow and turbid, and populations progressively declined to zero by the time the crop was 0.6m high (Chow, 1949). Boyd (1949) also reports breeding in many sorts of stagnant or running water, but adds artificial breeding sites such as buffalo wallows and roof gutters. 1953: rice fields and drains are

added. WHO (1982) and Bruce-Chwatt (1985) mention the same breeding places.

23. *Anopheles annularis* (Van der Wulp, 1884).
De Raadt (1918) classified *An. annularis* (at that time *N. fuliginosus*) as being a heliophobic species. He found *An. annularis* breeding in marshes with clear fresh water, where eggs were deposited underneath shade providing water plants. Swellengrebel & Swellengrebel-de Graaf (1919a) stress the importance of clear water; the water may be fresh, brackish or salt but not polluted. The 1921, 1932 and 1953 descriptions are the same: High preference for fresh clear water, rare in brackish water. Fresh water fish ponds, rice fields etc. often together found with *An. sinensis* and *An. barbirostris*. It increases in abundance in rice as the crop grows taller in much the same manner as does *An. sinensis*. Boyd (1949) gives some extra details: larvae occur in tanks, swamps, rice fields and borrow pits, predominantly in still water, associated with floating vegetation and filamentous algae, along shallow margins of lakes or in ditches. WHO (1982) also reports the preference for floating vegetation. Swellengrebel & Swellengrebel-de Graaf (1919a) found a vertical distribution from 0-600 m, Russell *et al.* (1946) report the species at 7000 feet (in India).

Photo 4 Semarang: *Anopheles* breeding site in a village. (source: photo archives of Dr. Swellengrebel private collection)

24. *Anopheles maculatus* (Theobald, 1901).
Swellengrebel & Swellengrebel-de Graaf (1919a) classified this species as a 'hill-species'. Though most often found in the vicinity of hills and/or mountains, the species is, apart from its preference for streams with clear running water (dead corners of small streams), quite indifferent (they report 13 other breeding places). The 1921, 1932 and 1953 versions describe the same breeding places, and classify *An. maculatus* as a stream and river-bed breeder. Russell *et al.* (1946) report its strong heliophilic character; Rodenwaldt (1925) already noticed the high increase of mosquito densities soon after the clearing of jungle vegetation had started; another example of typical man-made malaria (see also Bruce-Chwatt, 1985). The WHO (1982) description: small, sunlit stream margins, seepages, springs, rice fields with running water.

3C – The bionomics of adult mosquitoes

The taxonomic status and breeding sites of 24 of the most important anopheline species of Indonesia are described in the previous parts of this chapter. Adult behaviour as well as factors determining the threat that the adult mosquito constitutes will be reviewed in this section.

In estimating the importance of a species as a malaria vector, we have to consider the bionomics of the adults, consisting of the following parameters (after Swellengrebel *et al.*, 1919; Swellengrebel, 1920a; Rodenwaldt, 1924; Russell *et al.*, 1946; Boyd, 1949 and Bruce-Chwatt, 1985):

1. The density in which the species occurs (relative abundance);
2. Longevity;
3. Susceptibility of the species to malaria infection and its ability to transmit malaria;
4. Feeding habits (anthropophily – zoophily);
5. House-frequenting habits (exophily – endophily);
6. Site of feeding (exophagy – endophagy, related to 5.);
7. Dispersal (including flight range);
8. Climate and season in relation to transmission.

ad 1 – The density in which a species occurs is important if combined with the natural infection index. High infection indices combined with low densities have an epidemiological status equal to low indices combined with high densities.

ad 2 – Longevity of the vector is an important parameter: if it does not live long enough to mature an infection (*P. vivax* 9 days; *P. falciparum* 10-11 days at 26 °C.), then no transmission can occur. Furthermore the longer the vector lives the higher the chance that it becomes infected (more contacts with man), the more gonotrophic cycles can be completed (from blood meal to oviposition) and, consequently, the more offspring there will be.

ad 3 – Though being an important parameter on its own it should always be seen in combination with other factors (see ad 1.). Two indices can be estimated:

- *Experimental infection index*: the percentage of females that became infected after feeding on a gametocyte carrier. Experiments with different parasites can show whether there is a higher susceptibility for e.g. *P. falciparum* than *P. vivax*. It can be estimated what role an unimportant vector can play during an epidemic caused by a dangerous species.
- *Natural infection index*: the percentage of infected females caught in the field. Important is where and when to estimate the index (in relation to periodicity, see ad 8.); the age of the infected females; how many should be dissected to have an accurate estimate.

ad 4 – A species that solely feeds on animals is unimportant in malaria transmission; an overwhelming preference for human blood is of course very dangerous.

Species often show a high degree of variability in anthropophily: in space (geographical), and in relation to the abundance of animal hosts.

ad 5 and 6 – Exophilic species are considered to be more dangerous than endophilic species, especially since it is impossible to control them by indoor spraying. Species that are in the vicinity of human dwellings, and often stay indoors are important as well, because they can theoretically bite man at all hours of the night.

ad 7 – Some factors are important when considering mosquito dispersal:
- The wind, especially if strong, can determine the direction in which dispersal occurs.
- 'Host barriers': a group of (animal) hosts can stop the adults from further dispersal, thus protecting areas at a greater distance (from the breeding places).
- Productivity of the breeding places: the more adults emerge, the higher the densities, and it has been observed that migration to other areas occurs at certain densities of adult mosquitoes (of course in relation to the number of hosts available).

ad 8 – Periodicity: Determining the factors that induce periodicity can lead to new control methods (see *An. sundaicus*); implementation of vector control operations should coincide with lowest adult densities (just before the onset of the 'new' season).

Many of these factors were already understood by hygienists early in this century (Swellengrebel *et al.*, 1919; Rodenwaldt, 1924). In fact Ross (1911), in his first book presented some mathematical malariology, reviewed by Van der Eyden (1938). These are the most important factors, determining the importance of a certain *Anopheles* species. There are some other factors which can be of importance, but these are mostly related to one or two species. Now we can give some characteristics of a dangerous species: it occurs in great numbers; the females live long; it is highly susceptible for parasite infections; it is strongly anthropophilic; exophilic; exophagic; it has a strong flight capacity, active dispersal; and it prevails throughout the year. For a completely harmless species the following characteristics can be drawn: It does not occur in great numbers; it does not live long enough to mature the parasites; it is not susceptible to infections; it only feeds on animals (wild or domestic); it is not present in the vicinity of human dwellings; it takes its bloodmeal outside the house; it can not fly very far; it prevails only for a short period each season. These eight factors theoretically make it possible to define 128 different degrees to classify how dangerous a certain anopheline species is or might be.

Using the above mentioned criteria, the bionomics of the 24 selected species mentioned in Chapter 3A (Table 3.5) have been reviewed. The numbers placed in brackets at the beginning of a line refer to the factors (1-8) which determine a species' epidemiological importance as stated above. Whenever the years 1921,

Table 3.8 Characteristics of adult ecology of important malaria vectors in Indonesia and occurrence of resistance against organochlorine insecticides.

		A. aitkenii	*A. umbrosus*	*A. beazai*	*A. letifer*	*A. roperi*	*A. barbirostris*	*A. vanus*	*A. bancrofti*	*A. sinensis*	*A. nigerrimus*	*A. kochi*	*A. tesselatus*	*A. leucosphyrus*	*A. balabacensis*	*A. punctulatus*	*A. farauti*	*A. koliensis*	*A. aconitus*	*A. minimus*	*A. flavirostris*	*A. sundaicus*	*A. subpictus*	*A. annularis*	*A. maculatus*
Feeding habits	Anthropophilic	●	✱	●	✱	✱	✱	✱	✱	✱	✱	●	●	✱	✱	✱	✱	✱	●	✱	✱	✱	●	✱	✱
	Zoophilic	✱		●	●		●					✱	●		●	●			●				✱	●	
Resting habits	Exophilic		●	✱	✱	?	✱		?		✱		✱	✱	✱	✱	✱		✱		✱		●	●	✱
	Endophilic	✱	✱			?	●	✱	?	✱		✱	●			●	●	✱		✱		✱	✱	✱	
Biting habits	Exophagic	✱		?	✱	?	✱	?	?	?	✱		✱	●	✱	●	✱	?	●	●		●	●	●	●
	Endophagic		✱	?	●	?	●	?	?	?		✱	●	✱	●	✱	●	?	●	●	✱	●	●	●	●
Insecticide resistance	DDT									(✱)									✱			✱	✱	(✱)	
	Dieldrin, HCH									(✱)							✱		✱	(✱)	✱	✱	✱	(✱)	

✱ Common habit

● Rare habit (two dots: indifference for the factor concerned)

? No reference found for this parameter

+ Species resistant in Indonesia (Bruce - Chwatt, 1985)

(+) Species resistant in S.E. Asia (Bruce - Chwatt, 1985)

1932 or 1953 are mentioned these refer to the taxonomic works listed in Chapter 3A. Similarly to what was done for the aquatic stages, the data from this chapter have been summarized in Table 3.8.

1. *Anopheles aitkenii* (James, 1903).

(1) Swellengrebel & Swellengrebel-de Graaf (1919) found *An. aitkenii* larvae in large quantities in Soendatar (Sumatra) and the Karoo upland plains (Sumatra); in other localities it was rather rare.

(2) Green (in Boyd, 1949) found under laboratory conditions a mean survival of 5 days (range 3-7 days).

(3) Swellengrebel *et al.* (1919) did not include this species in their experiments on the susceptibility to malarial infections in Indonesia.

(4) Observed trying to feed on man, recorded feeding on a bull (1953). Walch (1932) did not include this species in his studies of biting habits.

(5) Although found breeding in valleys (streams) near plantations, it was not found in houses or cow-sheds by Doorenbos (1925). Puri (in Boyd, 1949): Adults are wild and shy and rarely found in houses.

(6) 1953 (after Christophers, 1933): it is doubtful whether this species takes a very active part as a bloodfeeder (see 5).

(7-8) No data were found.

2. *Anopheles umbrosus* (Theobald, 1903).

(1) No data were found.

(2) Boyd (1949) after Green (1935), reports mean survival under laboratory conditions of 38 days (range 28-59 days).

(3) *An. umbrosus* has been found infected in nature in all parts of its range. 1953: 4.96%, Bangka, Sumatra; 3.6%, Belawan, Sumatra; 0.4% Sanggau, Kalimantan [Borneo]; 15.2%, Sungei kakap, Kalimantan (Overbeek & Stoker, 1938).

(4) Walch (1932) reported that *An. umbrosus* is highly anthropophilic (results from 34 females all containing human blood in Sanggau, Kalimantan). Boyd (1949) after Green reports from Malaysia that out of 106 females caught (where cattle was scarce), 95% contained human blood.

(5) The adult is often caught inside houses (1932), and resting in the early morning on branches of rubber-trees is reported in 1921. 1953: In jungle *An. umbrosus* will feed at any time of the day. It enters houses and bites freely from dusk to dawn. It is not confined to the jungle or its immediate vicinity and will enter houses half a mile or more from the jungle edge (see 7!), and will attack boldly even under an electric light. Fierce biters, found in deeply shaded places in dense forests and also in houses (Puri in Boyd, 1949).

(6) see 5.

(7) Ave Lallement *et al.* (1931) reports the findings of Watson in the Malay States, who found a flight length of 750 m. Boyd (1949) after Barber reports a 'considerable distance'. Puri in Boyd (1949): *An. umbrosus* is a strong flier but its effective flight range probably does not exceed 1000 yards.

(8) No data were found.

3. *Anopheles baezai* (Gater, 1933).

(1-3) No data were found.

(4) It feeds readily on domestic animals as well as on man (Bonne-Wepster & Swellengrebel, 1953).

(5) The adults can often be found during the day, resting on Nipah palm fronds (Bonne-Wepster & Swellengrebel, 1953). The mosquito may be taken both indoors and in swamps (Horsefall, 1955).

(6-8) No data were found.

4. *Anopheles letifer* (Sandosham, 1944).

(1) In one area of Malaysia [Malaya] a moderate to severe epidemic of malaria occurred where this species comprised 99% of anophelines present (Reed & Hodgkin, 1950).

(2) In the laboratory females lived 38 days (range: 20-59 days) (Kingsbury, 1935).

(3) No data were found.

(4) *An. letifer* bites man more often than *An. umbrosus* but also commonly feeds on animals (Bruce-Chwatt, 1985).

(5) Rests outdoors after feeding (Bruce-Chwatt, 1985).

(6) The adult enters houses and bites freely from dusk to dawn (Bonne-Wepster & Swellengrebel, 1953); Bites animals and man mainly outdoors (Bruce-Chwatt, 1985); WHO (1982): females enter houses at night to feed on man; also attack by day in the shade.

(7-8) No data were found.

5. *Anopheles roperi* (Reid, 1950).

(1-3) No data were found.

(4) Feeds readily on man, found biting in the day time (Bonne-Wepster & Swellengrebel, 1953).

(5-8) No data were found.

6. *Anopheles barbirostris* (Van der Wulp, 1884).

(1) In Malaysia it was regarded as dangerous if present in large numbers, whilst from Indonesia it was considered to be a wild species, since often larvae were found in enormous amounts, but only few adults were detected (predation?) (Bonne-Wepster & Swellengrebel, 1953).

(2) Green (in Boyd, 1949) reports a survival under laboratory conditions of 34 days (range 7-63).

(3) Swellengrebel *et al.* (1919) report an experimental infection index of 10-13%. In Mandailing (Sumatra) they found a natural infection index of 0.5%, dissecting 544 mosquitos. Apart from being a malaria vector, *An. barbirostris* is the most important vector of *Brugia malayi* in Indonesia (Brug, 1937).

(4) Walch (1932) reports that from an area where cattle was present 9% of the examined mosquitos (46) contained human blood if cattle was scarce he found an index of 31% (out of 13 females). Swellengrebel & Rodenwaldt (1932) report a preference for cattle 23x larger than for humans. Boyd (1949) adds to this that the degree of anthropophilism in this species in different regions may show marked variation (India: zoophilic; Sulawesi [Celebes]: anthropophilic).

(5) see 1, according to the large densities of larvae, and comparatively few adults, this species is wild and has an exophilic character. In India it is much less often found indoors than further to the East. In Sulawesi it is the commonest species in houses (Boyd, 1949).

(6) Since this is correlated to the geographical distribution, in India females will be exophagic, while on Sulawesi they will spent more time inside houses.

(7) Ave Lallement *et al.* (1932) report a peak of activity between 19.00 en 20.00 h, with a rapid decline afterwards and record flight distance of 300 m.

(8) Russell *et al.* (1946) report a seasonal distribution, with a peak in January (Madras, India). Swellengrebel (1921) found a seasonal abundance correlated with the rice-growing season (as for *An. aconitus*).

7. *Anopheles vanus* (Walker, 1859).

(1-2) No data were found.

(3) Bonne-Wepster & Swellengrebel, 1953 (after Machsoes 1939) report a natural infection index of 13.3% from Sulawesi [Celebes].

(4) The adults are decidedly anthropophilic and are found far more frequently in houses than in stables (Bonne-Wepster & Swellengrebel, 1953 after Van Hell (1950)).

(5-8) No data were found.

8. *Anopheles bancrofti* (Giles, 1902).

(1) In Irian Jaya [New Guinea] it is considered to be an important vector because it appears in much larger numbers than other vectors. Out of 10,668 anophelines caught in barracks, 7840 or 73.5% were *An. bancrofti*, and 2735 or 25.9% *An. farauti* (see below) (Bonne-Wepster & Swellengrebel, 1953).

(2) No data were found.

(3) The average number of oocysts on the stomach wall of infected specimens is always low: 8, against 12 in *An. farauti* (Bonne-Wepster & Swellengrebel, 1953, after De Rook, 1935). It may also be a host for *Wuchereria bancrofti* and *Brugia malayi*. Swellengrebel & Rodenwaldt (1932) report a natural infection index of 4.3% (438 specimens) in Irian Jaya but the index for *An. farauti* was higher, 12.7% (63 specimens).

(4) Walch (1932) reports that this species solely feeds on man. Known to feed readily on man, indoors and out (Boyd, 1949), but Bonne-Wepster & Swellengrebel, 1953 report specimens from Irian Jaya that did not feed on man, and were morphologically indifferent. Horsefall (1955) states that this mosquito seems to vary considerably in its feeding habits in different localities.

(5) No data were found.

(6) This species is not as endophagic as *An. farauti* (3:1), and is particularly active at night (Overbeek & Stoker, 1938).

(7-8) No data were found.

9. *Anopheles sinensis* (Wiedemann, 1828).

(1) Overbeek & Stoker (1938) report its importance in areas where it occurs in large densities.

(2) Green (in Boyd, 1949) reports a survival under laboratory conditions of 28 days (range 7-57 days).

(3) From the Sumatran coast infection data are described of *An. hyrcanus* (the complex), by Swellengrebel & Rodenwaldt (1932). They report infections from Soendei Toean (1%, 15,612 specimens). Doorenbos (1925) found *An. sinensis* capable of causing an epidemic also in Sumatra (Kisaran, 6.8%, out of 1398 specimens). Doorenbos (1925) also reports epidemics caused by *An. sinensis* from Deli (Sumatra). Swellengrebel *et*

al. (1919) give experimental infection indices: 20.8% with *P. vivax* (129 exam.); 1.16% with *P. falciparum* (258 exam.).

(4) In China *An. sinensis* is zoophilic, in Indo-China the species is opportunistic in its feeding habits, while in Indonesia the species is much attracted by man (Horsefall, 1955); the relative abundance of cattle does not influence its preference, it remains highly anthropophilic (Walch, 1932). He reports 83% human blood meals if cattle is present; 90% if absent. Boyd (1949) also reports the overwhelming preference for human blood.

(5) The adults often can be found in large numbers inside the houses, during the daytime (Bonne-Wepster & Swellengrebel, 1953)

(6) No data were found.

(7) Ave Lallement *et al.* (1931; 1932) report peak activity at 20.00h and a maximum flight range of 1500m.

(8) No data were found.

10\. *Anopheles nigerrimus* (Giles, 1900).

(1) No data were found.

(2) Green (in Boyd, 1949) reports a survival under laboratory conditions of 23 days (range 6-45 days).

(3) Data on the feeding habits and dissections indicate that this species rarely if ever enters the reservoir for human plasmodia (Horsefall, 1955). However, Swellengrebel & Rodenwaldt (1932) report a natural infection index from Tandjong Morawa (Sumatra) of 11.79%, out of 3638 specimens dissected.

(4) Generally, *An. nigerrimus* bites man an animals (Horsefall, 1955). Van Thiel (in Boyd, 1949) reports 83% of the bloodmeals being of human origin.

(5) The female rests outdoors after feeding (exophilic) (Bruce-Chwatt, 1985).

(6) Bites man and animals mainly outdoors (exophagic, Bruce-Chwatt, 1985). It feeds readily on human and animal blood, usually at dusk or by night, but also sometimes by day, even in full sunshine (Bonne-Wepster & Swellengrebel, 1953).

(7-8) No data were found.

11\. *Anopheles kochi* (Dönitz, 1901).

(1) Overbeek & Stoker (1938) report that if *An. kochi* prevails in large densities it can be an important vector; if not, then its pathogenetic role can be neglected.

(2) Green (in Boyd, 1949) found a survival under laboratory conditions of 32 days (range 10-59 days).

(3) Swellengrebel *et al.* (1919) did not find *An. kochi* infected in Java; neither did Swellengrebel & Rodenwaldt (1932). In Sumatra *An. kochi* was found responsible for an epidemic (Doorenbos, 1925). Infections found in Sumatra: Kisaran, 1% (Doorenbos, 1925), Soengei Toean, 5.08% (Schüffner, 1923) and Angoli, 2.1% (all natural infection indices). Bonne-Wepster &

Swellengrebel (1953) report varying indices (0.4-11.5%) from Indonesia (Sumatra?).

(4) Walch (1922) classified *An. kochi* as more or less zoophilic (cattle scarce: 17% human blood meals; cattle present 4%). Bonne-Wepster & Swellengrebel (1953) reported that in experiments the females preferred buffalo blood to that of man; the percentage of engorged females that had animal blood in their guts was always higher than with human blood.

(5) Classified by many authors as typically endophilic (Swellengrebel, 1921; Swellengrebel & Rodenwaldt, 1932; Boyd, 1949); being a domesticated species it is found in houses, stables and cow-sheds, having a peak activity between 19.00-20.00 h. (Ave Lallement *et al.*, 1932).

(6) Though preferring animal blood, because of its highly endophilic character will bite man inside houses.

(7) Ave Lallement *et al.* (1932) experimentally recorded a maximum flight distance of 1000 m.

(8) No data were found.

12. *Anopheles tesselatus* (Theobald, 1901).

(1) Boyd (1949) states that since this species almost never occurs in large numbers in can be considered of minor importance.

(2) No data were found.

(3) Swellengrebel & Swellengrebel-de Graaf (1919) found a natural infection index of 0.7% (139 exam.) in Modjowarno (Java), Soesilo an index of 0.79% (126 exam.) from Nias (Sumatra).

(4) Over all of its range, man is a minor host (Horsefall, 1955) and bovines are the preferred host. Walch (1932) recorded 47% (19 examined females) human blood meals when cattle was scarce.

(5) Buxton & Leeson (in Boyd, 1949) report enormous amounts of resting females on the brick lining walls of wells, thus exophilic tendencies. Russell *et al.* (1946) reports the same places. Boyd (1949) also found them resting among roots of trees in jungle, along banks of streams, but also caught specimens inside houses and cow sheds.

(6) see 5.

(7) Ave Lallement *et al.* (1932) experimentally recorded a maximum flight of 1000 m.

(8) From Madras (India) peak densities were recorded in December, which continued prevalent for the next two months (Russel, 1946).

13. *Anopheles leucosphyrus* (Dönitz, 1901).

(1) Roper (in Boyd, 1949) reports selective breeding, sometimes numerous enough to be an important vector.

(2) No data were found.

(3) Clark & Chowdhury (in Boyd, 1949) report a natural infection index of 2.4% from Assam (859 exam.). Swellengrebel & Swellengrebel-de Graaf (1919) did not find infected females in Java. Doorenbos (1925) and Bias

(in Swellengrebel & Rodenwaldt, 1932) recorded natural infection indices of 1.94% and 1.7% respectively from Siantar (Sumatra). Bais experimentally infected up to half the females used with tertiana (Swellengrebel, 1921).

(4) Ramsey *et al.* (in Boyd, 1949) examined 102 females and found in 75.5 % human blood. In areas without cattle Walch (1932) recorded 90% human blood meals.

(5) The adults are seldom found in houses on account of the very late hours they choose for their meals and the habit of leaving the human habitation immediately afterwards to fly straight back to the jungle (Bonne-Wepster & Swellengrebel, 1953).

(6) Adults enter houses to feed on man, with peak activity between 12.00 and 02.00 hours (WHO, 1982). Bruce-Chwatt (1985) on the contrary reports outside feeding and resting.

(7) Although females may travel at least 800 m, Bruce-Chwatt (1985) reports only short flights, which makes it important only in the vicinity of heavy vegetation.

(8) Bais noted declining densities in December and January in Siantar because of drying of breeding places (Swellengrebel, 1921).

14. *Anopheles balabacensis* (Baisas, 1936).

(1-2) No data were found.

(3) Colless (in Bonne-Wepster & Swellengrebel, 1953) found a natural infection index of 1.6% in Kalimantan [Borneo].

(4) Adults bite animals and man (Bruce-Chwatt, 1985); WHO (1982) classifies *An. balabacensis* as strongly anthropophilic.

(5) After feeding the adult rest outdoors (Bruce-Chwatt, 1985); WHO (1982) report that shortly before and after feeding the adult female rests inside houses.

(6) The adults bite humans and animals outdoors (Bruce-Chwatt, 1985); WHO (1982) reports feeding in or near forests, indoors and outdoors. Maximum rates of attack occur between 24.00 and 03.00 hours with no significant difference between rates indoors and outdoors (Kirnowardoyo, 1988).

(7-8) No data were found.

15. *Anopheles punctulatus* (Dönitz, 1901).

(1-2) No data were found.

(3) Swellengrebel *et al.* (1919) did not find naturally infected females in Java, and could not succeed in infecting them experimentally. Later, De Rook *et al.* (1932) report a natural infection index of 2.4% from Irian Jaya [New Guinea].

(4) King (in Boyd, 1949): all members of the punctulatus group are known to attack man, and their feeding activity is chiefly at night, either in or outdoors. Furthermore it is stated that *An. farauti* and *An. koliensis* were

found biting in much larger numbers than *An. punctulatus*. Walch (1932) found that this species exclusively fed on human blood, and seldom found it indoors.

(5) For the punctulatus group (*punctulatus typicus*, *farauti* and *koliensis*) the same behaviour patterns are described (WHO, 1982): anthropophilic, endophilic, endophagic; Gandahusada & Sumarlan (1978) report exophagic and exophilic characteristics (?).

(6) see 5.

(7) WHO (1982) reports an observed flight of 1 km. Bruce-Chwatt (1985): species of the punctulatus complex are relatively poor fliers, they do not move far away from their breeding places.

(8) No data were found.

16. *Anopheles farauti* (Laveran, 1902).

Because of its similarity with *An. punctulatus* many descriptions of bionomics are given for the punctulatus complex as a whole.

(1) No data were found.

(2) Under laboratory conditions, caged females lived as long as 51 days (Perry, 1946).

(3) De Rook (Overbeek & Stoker, 1938) found a natural infection index of 12.7% in Irian Jaya [New Guinea]. Heyden (in Boyd, 1949) established a 100% experimental infection with *P. falciparum*, and 40% with *P. vivax*, and found a natural infection index of 3.9% (206 exam.) from Irian Jaya.

(4) King (in Boyd, 1949): *An. farauti* partly has the same biting habits as *An. punctulatus*, but is a more vigorous human biter. Of 321 precipitin tests 11% was of human blood (rather low compared to the figures given by Walch (1932) for *An. punctulatus*).

(5) Horsfall (in Boyd, 1949) reports adult resting places: grass stems, close to the ground in heavy stands of Kunai grass; resting often in the vicinity of man, sometimes far away from the breeding places; also in human dwellings (huts, houses, inside bed nets); Bonne-Wepster & Swellengrebel (1953) mention cool, moist and shaded spots.

(6) Bonne-Wepster & Swellengrebel (1953) found feeding outdoors, and during the daytime in shady places.

(7) King (in Boyd, 1949) found, that if this species was present in larger numbers, it could fly considerable distances. Females have been observed to fly as far as 1600m (Daggy, 1945).

(8) No data were found.

17. *Anopheles koliensis* (Owen, 1945).

Much of the bionomics of this species are characteristic for the punctulatus complex, see *An. punctulatus* and *An. farauti*.

(1-3) No data were found.

(4) Adults were found biting on man in larger numbers than *An. punctulatus* (King, in Boyd, 1949). Bonne-Wepster & Swellengrebel (1953): The adults

are strongly anthropophilic, and have been found resting during the day in houses in greater numbers than any of the other local anophelines (up to 90%).

(5) see 4; They become active about 9:00 pm and continue to fly until daylight. The period of greatest nocturnal activity was after midnight.

(6-8) No data were found.

18. *Anopheles aconitus* (Dönitz, 1902).

(1) It is only dangerous and can cause severe endemic malaria if it occurs in high and continuous densities (Gandahusada & Sumarlan, 1978).

(2) Green (in Boyd, 1949) found a mean survival under laboratory conditions of 24 days (range 8-41 days).

(3) Infection rates recorded from W-Java vary between 2.9- 17.8% (various authors e.g Swellengrebel *et al.* 1919). Doorenbos (1925) found it naturally infected up to 11.5% in Sumatra. Mangkoewinoto (1919) 7.3% (W-Java); Swellengrebel *et al.* (1919) 2.3% Modjowarno (E-Java).

(4) Walch (1932) reports that in areas where cattle was present 12% (229 exam.) were human blood meals, if cattle was absent 61% (137 exam.). He does not record this species as highly anthropophilic, though Mangkoewinoto (1919) found it this way in the Cihea [Tjihea] plain (W-Java). Generally it is considered to be an important man biting species, though locally it can show zoophilic tendencies, especially if cattle is present in large numbers (Bonne-Wepster & Swellengrebel, 1953; Chow *et al.*, 1959).

(5) Though sometimes found in houses and cow-sheds, this is a highly exophilic species; it can be found resting in large numbers along stream banks and irrigation ditches (Gandahusada & Sumarlan, 1978; Bonne-Wepster & Swellengrebel, 1953). Bruce-Chwatt (1985) records endophilic and exophilic habits.

(6) Biting of man occurs indoors and outdoors (WHO, 1982; Bruce-Chwatt, 1985).

(7) Mangkoewinoto (1923) recorded 350 m (W-Java); Ave Lallement *et al.* (1932) recorded a maximum of 550 m; they also mentioned that *An. aconitus* was highly anthropophilic since most specimens were (re)captured inside human dwellings. Puri (in Boyd, 1949) regards *An. aconitus* capable of long flights. WHO (1982): observed flight 1 km.

(8) *An. aconitus* in Indonesia has a defined periodicity, strongly correlated with the harvest time. In the south coastal area of Java *An. aconitus* appeared together with *An. sundaicus* causing endemic malaria. Near Semarang, Central Java two peaks were found, one in March-April, the other in August-September (Gandahusada & Sumarlan, 1978, after Joshi *et al.* 1977).

19. *Anopheles minimus* (Theobald, 1901).

(1) No data were found.

(2) Treillard (in Bonne-Wepster & Swellengrebel, 1953) report that *An. mini-*

mus lives 5-10 times longer than *An. vagus* under identical conditions in the laboratory which might be the reason of its efficacy as a malaria vector.

(3) No detailed information from Indonesia was given in before 1953; Soesilo found it infected up to 3% in Sulawesi [Celebes].

(4) Boyd (1949) classified *An. minimus* as a distinctly anthropophilic species. From Indonesia no feeding habits were recorded but from other regions high percentages of human blood meals are recorded (up to 86.5%).

(5) The adults are commonly found in houses and cattle sheds (Bonne-Wepster & Swellengrebel, 1953). Puri (in Boyd, 1949): Adults are found in large numbers in dark houses and huts, the majority resting on the lower half of the walls. Most of them feed after midnight and there is very little feeding activity two or three hours after sunset.

(6) Adults feed on man both indoors and outdoors; biting activities occur during the first part of the night (WHO, 1982).

(7) Harrison & Ramsey (in Boyd, 1949) reported a maximum flight of 1 mile.

(8) No data were found.

20. *Anopheles flavirostris* (Ludlow, 1914).

(1-2) Females lived up to five weeks (Thomson, 1941).

(3) Walker & Barber (in Boyd, 1949) achieved an experimental index of 18.01% (320 females tested), and recorded a natural infection index of 0.3% in Manalang, Philippines (10820 exam.). Overbeek & Stoker (1938) report results from Indonesia: 3% natural infection in West-Java (Tjipadani), and infected specimens from Poelau Laoet (Kalimantan [Borneo]). Locally, it can be an important vector (Afridi, 1948).

(4) Zoophilic species, although it will bite man indoors.

(5) Resting adults may be taken from overhanging creek banks and similar outdoor shelters (WHO, 1982).

(6) Adults enter houses to feed on man but leave early in the morning so that they are seldom found in house catches (WHO, 1982). Bruce-Chwatt (1985) describes the same habits: endophagic/exophilic.

(7) Craig (in Boyd, 1949) recorded a maximum flight of 2.5 miles, but wind played an important role in the experiments. WHO (1982): maximum observed flight 2 km.

(8) Manalang (in Boyd, 1949) reports a seasonal incidence of infection of *An. flavirostris*, with highest rates in May (2.56%), until August (1.29%), data from the Philippines.

21. *Anopheles sundaicus* (Rodenwaldt, 1926).

(1) Van Breemen (1919) studied mosquito densities in Northern Java (Batavia) and estimated an average daily production of 0.6 billion mosquitos in an area of 5 million square meters.

(2) Green (in Boyd, 1949) reports a mean survival under laboratory conditions of 27 days (range 5-46 days).

(3) This species has been found infected in almost every occasion; Swellengrebel & Swellengrebel-de Graaf found it naturally infected up to 35% in Java; Kuipers & Stoker (1934) even up to 46.6% (see also Snellen, 1988). Experimentally Swellengrebel *et al.* (1919) could infect it with *P. vivax* up to 80%, with *P. falciparum* up to 100%. Overbeek & Stoker (1938) report an index of 39.2% from Banjoewangi, East-Java. In Sumatra it was also found highly infected: 20% in Belawan (Deli) (Swellengrebel & Rodenwaldt, 1932). In other areas only low indices were found (Batavia 1.6% in 1917; 2.4% 1918 (Van Breemen, 1919). Soesilo (in Boyd, 1949) compared experimental infection rates of the fresh and salt water form (with *P. falciparum*): 88.8% against 80% respectively.

(4) Walch (1932) reports a very strong anthropophilic character: If cattle is present (even in large numbers) still 86% of the blood meals were of human origin; if cattle was scarce 94% were human blood meals. These figures count for both the fresh and salt water form, both are highly anthropophilic.

(5) The adults are found abundantly indoors, in houses but also in cow sheds (Bonne-Wepster & Swellengrebel, 1953). WHO (1982) reports an activity peak between 22.00 and 24.00 hours; WHO also reports outside resting sites (crevices in sand banks and bushes). Bruce-Chwatt (1985) adds mainly indoor resting, especially after feeding.

(6) Bites man and animals indoors and outdoors (Bruce-Chwatt, 1985); during the daytime and nighttime (Puri, in Boyd, 1949).

(7) Van Breemen (1919) recorded experimentally a flight distance of 6 km (Batavia, Java). Swellengrebel & Swellengrebel-de Graaf recorded 1-3 km in Semarang (W-Java). there is evidence that the flight distance is correlated with the adult density and the availability of hosts. Leopold (in Swellengrebel & Rodenwaldt, 1932) recorded flights of 9 km, when adult densities were high. It was found that *An. sundaicus* sometimes travels 'by train', so that the data have to be regarded with some susceptibility (Mangkoewinoto in Swellengrebel & Rodenwaldt, 1932). WHO (1982): observed flight 0.5-6.2 km.

(8) Especially in the salt-water breeding sites a marked seasonal periodicity was found. In June, July, and August numbers declined, and from September onwards no larvae could be found. It is thought that evaporation causes a sharp increase in salinity thus preventing *An. sundaicus* from breeding (*An. subpictus* was still present then, up to a salinity of 86.4%) (Van Breemen, 1919; Swellengrebel, 1921; De Vogel, 1929; Zon, 1939). No periodicity was found in the fresh water form.

22. *Anopheles subpictus* (Grassi, 1899).

(1) Van Breemen (1919) recorded very high densities from Batavia (see *An. sundaicus*), and though found only with low infection rates, its density increases its importance.

(2) Mayne (in Boyd, 1949) found a short longevity, often less than one week.

(3) Natural infections were always low (0.3-0.7%), sometimes up to 3% (Swellengrebel & Rodenwaldt, 1932). Swellengrebel *et al.* (1919) were not able to infect it experimentally in Java. Though infection indices from Sulawesi [Celebes] were low, because of its high densities it became an important vector there (Overbeek & Stoker, 1938).

(4) Puri (in Boyd, 1949) reports feeding on man, but they apparently prefer animal blood. Walch (1932) found the same: if cattle was present, 12% of the blood meals were of human origin; if cattle was absent, it increased to only 15%. Buxton & Leeson (in Boyd, 1949) found a geographical variation in the feeding habits: They recorded it solely zoophilic in India, but more eastward (Sulawesi) it was found to be more anthropophilic.

(5) Buxton & Leeson (in Boyd, 1949) often found specimens in man's sleeping places though containing animal blood (cattle/buffalo). It is quite regularly found in houses, and an interesting relationship with the *An. sundaicus* density has been discovered; if *An. sundaicus* densities dropped, *An. subpictus* was found more in houses and vice versa.

(6) Bruce-Chwatt (1985): Bites man indoors and outdoors and rests indoors and outdoors.

(7) In Java females were retrieved 6.2 km from points of release (Van Breemen, 1920). Ave Lallement *et al.* (1931) recorded a maximum flight of 200 m, and an activity peak between 20.00 and 22.00 hours.

(8) No data were found.

23. *Anopheles annularis* (Van der Wulp, 1884).

(1) It was only considered to be of any importance if it occurred in large numbers, mainly because of its low infection indices.

(2) Bates (in Boyd, 1949) reported a mean survival under laboratory conditions of 17 days. Green (in Boyd, 1949) found 27 days (range 9-41 days).

(3) *An. annularis* is rarely found infected (Horsefall, 1955). In Soendatar (W-Sumatra), however, an infection of 0.3% was reported; other data are difficult to interpret because they might refer to closely related species such as *An. philippinensis*.

(4) Walch (1932) classified *An. annularis* more or less as a zoophilic species; if cattle was present 10% were human blood meals; if absent 50% (only 2 examinations). In experiments (Chang in Bonne-Wepster & Swellengrebel, 1953) *An. annularis* preferred human blood to buffalo blood; it fed readily in nature in certain areas and then was one of the most greedy human blood suckers.

(5) Puri (in Boyd, 1949): Adults are found in large numbers in cattle sheds, and sometimes in houses also.

(6) Bites man indoors, rests inside and leaves the house in the early morning (Swellengrebel & Rodenwaldt, 1932).

(7) Ave Lallement *et al.* (1931) found a maximum flight of 250 m, and an activity peak between 20.00 and 23.00 hours.

(8) Swellengrebel & Swellengrebel-de Graaf (1919) recorded a periodicity like that for *An. aconitus* in Modjowarno (E-Java).

24. *Anopheles maculatus* (Theobald, 1901).
(1) No data were found.
(2) Green (in Boyd, 1949) recorded a mean survival under laboratory conditions of 34 days (range 13-66 days).
(3) Lamprell (in Boyd, 1949) recorded a natural infection index of 1.9% from Indonesia. Doorenbos found a natural infection index of 2.83% in Kisaran (Sumatra); Walch & Soesilo in central Java 3%; Essed & Rodenwaldt in Riouw 11% etc. (Swellengrebel & Rodenwaldt, 1932). Doorenbos (1931) 17% in Londut, Sumatra.
(4) Walch (1932) did not classify this species as distinctly anthropophilic though if cattle was absent 97% human blood meals were found (cattle present: 11%). Puri (in Boyd, 1949) reports a geographical variation in feeding habits, but classifies *An. maculatus* as anthropophilic in Indonesia.
(5) The adult is usually not found in houses in the daytime, though in certain areas and circumstances it may be taken in houses and cattle sheds (Bonne-Wepster & Swellengrebel, 1953). Rests mainly outside after feeding (Bruce-Chwatt, 1985); WHO (1982) adds an activity peak between 21.00 and 24.00 hours, and that most females leave houses before 8.00 hours. Daytime resting places are probably dense vegetation, woods.
(6) Bites domestic animals and man indoors and outdoors (Bruce-Chwatt, 1985).
(7) Wallace (in Boyd, 1949) recorded experimentally a maximum flight of 1.38 miles. WHO (1982): observed flight: 2 km.
(8) No data were found.

3D – Evaluation of taxonomic and bionomic data with respect to malaria epidemiology and control through species sanitation.

Using the data from the previous sections (Chapter 3A-C), it is now possible to estimate the danger each species constitutes as a malaria vector (the epidemiological importance) and whether species sanitation may be considered a potential method of control for that species. The anopheline species discussed are those mentioned in Table 3.5 (Chapter 3A). A map indicating the location of the more important towns and villages mentioned in this chapter is added as Figure 3.1.

1. *Anopheles aitkenii* (James, 1903).

Generally speaking *An. aitkenii* is not considered to be a very important vector. Its role as a contributor in malaria-epidemics with more dangerous species (with *An. aconitus* in Soekaboemi and Bandjar, where spleen indices of 65% and 85% were found (Mangkoewinoto, 1919); Swellengrebel (1921) found it together with *An. farauti*), is not understood. Therefore this species has to be regarded with suspicion. In this literature study no records of positive infections of *An. aitkenii* were found. Swellengrebel & Schüffner (1920) dissected two females from Mandailing, both negative, one from Soendatar, also negative. If its longevity is really that short, combined with its exophilic and exophagic habits, the species logically can be regarded as being of minor importance.

2. *Anopheles umbrosus* (Theobald, 1903).

This species is a very important vector in Malaysia, but its bionomics make it an important vector in Sumatra, Java, and Kalimantan [Borneo] as well. It is however difficult from old literature to extract its importance since many data refer to closely related forms. Although found in the vicinity of other important vectors, *An. umbrosus* has shown to be responsible for the hyperendemic situation in Sanggau, Kalimantan, where it was the only *Anopheles* found infected (Soesilo, 1932b).

Since *An. umbrosus* is a typical shade loving species, control of it would simply imply exposing the breeding places to sunlight. But since these places are of many different origins, this hinders control, especially species sanitation *sensu strictu*. Although exposing to sunlight might be useful (1. clearing of hidden breeding places; 2. drying of shallow breeding places; 3. land development) according to Russell *et al.* (1946) the removal of shade has more often resulted in increased mosquito breeding than otherwise. Moreover hygienists in Indonesia noted that the eradication of shade loving species (in this case *An. umbrosus*) by clearing of jungle resulted in extensive breeding of a sun loving species, *An. maculatus*, an even more dangerous species (Schüffner, 1917; Swellengrebel, 1920b). So prevention of breeding after clearing implies draining of the exposed breeding places, which was too expensive or impracticable. Swellengrebel (1920b) reports the results of the British in Malaysia, where they immediately

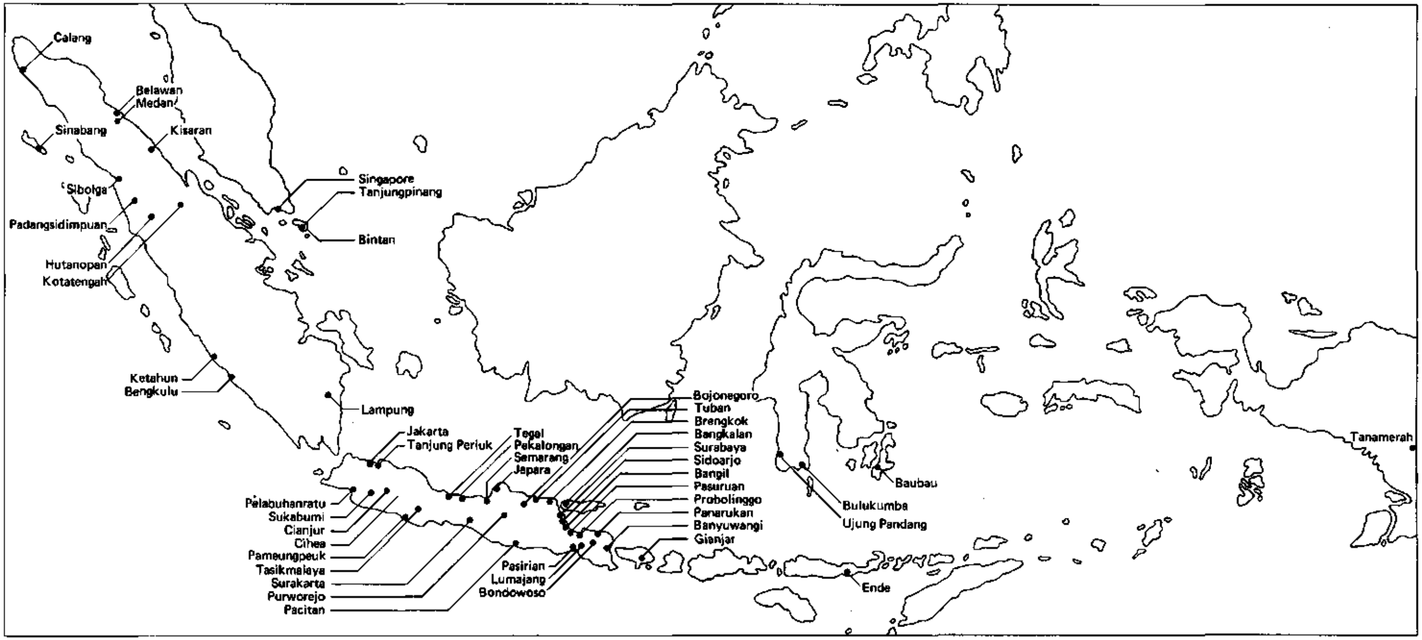


Fig. 3.1 Towns and villages of Indonesia which are mentioned in connection with species sanitation (Chapter 3D).

after clearing of the jungle planted rubber trees, providing shade and thus preventing *An. maculatus* from breeding.

Swellengrebel (1921) writes about the species sanitation in Malaysia against *An. umbrosus* (after Watson, 1913; 1915): 'They cleared vegetation and drained pools where this species occurred, and completely neglected the breeding sites of *An. subpictus* and *An. kochi*, this being one of the first examples of successful species sanitation'. Watson also controlled malaria by clearing the vegetation 750 m around the houses, the maximum flight distance of this species (Ave Lallement *et al.*, 1931). Boyd (1949) reports that pollution of water with cut vegetation of breeding places can be successful for *An. umbrosus* control since this species occurs in waters with 'a surprisingly low degree of pollution'.

3. *Anopheles baezai* (Gater, 1933).

Comments: see below (under *An. roperi*).

4. *Anopheles letifer* (Sandosham, 1944).

Comments: see below (under *An. roperi*).

5. *Anopheles roperi* (Reid, 1950).
What can be said regarding the *umbrosus* group with respect to species sanitation:
From the taxonomic point of view, it has been stated that early data are difficult to interprete, since they might refer to allied forms (Bonne-Wepster & Swellengrebel, 1953). This becomes obvious if we compare the distribution maps. Data of *An. umbrosus* from 1932, refer to *An. baezai* in 1953, for Sulawesi [Celebes] and Java. The importance of this species as reported by Swellengrebel in 1921 and 1932 in Sanggau, Kalimantan [Borneo] is probably because of the occurrence of *An. letifer* in that specific area. Furthermore it can be said that the taxonomic division of the *umbrosus* group is of considerable importance since of the eight forms described in 1953, only four are of any importance. (An easy explanation for the fact that hygienists found *An. umbrosus* infected in one area, but not in another is the lack of taxonomic insight into this group of closely resembling species).

On regarding the breeding sites we can conclude that these four taxonomic different forms use breeding places which vary considerably:

- *An. baezai*: Brackish water zone.
- *An. letifer* and *An. umbrosus*: Flat coastal plain, the first in the open country, the second in the virgin jungle.
- *An. roperi*: Foothills.

The division of early forms of *An. umbrosus* into *An. letifer* and *An. umbrosus* ('*typicus*') is, from an epidemiological point of view very important, especially since these species differ in their bionomics: *An. letifer* bites outdoors, man and animals, and rests outdoors often in the vicinity of human dwellings, whilst *An. umbrosus* is mainly endophilic/endophagic, and is more restricted to jungle/forest.

6. *Anopheles barbirostris* (Van der Wulp, 1884).
Because of its preference for fresh water breeding places (not always though), mainly fish ponds and rice field, especially if there is shade and vegetation, species sanitation as described in chapter 4 becomes advisable. Boyd (1949) gives two control measures for *An. barbirostris*: 1. The use of voracious weed-eating fish (*Puntius javanicus*), as stated by Walch & Soesilo (1935) which secured effective control of the anophelines (*An. barbirostris*, *An. sinensis* and *An. aconitus*) breeding among the aquatic vegetation, close trimming of the margins, also being necessary, and 2. pollutional ponding by cut vegetation, especially effective if combined with larvivorous fish (see chapter 4).

7. *Anopheles vanus* (Walker, 1859).

Comments: see below (under *An. bancrofti*).

8. *Anopheles bancrofti* (Giles, 1902).
Comments: As stated before this species is an important malaria transmitter in Irian Jaya [New Guinea]. Because of its preference for shade it has been controlled in some areas by clearing of vegetation. In other areas though it worsened the situation because of expansion of *An. farauti*, causing severe epidemics (Boyd, 1949).

The species *An. barbirostris*, *An. vanus* and *An. bancrofti* are geographically separated so it is difficult to confuse them: *An. barbirostris* on Sumatra, Java, and Kalimantan [Borneo]; *An. vanus* on Sulawesi [Celebes]; and *An. bancrofti* in Irian Jaya [New Guinea]. Taxonomically the division of the group has led to six forms of which three play an important role in malaria transmission.

9. *Anopheles sinensis* (Wiedemann, 1828).

Comments: see below (under *An. nigerrimus*).

10. *Anopheles nigerrimus* (Giles, 1900).
The interpretation of bionomic data of this species is extremely difficult, since species of this group are very difficult to separate. Therefore the records on the biology and the pathogenic importance consequently are unreliable. Of the 10 forms of the 'hyrcanus' group (described in 1953) only two are known to be important, *An. sinensis* and *An. nigerrimus*. In 1921 *An. nigerrimus* was described by Swellengrebel as *An. sinensis var. vanus*; in 1932 by Swellengrebel and Rodenwaldt as *An. hyrcanus nigerrima*. Both these descriptions lack bionomics, and only bionomics of the group as a whole are described. Soesilo (1935)

reported a form in between *An. sinensis* and *An. nigerrimus*, Venhuis (1940) described it as *An. hyrcanus* X from Java and Sulawesi [Celebes], later called *An. venhuisi*, taxonomically changed into *An. nigerrimus*. This latter deviation is odd since these two forms show interesting differences in their bionomics (which of course is important considering species sanitation):
An. venhuisi is frequently caught in houses, which suggests endophilic and endophagic characteristics, whilst *An. nigerrimus* was described (Bonne-Wepster & Swellengrebel, 1953) as being a wild form, breeding independently of the proximity of habitations and was not commonly found resting in houses and cow-sheds.

Species of the hyrcanus group are often found breeding in rice fields, and control of this species as a rice field breeder will be discussed in detail in Chapter 5.

11. *Anopheles kochi* (Dönitz, 1901).
Mangkoewinoto (1919) considered the importance of *An. kochi* as low. This was quite logical since he worked in west Java, where *An. kochi* was not found infected. But since many records of infected females were reported from Sumatra, its importance especially if occurring in large numbers should not be neglected (Doorenbos, 1925; Swellengrebel & Rodenwaldt, 1932). Bosch (1925) confirmed Doorenbos' findings, he found *An. kochi* in large densities, naturally infected (3.7%) and could experimentally infect it up to 86.6% (with *P. falciparum*); no other anophelines were found infected.

Boyd (1949) also denotes *An. kochi* as an important vector in Sumatra. Doorenbos (1925) who describes an epidemic solely set up by *An. kochi* (Soengei Baleh, Kisaran, Sumatra) reports the impossibility of controlling *An. kochi* by using species sanitation since this species is found in many different types of water collections.

12. *Anopheles tesselatus* (Theobald, 1901).
Though being recorded as a vector in Indonesia by Boyd (1949), indirectly it was not considered to be of any importance (Swellengrebel & Rodenwaldt, 1932).

13. *Anopheles leucosphyrus* (Dönitz, 1901).
McArthur (in Boyd, 1949) reports *An. leucosphyrus* as being the most important vector in Kalimantan [Borneo], and that *An. flavirostris* nor *An. maculatus* are of significant importance. Bonne-Wepster & Swellengrebel (1953) noted the importance of clearing up the systematics of this species, and reported six to seven forms, of which *An. balabacensis* (see further) also was of some importance. Since breeding occurs in dense vegetation inside the forest, control of breeding is difficult to achieve. Exophilic and (often) exophagic habits make control attempts even more complex. Vegetation removal and jungle clearance would seem appropriate control strategies (WHO, 1982) but the creation of extensive breeding sites for heliophilic species should be kept in mind.

14. *Anopheles balabacensis* (Baisas, 1936).
Of the *An. leucosphyrus* group this is considered to be the most important species, in Kalimantan [Borneo] mainly together with the type-species. Colless (in Bonne-Wepster & Swellengrebel, 1953) reports this species as being the principle malaria vector in Sabah [British N. Borneo]. Because of the shy habits and late flight period not much is known about this species.

15. *Anopheles punctulatus* (Dönitz, 1901).
In Java *An. punctulatus* is not considered an important vector unlike in Irian Jaya [New Guinea] where it plays a very important role in malaria transmission. Boyd (1949) regards *An. punctulatus* as the most important vector of the Australian region, and it is considered to be as important as *An. sundaicus* in Java, responsible for the maintenance of the hyperendemic malaria in those regions. In recent years several ecological studies on the *An. punctulatus* complex have been undertaken on Papua New Guinea, providing much information that was unknown to the scientists working in pre-World War II Indonesia (Charlwood *et al.*, 1985; 1986). This information has not been included in the present review. Control: see after *An. koliensis*.

16. *Anopheles farauti* (Laveran, 1902).
The role which *An. farauti* plays in Irian Jaya [New Guinea] was compared with the role of *An. sundaicus* in Java (Covell, in Boyd, 1949). It is also a typical species regarding man-made malaria situations because of its heliophilic character. Wherever the jungle is cut, or vegetation is cleared, breeding in almost every type of water collection occurs. *An. punctulatus* and *An. farauti* also play an important role as vectors of human filariasis (*Wuchereria bancrofti*). Control of the complex will be described after *An. koliensis*.

17. *Anopheles koliensis* (Owen, 1945).
Bonne-Wepster & Swellengrebel (1953): This species has to be considered as a dangerous carrier.

De Rook (1924) did some research on two species of the *punctulatus* species complex, *An. punctulatus* and *An. farauti*, in Pioniersbivak and Prauwenbivak (Irian Jaya [New Guinea]), and confirmed their role as important malaria transmitters.

Ford (in Boyd, 1949) gives some general considerations for the control of the species of the punctulatus group: a) breeding occurs in many types of water collections, b) females rest outdoors after feeding, c) deviation to animals is difficult and can worsen the situation (extensive breeding in hoof marks). Control of these species in the past has been successful by aerial spraying of residual insecticides (95% population reduction) (Gandahusada & Sumarlan, 1978), but resistance to insecticides makes this strategy unapplicable. Against *An. punctulatus* drainage can be a very successful method, and can easily be achieved since *An. punctulatus* only breeds in shallow water collections. Stream rectification causing a freer flow has also been able to reduce *An. punctulatus* breeding. Clear-

ing of vegetation has been unsuccessful (once again) and in some places worsened the malaria impact (see also *An. bancrofti*).
From recent research on the ecology and control of members of the *An. punctulatus* complex in Papua New Guinea (J.D. Charlwood, personal communication) it appears that control of these species is difficult. The best approach seems to be to undertake a detailed ecological investigation in each locality before decisions on specific control measures are being taken. The use of impregnated bednets has proven to provide protection against new infections, especially in small children (WHO, 1989).

18. *Anopheles aconitus* (Dönitz, 1902).
This species has been found infected in Indonesia, India, Indo-China and Malaysia but only in Indonesia it appears to be a vector of real importance. In central Java it is considered to be the principal malaria vector (Chow *et al.*, 1959). Overbeek & Stoker (1938) considered *An. aconitus* in W-Java as important as *An. sundaicus* in other areas. Christophers (in Boyd, 1949) almost always found *An. aconitus* in combination with malaria infestation. Bruce-Chwatt (1985) reports that *An. aconitus* in central and west Java is fully resistant against DDT. Williamson (in Boyd, 1949) reports the achievements from Indonesia in controlling *An. aconitus* with naturalistic methods (see Walch & Soesilo, 1934). These sanitations and others (such as control of *An. aconitus* in rice field) will be described in detail in Chapter V.

19. *Anopheles minimus* (Theobald, 1901).
The importance of *An. minimus* is not as great in Indonesia as elsewhere. In India, Assam and Northern Bengal it is the most important vector (Bruce-Chwatt, 1985). Control: screening of houses was considered to be ineffective because of the exophilic and exophagic characteristics of this species. Because of its heliophilic habits, this is another species often contracted whenever vegetation is cleared (man-made malaria). In Assam there have been successful vector control campaigns by shading of the breeding sites (Russell *et al.*, 1946). Not only the shading inhibited this species from breeding, but the growth of grass along the edges declined, leading to increased current velocities, in which *An. minimus* could not breed. In Indonesia these techniques were first applied in the 1930s, typical examples of species sanitation. Not only for *An. minimus* but (in Indonesia) mainly for *An. maculatus* shading of slow running streams by planting *Tithonia diversifolia* (marigold) was very successful (Soesilo, 1936; Overbeek & Stoker, 1938).

20. *Anopheles flavirostris* (Ludlow, 1914).
Though previously reported as the chief malaria vector in the Philippines its role as a vector in Kalimantan [Borneo] and West-Java is doubtful, see *An. leucosphyrus*. Bruce-Chwatt (1985) states *An. flavirostris* sometimes is seen as a subspecies of *An. minimus* as it was before (Swellengrebel & Rodenwaldt, 1932). Since *An. flavirostris* is a typical slow running water breeder stagnating of the

water could prevent the species from breeding. This however was not successful in the Philippines, because freshening of a series of pools still occurred. Another proposed method was the use of a fungus against *An. flavirostris*, since specimens were found disabled by it in the Philippines. It would be interesting to experiment with sowing of cultures of this fungus in the daytime resting places (Russell *et al.*, 1946). WHO (in Bruce-Chwatt, 1985) reported resistance against Dieldrin in Java, 1978.

21. *Anopheles sundaicus* (Rodenwaldt, 1926).
Because of the importance of *An. sundaicus* as a malaria vector in Java and Sumatra, much has been written about this species in the past. Species sanitation, the major issue of this review, was mainly undertaken against *An. sundaicus* and some examples are presented in Chapter V. Control of the fresh water form from Sumatra has been described by Soesilo (1936). Overviews of the sanitation works against *An. sundaicus* have been given by various authors e.g. Walch & Soesilo (1935), Soesilo, (1936) and Overbeek & Stoker (1938). They report on malaria control through sanitation from many places: Sibolga (Sumatra, 1919); Tegal (Java, 1928-1929); Batavia (Java, 1928-1932); Soerabaya (1916-1920); Belawan (Deli, Sumatra, 1919); Tjilatjap (Java, 1919); Semarang (Java, 1927); Probollingo (Java, 1921); and Banjoewangi (1928). All these works were primarily directed against the salt water form of *An. sundaicus*. They consisted mainly of mechanical measures like filling, draining, construction of open connections with the sea etc.; in some places natural methods were used (Pasoeroean, Semarang, Batavia). These sanitations were executed by civil engineers often in combination with hygienists or fish-culture experts. Other methods need to be mentioned briefly:

- Salination: because of the specific range of salinity *An. sundaicus* can tolerate, changing the salinity of fish-ponds or other breeding places has shown success in the past, and is still used in Indonesia (Russell *et al.*, 1946; J. Hudson, personal communication).
- Tidal movement: it has been shown in the past, that tidal movement will prevent *An. sundaicus* from breeding (i.e. mangrove forests along the coast (Rodenwaldt, 1925).
- Shading: because of its heliophilic character shading by plants may be useful for partial control (Bruce-Chwatt, 1985).
- Larviciding, and the use of adulticides has declined partly because of resistance against DDT and Dieldrin in various parts of Indonesia (Bruce-Chwatt, 1985).
- Zooprophylaxis: it was thought (Doorenbos, 1925) that *An. sundaicus* could be deviated from man, by using cattle as a 'barrier' around houses (zooprophylaxis). Schüffner *et al.* (1919) rejected this method, because of *An. sundaicus*' high preference for human blood; and moreover the vector production would not drop, but might even increase. Walch (1932) found the same.

A detailed overview of the control measures against *An. sundaicus* in Indonesia has been given by Gandahusada & Sumarlan (1978). In Chapter 5 some examples of species sanitation from Indonesia have been described in detail.

22. *Anopheles subpictus* (Grassi, 1899).
Christophers (in Boyd, 1949) regarded this species as totally unimportant, but it has shown to be a locally important vector in Sulawesi [Celebes] (Bonne-Wepster & Swellengrebel, 1953), and in Irian Jaya [New Guinea] it has shown to be an important co-transmitter together with *An. farauti* (Gandahusada & Sumarlan, 1978). Residual spraying with DDT in those areas achieved a 95% population reduction of those species.

23. *Anopheles annularis* (Van der Wulp, 1884).
This vector was found naturally infected on several occasions and in different areas. Though in several areas *An. annularis* is not considered as a vector of importance, in other parts it appeared to be the principal transmitter, with other vectors quite rare (*An. minimus*). On the other hand it may be found uninfected in areas where *An. minimus* is the principal vector (Bonne-Wepster & Swellengrebel, 1953). An epidemic of malaria was reported by Swellengrebel & Swellengrebel-de Graaf (1920) where *An. annularis* and *An. sinensis* were the only species found infected, although *An. aconitus* and *An. maculatus* were also present.

24. *Anopheles maculatus* (Theobald, 1901).
Originally, though being an important vector in Malaysia (Watson in Swellengrebel, 1921), *An. maculatus* was not seen as important as it was. Later on it was found that it was capable of keeping up an epidemic in Sumatra (Doorenbos, 1925; 1931). Often it was closely connected with man-made malaria because of its heliophilic character.

Control of this vector has been implemented in various ways: the eldest known (though quite expensive) is sub-soil drainage, which was indeed very effective and inhibited *An. maculatus* from breeding (also used at Sibolga, see Nieuwenhuis, 1919). Shading experiments, along stream banks with *Tithonia diversifolia* and other scrubs or trees were used in Western Java estates, with varying success (Soesilo, 1936; Overbeek & Stoker, 1938). Agitating and stagnating (with addition of larvivorous fish) have been used successfully in Malaysia (Russell *et al.*, 1946).

Discussion

The data from this section are summarized in Table 3.9 which shows the historical methods used for the control of aquatic stages of anophelines in Indonesia. From this it is immediately apparent that species-specific control methods were used successfully against only a few species in Indonesia (asterices) and elsewhere in South East Asia (solid circles). Using the data from this chapter, we have indicated how each method, in theory, could be effective against a number of

Table 3.9 Summary of the control of the aquatic stages of *Anopheles* spp. in Indonesia with respect to species sanitation (after Russell *et al.*, 1946; and this review).

		A. aitkenii	*A. umbrosus*	*A. beazai*	*A. letifer*	*A. roperi*	*A. barbirostris*	*A. vanus*	*A. bancrofti*	*A. sinensis*	*A. nigerrimus*	*A. kochi*	*A. tesselatus*	*A. leucosphyrus*	*A. balabacensis*	*A. punctulatus*	*A. farauti*	*A. koliensis*	*A. aconitus*	*A. minimus*	*A. flavirostris*	*A. sundaicus*	*A. subpictus*	*A. annularis*	*A. maculatus*
MODIFICATION OF BREEDING SITES																									
Cultural methods	- replacement of natural vegetation				○																	*	*		
	- exposure to sunlight	○	*	○		○			○				○	○	○						○				
	- introduction of aquatic vegetation	○	●				○	○	○	○	○				○				○	●	○			○	●
	- shading									○	○									●		○	○		*
Mechanical methods	- screening (=shading)															○	○								
	- modification of water edges favourable for breeding	○			○																				
	- silting	○							○																
	- flooding		○	○	○	○					○														
	- agitation of water		○	○	○	○					○														●
	- water stagnation, impoundment	○							○											●					●
	- control of river flow																								●
	- freshening of water			○																		●			
	- salinifying				○	○			○	○	○		○		○				○	○	○	*			
	- intermittant drying						○	○		*	○								*		*	*	○	○	●
ELIMINATION OF BREEDING SITES																									
Cultural methods	- drying by planting of crops																								●
Mechanical methods	- water diversion					○																			
	- reparing of leaks					○																			
	- removal of empty containers															○	○								
	- earth filling		○	○	○	○			○	○	○	○	○	○	○	○	○	○	○			○	○	○	
	- removal of standing water by pumping		○																						
	- construction of tidal gates																					*	*		
	- water drainage		○			○			○			○													*
DIRECT CONTROL																									
Biological control	- create conditions favourable for predatory fish						*	○		*	*											*			
Chemical control	- larvicides									*	*											*			

* = method successfully applied in Indonesia in the period 1900-1940;

● = method successfully applied in South-East Asia in the period 1900-1940;

○ = method recommended against that species based on the findings from this review.

species (open circles). Although each method will have to be retested in the field, there is good reason to believe that several of these methods can be used for malaria control today. The implications of these results will be discussed in Chapter 8.

Chapter 4

Swellengrebel and species sanitation, the design of an idea

J.P. Verhavè

Introduction

General principles of malaria control were established as soon as the role of anophelines in transmitting the disease was discovered. The specialized control method, which is the subject of this review, assumed its shape after several of these measures had failed locally. Here we attempt to trace its conception, larval growth, pupal rearrangements and final emergence as a full grown idea as it occurred in the Indonesian Archipelago. A selection from writings of the central figure, the zoologist Nicolaas Hendrik Swellengrebel, in his particular style, gives a vivid impression of visionary science. The genesis of his ideas took place in three phases: the chance confrontation with malaria control in The Netherlands East Indies (1913); the preconceived investigations in the Archipelago (1917-1919); the malaria control in The Netherlands (1920-1960).

The first stage

Professor J.J. van Loghem, director of the new department of Tropical Hygiene of the Colonial Institute, Amsterdam, recruited Swellengrebel in 1911 to teach protozoology. The zoologist, 27 years of age at the time, had studied biology and received advanced training in Paris, at the Institut Pasteur, under Professor Mesnil. In 1908 he did his PhD studies on potato diseases under Professor Lang in Zürich. He was nominated lecturer in protozoology at the University of Amsterdam and subsequently carried out postdoctoral work in Professor Nuttall's department in Cambridge. In 1912 he completed a second edition of the handbook of parasitology by Sluiter and participated in courses for the training of government physicians selected to work in the colonies.

In 1912 Swellengrebel himself was sent to the Netherlands East Indies to lead the control programme of plague, under the auspices of the Civil Medical Service, founded in 1911. When his term was over he was charged with staying and collecting biological and pathological specimens for the educational museum of the department in Amsterdam. Swellengrebel travelled to Deli (Sumatra) where he collaborated with Dr. W. Kuenen in studies on amoebae. He learned a great deal about clinical, tropical hygienic and control aspects of parasitic protozoa from Kuenen and planned to use this knowledge in an update of Sluiters' handbook on parasites (which he issued in 1923).

Since the discovery of the role of anophelines in malaria transmission, several studies had been undertaken in the Netherlands East Indies, which were mostly published in the 'Geneeskundig Tijdschrift voor Nederlandsch-Indië'. Swellengrebel knew the authors and must have had a general knowledge of their work, although he had no special interest in malaria.

Dr. Terburgh, military physician and later inspector of the Civil Medical Service in East-Java, had been sent to Italy as early as 1903 to study malaria control; in 1904 he had recommended the prophylactic use of quinine and, if possible, clearing of marshes and regulating the water drainage. Around Jakarta [Batavia] general sanitation works had been carried out. There Dr. Kiewiet de Jonge had reported on his search for breeding places, fish ponds and rice fields, and how to make them unsuitable for anopheline larvae (1908). Except for combatting epidemics he saw no possibility to control malaria among the local population by quinine prophylaxis. The hopelessness of the prospect of quininisation was later confirmed by Terburgh (1919). Back in Holland Kiewiet de Jonge pleaded for better education of physicians in protozoology, a job with which Swellengrebel was charged. Dr. De Vogel, Resident and physician in Semarang, had found that certain anophelines were adapted to water with a high degree of salinity (1906); one of these mosquito species appeared to be an efficient vector of malaria (1909). Despite De Vogels' complaint that literature was difficult to come by, he had set the trend for research in the years to come.

By the time of Swellengrebel's stay, De Vogel was Chief Inspector Civil Medical Service and thus his superior. Swellengrebel conveyed to his parents that discussions with De Vogel were very enlightening. After the initial discoveries of malaria being transmitted by mosquitoes, and indeed, by *Anopheles*, awareness was growing that only certain species of *Anopheles* transmit the malaria parasite.

At that time Swellengrebel also met Schüffner, physician of the Senembah Tobacco Company, who was interested in the biological and clinical aspects of malaria and its prevention (Schüffner, 1902). To his parents Swellengrebel wrote meticulously about his activities and whereabouts. Although malaria was hardly mentioned in his correspondence, he made series of blood smears from patients in Medan with quartan malaria and began a study of the relatively little known parasite. He was more interested in the protozoa than in the insects which transmitted them.

Then, in Medan, Swellengrebel met someone else...

In a letter to his parents from Medan, March 12th, 1913 he wrote (*)[1]

From Thursday till Monday we had a visit by an Englishman from Malaysia, who had been controlling malaria there. The strange thing is that whilst malaria is so bad in Malaysia (close by), it hardly occurs here. Thus, he wants to know why this was so and it appeared that those anopheline species that transmit malaria in Malaysia, do not occur here at all. One doesn't know why. Maybe it is because Malaysia has a granite ground and here there is a volcanic soil that pollutes and troubles the water, inhibiting Anopheles *to live in it. For him it's of course of*

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[1] All marked (*) citations are translated by the author (J.P.V.); Otherwise the citations were originally written in English and cited without attempting to correct the English.

major importance to know the ins and outs of it and thus, Strickland (who is now also in Malaysia) will probably come over to investigate the case more closely... I went with the Englishman to the rice paddies in the neighbourhood to catch anopheline larvae.

Malcolm Watson, of whose work apparently no one in Deli was aware, had been supervising the general sanitation of Klang and Port Swettenham in the nearby Malay States. The resulting decrease of malaria was achieved at extremely high costs. In 1911 he had published his book 'Prevention of Malaria in the Federated Malay States' in which he described that different species of anophelines occur in the plains of Malaya. On the basis of their natural infection index he concluded that only *Anopheles umbrosus* was responsible for the local malaria transmission. It bred in the forest and Watson had found that spleen and mortality rates decreased in people who lived away from the forest. The government decided to clear the forest within 0.5 mile from the houses of plantation labourers. Water reservoirs outside that area and the anophelines breeding therein could be ignored from then on, which meant a considerable reduction in control expenditure. Watson found that another mosquito, *A. maculatus*, was responsible for malaria transmission in the hills. This species bred in clear brooks with fast-running water. He suggested subsoil drainage as a measure of control, which had an immediate effect.

Swellengrebel described the encounter with Watson in Deli thirty-seven years later in a lecture presented at the London School of Tropical Medicine & Hygiene as follows (1950):

Kuenen, director of the laboratory for pathology in Medan (eastern Sumatra), entered my room one day in May 1913, and inquired if, as he expressed it, I could talk Anopheles. *Without the least feeling of shame I was able to say that I could no more talk* Anopheles *than I could talk Egyptian. Neither could Kuenen. He told me he had been interviewed by a man 'from the other side', meaning Malaya, and I had better come and talk to him, as Kuenen could not make head or tail of what he was saying. We were both deeply immersed in the subject of dysentery amoebae, and much resented having to turn our attention to anything so uncongenial as* Anopheles. *However, the sacred duties of hospitality compelled us to do so; half-heartedly at first, with our whole heart and mind once we had succeeded in grasping Sir Malcolm's meaning for I need not tell you that he was our visitor.*
It was rather a shock to him, I believe, to find that malaria was not a major health problem in that part of Sumatra, but Schüffner, to whom we introduced him the same afternoon, convinced him that we knew what we were talking about when we said it was not. We took him around through various parts of the province, to show him whatever small foci of malaria there were to be seen. He showed us our own Anopheles, *adults and larvae, and introduced us to the first principles of that field of entomology. Shortly after he left, Schüffner and I gathered the first fruits of Watson's tuition, by collecting* A. leucosphyrus *in houses in the only malarious spot in the neighbourhood, and nowhere else...*

A few weeks afterwards, De Vogel, Director of Health for the whole of Indonesia, came to us for a short visit. He was on his way to Sibolga, an important seaport on the west coast of Sumatra, where a serious malaria epidemic had broken out. We told him all about Watson's work in Malaya. I am afraid it was not all quite accurate, the information we gave him... He was so much impressed by all this that he got it in his head that we knew a great deal about the subject. As a matter of fact, he himself and Schüffner were the only ones who had ever before occupied themselves with it. Of the three of us Schüffner, Kuenen and myself, I was the only one who was under De Vogel's orders, and so it was I who had to accompany him on his five days' crossing of the island of Sumatra [to Sibolga]...

For his parents Swellengrebel recorded on April 20th, 1913 (*):

Practically everyone falls ill here (if you don't take 0.5 gram quinine per day prophylactically, as De Vogel and I do). Malaria reaches out into the town: masses of anopheline larvae in saltwater puddles in parts that are incompletely filled up. Further filling up would, at least initially, create many breeding places. More mosquitoes, more parasite carriers, more malaria right into the European quarters! The further off the less malaria. But larvae are also found in the paddies; apparently these were not so dangerous earlier. They must disappear in order to allow for expansion of the town on behalf of the Europeans.

Naturally, all these plans, based upon our investigations on malaria and anophelines, are carried out technically by an engineer, if it appears at all possible, financially and otherwise... Furthermore, I have got an apprehension of the course of a campaign for malaria control and finally I became really able to assist De Vogel with the determination, collection etc. of mosquitoes.

And during a lecture on malaria-epidemiology, in 1916 for the Netherlands Society for the Advancement of Science, Medicine and Surgery, he recalled the situation as follows (*):

The health situation there was so bad and the continual evacuation of officials was so detrimental, that the transfer of the site of local administration to another place was contemplated... the malaria was a direct obstacle for the development of this seaport.

One year later he and Schüffner wrote in an article on anophelines and malaria in Deli (*):

Behind the heavily infected quarter of the Europeans were rice paddies, where Myzorrhynchus sinensis *breeds. Yet, the danger doesn't hide there, because – as Schüffner demonstrated – this mosquito does not transmit pernicious malaria (the almost exclusive type in Sibolga). The source of the evil was the partly filled up marsh in another section of the town, where* Myzomyia vaga (ludlowi) *occurred in large quantities, a mosquito that, according to the investigations by De Vogel and Christophers, also transmits perniciosa.*

The species differentiation of the anophelines is of importance for the practice of malaria control.

Swellengrebel evaluated the situation further in his lecture for the London School in 1950:

Failing to find maculatus, *we turned our attention to* sundaicus *(or* ludlowi

Photo 5 Dr. Schüffner and the Swellengrebels in Loeboeg Sikaping (Sumatra), May 1918.
(source: photo archives Dr. Swellengrebel, private collection)

as it was then called). At that time it derived its only claim to be ranked as a vector from Christophers' investigations in the Andamans; Malayan experience did not lend much support to the claim and was hardly taken seriously. But the epidemic was certainly caused by sundaicus. *It was the old story over again: man-made malaria, this time by trying to improve health conditions by attacking mangrove swamps... It had been done on the false assumption that the smell arising from mangrove swamps is deleterious to health; a tragic mistake which caused all the mischief it tried to prevent: breeding places of* sundaicus *appeared and malaria with it.*

Dr. Watson invented the method of malaria control to which he afterwards allowed me to give the name of 'species sanitation', that is, reducing the incidence of malaria by making use of the habits of one species of Anopheles.

Sibolga became the first example in Indonesia of malaria control consciously directed against one species of Anopheles. *It was not a clear-cut example, because it came to comprise a general welfare scheme, with new town quarters requiring much wider drainage than was necessary in order to deal with* sundaicus *successfully. The plan more and more...lost its character of species sanitation.'*

Swellengrebel took the chance of further training in entomology by assisting

Schüffner in Medan. From there he wrote to his parents on May 26 and July 24, 1913 (*):

Have been catching mosquitoes together with Schüffner on the Senembah Comp., where malaria is frequent. Of course, as always long searches in vain. Finally we found breeding places of anophelines near coolie houses and the mosquito itself inside those houses. We imagine so freely, that Anopheles *breeds everywhere in a malarious area; nothing is less true, it sometimes takes ones utmost to find the breeding places. Puddles everywhere, mosquito larvae nowhere; then all of a sudden you run into a pool, just like the others, riddled with larvae. Not all anopheline species transmit malaria, that is something to take into account. Of the species that we found yesterday it is not yet known; therefore, the cause of malaria at the Tandjong Morawa estate is not yet completely clear.*

My article with Schüffner is finished. Earlier on, malaria was rare here and now it is strongly on the increase. In those days Schüffner investigated the anophelines here and during our present studies there appear to occur species that weren't here earlier. Firm conclusions not yet possible, but significance demonstrated of a careful study of the anopheline fauna, not only here but in the whole archipelago. It is an 'Anregung' for a study on which nowadays the whole malaria control in other countries is based, but that is very much neglected here, through the insufficient education of the physicians. I know that De Vogel thinks along similar lines.

In their report on malaria and mosquitoes Swellengrebel and Schüffner (1914; 1917) stated that tertian malaria was everywhere, pernicious malaria along the coast and quartan malaria in the hills. Although the authors described several species, knowledge was lacking to determine which mosquito species were responsible for malaria transmission in these areas. They saw enormous advantages in knowing the 'perniciousness' of the various species to enable sanitation measures to be taken.

Intermission

Directly after his return to Amsterdam Swellengrebel was appointed head of the zoological laboratory, and his superior, Van Loghem urged him to concentrate on getting the educational collection in order; *'the study of anophelines can come later'*. But it remained an urgent matter as well, because he wrote to Dr Malcolm Watson, then on leave in Scotland: *'Dr Swellengrebel has returned from Sumatra and will tell you everything we know and especially the things we do not know about Anopheles in Java and Sumatra. He will also give you a short report about the distribution of malaria, but I am sure that it will not be very complete.'*

On February 6th 1914 Van Loghem presented to the board of directors his motives to have Swellengrebel study anophelines with Prof. Theobald in England, then the world's leading mosquito taxonomist.

It has appeared necessary to perform the determination of anopheline mosquitoes as precisely as possible: one species can play an important role, whilst another species remains irrelevant. This correct distinction is of course of great practical *importance for control, as it determines which breeding places of mosquitoes are first to be eligible for destruction. According to this experience Dr. de Vogel has expressed the necessity to reach as soon as possible a complete overview of the anophelines in the Indian Archipelago, which has to be used as a lead in the local malaria control. Dr. Swellengrebel is ready to perform the necessary determinations...*

The onset of the war prevented his trip.

In May 1914 Van Loghem was asked to advise the Minister for the Colonies about the intended sanitation of Surabaya. Some members of parliament wanted a more aggressive approach, impressed by the American successes of malaria control in Panama, Cuba and the Philippines. Van Loghem pointed to the activities of Terburgh in Surabaya, who reported in 1912 on the sanitation of Japara and the installation of a malaria brigade, through which breeding places of anophelines were detected.
Malaria was to be studied locally: *'as not every anopheline transmits malaria, it is necessary to know what is the local vector and its breeding sites. This should be the basis for choosing appropriate sanitation measures'*. This advice, apparently inspired by Swellengrebel, was rewarded with an extra Dfl. 300.000 for the malaria control in Surabaya.

In the next year Swellengrebel set himself to the desired systematical work on anophelines and prepared a series of paintings of the described mosquitoes; after being drafted for the army he continued in his free time to write a monograph on the anophelines of the Netherlands Indies. Some haste was needed, because one species on his list had just been described by somebody else from the Straits! It appeared in May 1916 under the title 'De Anophelinen van Nederlandsch Indië'.
Meanwhile he reviewed an article by Walker & Barber and a book on rural sanitation by Malcolm Watson, in which he found support for his ideas about the need for study of the anopheline fauna in the Dutch East Indies and the importance of knowing which species transmits in a particular area.

By this time Dr. De Vogel thought the time ripe for a more thorough study in the Archipelago. In his answer of 27 July 1916 Van Loghem stated that Swellengrebel could only be missed for a short period. He was to arrange his activities in such a way that he develop a research principle, and leave the execution of the research to others.
Little was known about transmitting species. In the preparation of his work it came handy that a preliminary report on malaria research in Mandailing by Schüffner was received in Amsterdam.

The situation in the interior of Sumatra was serious; one in four people carried parasites, half of the pernicious form *Plasmodium falciparum*. The exclusive vector for the latter was *A. ludlowi*, surprisingly, because elsewhere it was a coastal mosquito. Its breeding places were unknown; certainly not the fish ponds...

Local authorities had enforced strict rules for general sanitation by cleaning the dwelling places; this as well as other alternatives (compulsory use of quinine or bednets, regulated rice culture and petrolisation of the water) had become burdens and failures.

Schüffner introduced a new form of sanitation, only based on the extermination of anophelines inside the houses. He instructed the people to catch anophelines daily, particularly the fed ones.

Swellengrebel recalled this unusual approach in his London lecture of 1950 as follows:

Schüffner taught the people to recognize Anopheles, *he taught the schoolchildren to identify* sundaicus, hyrcanus, annularis, aconitus *and* vagus. *On visiting a village for spleens and parasites, the first ceremony enacted was the schoolmaster, with some of his senior wranglers, appearing on the scene, carrying bamboo tubes containing freshly caught specimens of each... Each village head-man of certain selected villages had to deliver the early morning's catch to the malaria laboratory, where every catch was identified and registered. Conscientious villages could be known by the majority of* sundaicus, *the principal house-haunting mosquito. Lazy villages showed more* hyrcanus; *they had found out that it is easier to make catches in the carabao sheds.*

The first year (1916) it looked as if Schüffner might succeed. The next year the plan miscarried, because the Central Government stepped in by declaring this procedure illegal, being tantamount to enforced labour...

The second stage

Swellengrebel had recently married a schoolteacher, Meta de Graaf, and Professor Van Loghem urged the couple to go together on this trip to the East. Young Mrs. Swellengrebel could give her husband a hand in his work on identifying malaria vectors and establishing guidelines for malaria control. Directly after their arrival in February 1917, they were received by Dr. de Vogel, who gave his vision on the expected work: '*You are to find out what species of* Anopheles *occur in these islands. We know already, from experience in Malaya, which are vectors and which are not. That is no concern of yours. You simply give me lists of names of* Anopheles *in every locality you visit. That is all we require of you'.*

Indeed, a period of travelling lay ahead, the length of which was by no means clear, nor were the plans; it turned out to be half a year in Java, one year in Sumatra, with a short trip to Malaysia, and again more than a year in Java, with a long trip to the eastern part of the Archipelago. What became obvious from the very beginning was, that Swellengrebel had made up his own mind when it came to the actual investigations.

In a letter to his mother, from Batavia, 15 February, 1917, he wrote (*):
De Vogel wants me to design a regulation, by which all native doctors throughout the Dutch Indies are supposed to catch mosquitoes and send them to Amsterdam. Furthermore, he wants me to visit a number of places and do explorative work. I told him that in my opinion the latter should come first, because the experience

gained would be helpful in the setting up of that regulation. He agreed and thus we go out, firstly to Tjilatjap at the south coast of Java.

From there, he wrote on March 18, 1917 to Van Loghem (*):
Our work consists of: 1) exploring the breeding places and determining the anophelines of those places, 2) taking the spleen sizes in hamlets, 3) catching anophelines inside the houses and dissecting for natural infection.
Concerning item 1) I find it convenient to use the larvae for species determination. As a control I allow them to emerge, but it always tallies. Unfortunately, not all larvae of our D.I. anophelines are known. Meanwhile, this is such a convenience, that I have to strive with all my force to fill in this lacuna.

In Tjilatjap no infected mosquitoes were found, though the common *ludlowi*, breeding in saltwater marshes was suspect; the proof was easily found during their subsequent stay in Cheribon (west coast of Java) where a ravaging epidemic took place: 35% of caught *ludlowi* was found infected, the very first documented evidence that this species was a highly efficient vector!

Their next stop was Surabaya on the north coast; Swellengrebel wrote to his mother on July 1st, 1917 (*):
Surabaya has to expand and the edge is very unhealthy; this needs improvement. Puddles are everywhere, partly fresh, partly salt. Are all those puddles dangerous, or only the saltwater ones? In the saltwater puddles and in the freshwater ones breed different mosquitoes. Which of those species transmit malaria here? It was necessary to examine a large number of mosquitoes for this. We examined 740 mosquitoes of the saltwater species and found 69 infected with malaria; of the freshwater species we examined 634 and found 3 infected. So, the freshwater species is not completely harmless, but yet less dangerous. It is impossible to get rid of all puddles in Surabaya, but for the saltwater puddles (former fish ponds) it is feasible, indeed. Fairly whole-heartedly we could advise here: do away with the saltwater breeding places only and leave the rest.

To Van Loghem he reported on October 2nd, 1917 (*):
The big sanitation plans are intended to have that part of the broad stretch of fish ponds bordering the city of Surabaya to disappear. M. ludlowi *and* M. rossii *breed in those fish ponds. Further away from the coast breed* M. rossii, M. indefinita, M. sinensis, M. barbirostris, N. fuliginosus *and* M. aconita. *Now the question was: does one take away the dangerous anophelines with this sanitation? In the hamlets with malaria... particularly* M. ludlowi *occurred; the next one in numbers is* M. rossii... *For investigation of the natural infection we focussed on these two... The infection rate of the first species was 2-22% (in different hamlets) averaging 9%; that of the last one averaged 0.6%...* aconita *remained a gap in the study; it is a species that generally is considered very dangerous, but that was collected here, during our work, in insufficient numbers... Thus, the question remained, whether one wouldn't keep the enemy in the rear, with the proposed sanitation; this seems the more a danger since the* aconita *(as I now understand) starts to increase in numbers after our departure.*
As we had found out that for one and the same species this index is subject to local changes... we had to determine it anew for ludlowi *in Mandailing. This pre-*

caution appeared not superfluous, as the index was only 3% for 1800 examined ludlowi.

With the huge excess of ludlowi *occurring here in the houses, one would think it not difficult to find larvae in corresponding quantities. This is, however, not the case. My wife found only 50* ludlowi *among thousands of anopheline larvae, particularly in the (freshwater) fish ponds. Here, we are facing an as yet unsolved problem.*

Working in Tandjong Morawa, near Medan, Swellengrebel wrote to his mother on November 18th, 1917 (*):

On Thursday, October 18th, we went to Sibolga, where I was in 1913 during that severe malaria epidemic, together with De Vogel. The situation there is much better now, let us hope thanks to the very expensive sanitation measures. A lot has been done, but not yet enough, I fear. How much better could I have helped De Vogel, when I had known then, what I know now! Still, the difference between the paralysed town of 1913 and Sibolga of 1917 is enormous... But that sort of improvements may happen in malarious areas also without any measures!

In another letter on New Year's Day, 1918, to his mother, he confided (*):

How little one can rely on some statements from other countries, may appear from the following: Watson, the man who actually brought us to study mosquitoes in 1913, claimed that a certain mosquito, umbrosus, *living in the forests of lowland Malaysia, was the most important vector. By cutting the primeval forest one can get rid both of that mosquito and the malaria. If unsuccessful, that was always due to a forgotten piece of forest somewhere. Now, Watson has never really checked whether this* umbrosus *actually allows the malaria parasite to grow in her body. He saw the malaria often in the neighbourhood of* umbrosus *and not or less near other mosquitoes, and said then that the* umbrosus *must be the culprit. We have now done many experiments with this* umbrosus, *taking care that in every experiment also some good vectors* (ludlowi) *were included; we found out that the* umbrosus *is one of the least susceptible vectors and only incidentally allows the benign form of malaria parasites to grow inside.*

We are inclined to assume, that in Malaysia the situation is not different, that Watson was thus mistaken and that the results he obtained were only sham results; thus, the malaria he combatted did not disappear because of his measures, but through one of those, to us so mysterious conditions that make the malaria disappear without human influence, for good or for some time, from a place were it prevailed so vividly. So many a measure, in itself utterly aimless, has obtained an odour of sanctity by this accidental meeting.

During a visit to Dr. Stanton, director of the Medical Laboratory in Kuala Lumpur (the one who in 1914 had described a new mosquito species from Sumatra) Swellengrebel was confirmed in his critical attitude about the approach of malaria control in the neighbouring country. To his mother he wrote from there on May 22th, 1918 (*):

Based on infection experiments with several anophelines biting on malaria patients, he concluded that almost all anophelines can be infected if only all circumstances are optimally favourable. That is why Stanton thinks that all anophelines are dan-

gerous and thus it makes no sense to discriminate between species.

We had chosen a completely different route in our investigations. Though we had done similar experiments, mostly we had emphasized the question, not 'which anophelines can transmit malaria', but: 'which anophelines actually do this in nature'. Apart from that, he was (rightly) very critically disposed towards the malaria control in British Malaysia. He particularly opposed the blunt way of going on with sanitation: knowing the mosquitoes and not caring about the people. I mean, they omit the examination of spleen and blood, 'pièce de resistance' of our way of working, either completely or they do only a bit of spleen examination. Thus, they have no idea how the situation was before the sanitation, nor do they know it afterwards... Stanton said: 'In Kuala Lumpur and Port Swettenham malaria is abolished by act of Parliament'. It is forbidden to get malaria in those places'...

Back in Java, the Swellengrebels were sent to Semarang, a city in the coastal plains and from time immemorial, very unhealthy because of malaria. In a letter to mother Swellengrebel on October 8th, 1918, the activities of their predecessors Terburgh and De Vogel were recalled (*):

Terburgh wanted to sanitate the plain by clearing away all anophelines in a belt of 500 meters around the city, thinking that mosquitoes wouldn't trespass the borderline. Inside the city all breeding places had to be cleared. The fish ponds along the coast, when kept tidy, were considered harmless and thus not given further attention in this plan.

De Vogel did not agree, because he thought that this zone of 500 meters without breeding places would not hold out the mosquitoes. He considered sanitation of the plain unfeasible because of the high costs involved. He thus proposed to have the population move to the nearby malaria-free hilly area (not only the Europeans but also the natives). This last plan was accepted in principal by the town council... Nowadays, after about 10 years, many Europeans live already in the hills, but there are only 2 small new hamlets created by moved natives.

A government doctor has found a high mortality there and also anophelines... De Vogel could not leave this situation unchallenged... He wanted to have the case thoroughly investigated and in the approved manner (examination of spleens and blood); that's why he had us come over from Sumatra to undertake this investigation.

In their report on the occurrence of malaria and anophelines at Semarang (Swellengrebel & Swellengrebel-de Graaf, 1919c), the Swellengrebels reported as follows:

The uncertainty still prevailing on the cause of foothill malaria, prevents us from applying a really rational sanitation in this district. If one does not want to wait until matters are elucidated, then it will be necessary to do away with all the breeding places.

In the plain, along the coast, the conditions are otherwise. There we know M. ludlowi *to be the cardinal carrier, which up to the present time is almost absolutely restricted to saltwater. Here a sanitation especially directed against this species seems to be indicated, although we should not forget that it possibly might surprise us in a disagreeable way, by, after the saltwater breeding places having been cleared* *away, shifting to the freshwater.*

The continuous presence of M. rossi *in freshwater means that the fear of a general exodus [from salt to fresh]... when the saltwater breeding places are destroyed, appears much more real than in the case of* ludlowi.

And in a report on the biology of *M. ludlowi* in Sumatra (Swellengrebel *et al.*, 1919) it is stated that:

The practical importance of this special study is quite obvious: it gives us a means for successfully fighting the dangerous insect... The observation that the larva of the mosquito does thrive in the fishponds, opens the widest possibilities, in subduing the mosquitoes by drainage.

This fact enables us to concentrate all works of sanitation on the fish ponds, leaving alone the remaining breeding-grounds in the malaria-infested region.

The Swellengrebels also made some studies in Modjowarno, a rice field area where an epidemic was going on (Swellengrebel & Swellengrebel-de Graaf, 1919a). The seasonal epidemics coincided with the appearance of *M. aconita*, which they found to be the major cause. The following recommendations were cautiously formulated:

It stands to reason that no measures can be taken reducing the amount of rice fields under cultivation, but it may be asked whether agriculturists would be opposed to the following regulations:

1) Rice fields should no longer be flooded after the rice has become mature. 2) No ricefields are allowed to remain flooded after harvesting. 3) Except those fields, where a second crop of rice has a fair chance of succeeding, no second crop of rice should be reared.

We do not want to insist on the immediate application of these seemingly simple measures but we only recommend a conference to be held with experts of the Department of Agriculture. Possibly their wishes as to renovations in the culture of rice will appear to run parallel to ours, and so will be of easy application.

Concerning sanitation principles the Swellengrebels stated in another report, on the habitat requirements of various anopheline larvae (1919):

When wishing to combat malaria by sanitation of the soil i.e. by destroying the breeding places of the anopheline larvae, we may follow two ways: 1) By destroying all actual or potential breeding places of **all** anophelines. This we call **general antimalarial sanitation:** *2) By destroying only the actual and potential breeding places of those kinds of anophelines, which have proven to be dangerous in the district which is going to be sanified, viz. the species which are able to transmit malaria there and actually do so. This we will call* **specific antimalarial sanitation** [in the Dutch version the term **species-sanitation** is used here for the first time: **species-assaineering**].

The first method does not require much preliminary investigation, but much and very costly work. The second method requires an extensive preliminary investigation, but it is less cumbersome and less costly in its execution...

We are inclined to the following conclusions:

1. For combatting the larvae of dangerous anophelines of the ubiquitous, hill- or shade-preferring sorts, specific sanitation, as far as our knowledge goes till now,

Photo 6 Fishculture in rice field (native method). Breeding of *Anopheles aconitus*; remaining stalks in the rice field; growing of weeds; grasses hanging from the dikes in the water. (source: Overbeek & Stoker, 1937)

Photo 7 Fishculture in rice field (hygienic method). Free from *Anopheles aconitus*; dikes kept clean from grasses; stalks removed; water surface clean. (source: Overbeek & Stoker, 1937)

is not appropriate, because these sorts do not have sufficiently specialized demands with regard to their breeding places, and because the fact of doing away with the preferred breeding places would interfere too much with the area's economical life. In the present stadium of our knowledge about these species, we can only recommend general sanitation as the means of combating their larvae.
2. In view of the specificity of its breeding places, and also because of the extraordinary danger of ludlowi, *much greater than met with in any other anopheline till now, specific sanitation [species-assaineering] i.e. doing away with its saltwater breeding places, might be considered appropriate. However it should only be regarded as a* **trial,** *that is: as a modus of sanitation which does not from the onset hold out a promise of success, but which should be considered to be an essential part of the investigation to be made in regard of the definite sanitation, and which has to be made in order to elucidate all the questions and doubts mentioned before.*

Towards the end of the work Swellengrebel wrote an article on his malaria research for the Netherlands Journal of Medicine (1920b) in which he summarized his views on sanitation(*):

It would be unjust to think that malaria in the Neth. East Indies is only a matter of investigation, thereby forgetting control through sanitation. The actual implementation was not part of my job and the BGD has not yet judged the time as appropriate for giving directions. Yet different sanitation projects are already in various stages of accomplishment.
We conclude from our studies that:
1. Ubiquitous anophelines are the least suitable for sanitation (i.e. An. indefinita*).*
2. Serious malaria foci inland, caused by An. aconitus *and* An. maculatus *are least accessible with sanitation (sawahs, irrigation canals). A better regulation of rice culture is recommended.*
3. Life habits of An. sundaicus *are more favourable for species sanitation; it has a future here, more than anywhere else.*
4. Among other control measures (i.e. catching mosquitoes inside houses, oiling of water, use of predatory fish, screening of houses, improvement of nutritional status, increase of living distance from breeding sites, zooprophylaxis, and protective chemotherapy of schoolchildren), particularly chemotherapy would aid the decrease of malaria.

At the end of their term the Swellengrebels were very well appreciated by Dr. De Vogel, who had read their regular reports 'like a novel' and had taken the initiative for a handy booklet for health personnel, to perform malaria studies, and charged Schüffner and Swellengrebel to write it (1918). De Vogel also had pleaded for a second edition of 'De Anophelinen van Nederlandsch-Indië'. Van Loghem allowed Swellengrebel to publish an addendum in 1919 (Swellengrebel, 1919a), whilst the second edition appeared in 1921 (and a third in 1932).

However, not everyone was enthousiastic about this. In 1919 there was a professional opposition which was voiced in the parliament of the Netherlands East Indies. Older members of the profession had always looked askance at doctors busying themselves with mosquitoes: '*their entomological pretensions, their bickering in entomology*'. And at a meeting of hygienists De Raadt showed his pessimism about species-directed sanitation, and rejected the method because there was not enough information. He called for an extensive research throughout the Archipelago, surprisingly at the time of the activities of the Swellengrebels and Schüffner, Van Breemen in Batavia/Tandjong Priok and Mangkoe Winoto in West Java.

On the way back home Swellengrebel summarized the work he had accomplished together with his wife and the ideas about control that had emerged, for the head of the Department of Tropical Hygiene of the Colonial Institute(*):
The most important result that our study has yielded, in our opinion, is the insight into the relative dangerousness of the various anophelines and particularly into the unexpected importance of M. ludlowi, *which earlier was known as a more or less doubtful vector, but not as the ubiquitously dangerous, first class transmitter that we found this mosquito to be... Investigations about the biology of the anophelines taught us that the various species are by far not so specifically adapted in their requirements for breeding places, and that species sanitation is out of the question for most species.*
This is, however, not the case for the very specialized ludlowi, *for the extermination of which species sanitation seems appropriate, although one needs to be prepared for disappointments even here.*

And in a popular cultural journal in the Indies, he wrote about the prospects for malaria control and species sanitation (1920b):
The knowledge that in the coastal areas only Anopheles ludlowi, *breeding in saltwater, was a dangerous vector, made a simplified sanitation possible, a so-called 'Species sanitation'; this was directed against the breeding places of one* Anopheles *species, whilst all others could be neglected.*
The prospects of sanitation have become definitely more favorable for all areas where the Anopheles ludlowi-*transmitted malaria occurs, due to the results of the modern investigations. Sanitation is in various stages of preparation or progress in different places along the coast: Batavia, Semarang, Surabaya, Tjilatjap and Tegal. In Sibolga it is virtually completed and the results are very favorable until now.*

The Swellengrebel 'School'

Swellengrebel did not assume it his duty to express clear ideas about the organisation of malaria control. Until 1924 there was no special malaria organisation within the Medical Service, unlike the situation in the Malay States. Yet Christophers, one of the important malariologists in British India, concluded after attending a meeting of the Far Eastern Association of Tropical Medicine in Batavia in 1921, that malaria had taken a very important place in the research work in the Dutch Indies (Christophers & Harvey, 1922). By then it had become clear that it is necessary that almost every malaria-sanitation be preceded by an investigation of the vector and its biological circumstances **on the spot**. Coordinated by the Central Malaria Bureau, the results of species sanitation further accumulated (De Vogel, 1929).

Sir Malcolm Watson later judged a particular application of species sanitation in the Netherlands Indies: *this brilliant application of scientific research in 1928 is an illustration of the control of malaria by changes in the chemical composition of water which I anticipated in 1910 might be seen by future generations* (Watson, 1935).

Swellengrebel had established a school of thought, and from then on he took a leading role in the malaria control activities in The Netherlands. One of his students, W. Essed, reported on the sanitation of Banjoewangi, which he coined as 'a perfect example of species-sanitation in the sense of Swellengrebel' (Essed, 1932a). Swellengrebel had suggested already in 1917 that composite species might exist, including sub-species as yet unidentified, but this was dismissed by the most influential member of the profession in Batavia as '*trying to find a loop-hole to save a theory which had been untenable from the outset*' (Swellengrebel, 1950).

The problems of splitting anopheline species encountered in The Netherlands, gave him the opportunity to compare his earlier and later experiences, in the Medical Journal of the Dutch Indies (*) (Swellengrebel, 1934) and the Bulletin of the Colonial Institute (Swellengrebel, 1937):

Watson inspired the investigators in the Dutch East Indies by his example. Whether he was right in every respect is not relevant. Fortunately, the Malaysian example was not taken for granted in the Dutch Indies. The experiences of Sibolga and Mandailing, as well as the phenomenal infection figure of 35% were necessary for us to appreciate the importance of ludlowi. *Its significance, together with the stringent demands it presents to its breeding places, have made it the most graceful subject of species sanitation, as soon as the hygienic exploitation of the fish ponds had paved the way for it. Of Watsons wide gesture:* 'umbrosus *and* maculatus *matter, let the rest fly', nothing has remained but a pinched statement such as: 'here in Semarang,* ludlowi *is the vector along the coast,* aconitus *and* maculatus *in the hills, but what the situation is in Tajoe, I don't know'.*

To the Dutch investigators belongs the credit of having found out the harm Anopheles ludlowi *was doing. To them also belongs the credit of having pointed out the danger attached to interfering – often quite unnecessarily– with mangrove swamps, which they proved to be quite harmless, as long as man does not spoil them... Mangkoe Winoto has successfully controlled malaria [transmitted by* Anopheles aconitus*] in Western Java by draining the fields shortly before the harvest...*

Facts were gradually accumulating to show that one and the same anopheline species may be a dangerous carrier of malaria in one country and perfectly harmless in another. This is very serious... At present, some sixteen years after that crisis, 'species control', i.e. the method of dealing with malaria by an action directed against one species of Anopheles *to the exclusion of all others, stands on a firmer basis than it ever did before.*

The principle of species control remains unshaken, but some of the so-called anopheline species... were proven to be groups of two or more species, very much resembling each other in shape and design, but differing in their habits to such *an extent as to render one an efficient malaria-carrier and another quite harmless... This result was worth the trouble, first and foremost because it fully restored our confidence in species control, and secondly, because it afforded an interesting example of very effective, although quite unpremeditated, collaboration between investigators in the Far East with those at home.*

It is to be noted that Swellengrebel used here the expression 'species-control'; later he returned to his own term of 'species sanitation' (Swellengrebel & De Buck, 1938).

In his obituary of Sir Malcolm Watson, who died in 1955, Swellengrebel summarised the pattern of a malaria survey (1956):

The preliminary stage of every anti-malaria campaign. This survey includes two main sections. The first consists of three parts: (1) determining the distribution of malaria in the district; (2) collecting adult Anopheles *and identifying them, so as to be able to compile a list of the anopheline species of the district, and to establish the distribution of each of these species; (3) comparing the data afforded by (1) and (2), in order to find out whether or not a correlation can be established between the distribution of malaria and one of the local anopheline species. If such a correlation exists, the species involved is suspect of being the local vector of malaria.*

The second section of the survey consists of two parts: (1) determining the natural rate of infection with malaria parasites of each one of the local Anopheles, *in order to check the results obtained in the first section; (2) identifying the principal breeding places of each anopheline species. When the principal local vector has been identified in this way, and it has been proven, moreover, that this species has more or less specialized breeding habits... it becomes possible successfully to suppress the breeding of that one species, by dealing with its preferential breeding places, while leaving undisturbed all other collections of water, and the larvae of the species breeding therein (species sanitation).*

Earlier, in their book 'Malaria in The Netherlands' (1938) Swellengrebel & De Buck stated about Watson:

We have been credited, occasionally, with the invention of species-sanitation, because we coined this term or, at least, its Dutch prototype. So we wish to make it quite clear that it was Sir Malcolm Watson who invented the method of dealing with one species of Anopheles *to the exclusion of all others. All the credit we can claim is of having seen and stated, more clearly perhaps than others, the great promise for the future this method holds* (p. 56).

In the same book we find several references to the principle of species sanitation:

In the Far-East matters look hopeful. Out there, Anopheles *belong to many species, some of them dangerous and numerous others harmless. Each one of them has its own peculiar habits, and so we can pick out and destroy the dangerous species, while leaving the harmless ones unscathed. Without practising species-sanitation one feels helpless (p. 56).*

If Anopheles *are to be controlled successfully by species-sanitation, they should belong to a taxonomic unit which remains constant in all circumstances. It is useless* *to apply species-sanitation to the control of an inconstant taxonomic unit, since it will show its inconstancy in its breeding habits and in its ability to act as a malaria vector (p. 80).*

Two separate races of Anopheles maculipennis *in The Netherlands – shortwings able to transmit malaria in the autumn (5.6% infected), longwings unable to do so because they do not feed during that season (0.04% infected) – cannot produce a viable progeny; thus species-sanitation in this country merits careful consideration (compilation from pp. 62-85).*

Its applicability depends on the answer to the question: where does that species of Anopheles *breed? If the larvae are not catholic in their taste, but show specific breeding habits, then species-sanitation has a chance of showing what it can do (p. 112).*

The association of shortwings with brackish water (in the narrow ditches) was close enough to make us contemplate the possibility of species-sanitation by controlling the brackish breeding places to the exclusion of the fresh ones (p. 117).

Freshening of the water in North-Holland, due to the reclamation of the Zuydersea would be no less an instance of species-sanitation (p. 198).

Nature has crowded all infected Anopheles *within a very small compass of time and space. In doing so, she is actually inviting us to kill them there at one stroke; the opportunity appears so favourable that it is difficult to hold one's hand (p. 203).*

Spraying of houses in the autumn greatly reduces malaria in the next year. It is a kind of species-sanitation directed against the adults of one single species: the shortwings (p. 217).

From 1916 onwards Swellengrebel had always had a keen interest in the epidemiology and immunology of malaria. He carefully indicated that epidemic and endemic malaria had different significances for human health as well as for control measures. In the later years he switched his attention more to what he had observed in Africa, in Surinam and in Irian Jaya, where he became impressed with the stability of malaria. Compared to those areas, the degree of communal immunity in Indonesia was not impressive (Verhave, 1989). In spite of all his accurate views, Swellengrebel hardly ever elaborated on the consequences this could have for the people who lived in areas where malaria had been greatly reduced though species sanitation. Surprisingly, he mentioned the danger of an epidemic due to loss of immunity only once and incidentally; certainly not within the context of a series of epidemics that occurred in the nineteen-thirties all over the Archipelago. Thus, when elsewhere in this issue the failures of species sanitation are mentioned and the inadequate attention to maintenance and surveillance are brought to light, as was done by many contemporary experts, we would like to fill a lacuna in the views of all those engaged in malaria control of the time:

Species sanitation has proved to be a successful vector control measure for reducing transmission and disease incidence; in order to maintain this desired effect over decades, **surveillance needs to be meticulously maintained in order to cope with the susceptibility of the increased amount of non-immunes.**

Chapter 5

Success and failure of malaria control through species sanitation – some practical examples.

W.B. Snellen

5A – Introduction

The cost of the sanitation works implemented from 1915 to 1919 in the small town of Sibolga, on the west coast of Sumatra, amounted to Dfl. 650,000 (Dfl. = Dutch guilders) or Dfl. 134 per inhabitant. The cost was so high because the initiators of the programme did not apply the concept of species sanitation. They implemented a total sanitation programme, aimed at the elimination of all breeding sites of all potential malaria vectors (Nieuwenhuis, 1919).

A species sanitation represents a considerable cost saving over a total sanitation:

- only the breeding sites of the vector species need to be considered,
- instead of eliminating a breeding site, it is possible to modify it in such a way as to make it unsuitable for the vector species to breed in; such modification often costs less than elimination,
- water collections that are breeding sites and have an economic importance – e.g. rice fields, fish ponds – could also be modified instead of being eliminated; the prevention of economic loss also represents an important cost reduction.

The diagram in Figure 5.1 shows cost per inhabitant for general sanitation programmes in three, and for species sanitations in four coastal towns. The diagram clearly brings out the cost savings potential of the species sanitation concept.

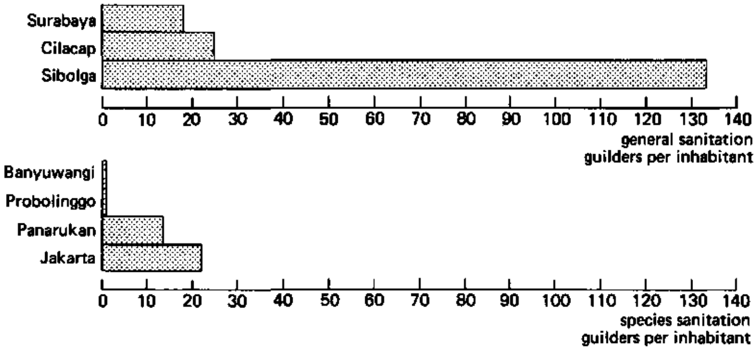


Fig. 5.1 Cost per inhabitant for general sanitation in three and for species sanitation in four coastal towns.

The same trend is apparent in the total expenditures on malaria sanitation works in Indonesia. In the period 1918-1922 this amounted to Dfl. 1,250,000 per annum, against Dfl. 500,000 p.a. in the late 1930's. The latter figure also reflects a trend away from technical measures towards biological control measures. Partly, however, this was an economic necessity: because of the economic recession of the 1930's funding of malaria control programmes became increasingly difficult.

The other side of the coin is that a species sanitation increases the uncertainty about the effects of a sanitation programme:

- an anopheline species that was harmless before might assume the role of vector once the dangerous species has disappeared,
- the vector might also change its breeding behaviour and move to another type of breeding site that has been unaffected by the sanitation programme.

Dr. N.H. Swellengrebel, who introduced the concept of species sanitation in Indonesia, was very much aware of these uncertainties. In addition, he found that the behaviour of a particular species may vary from place to place. Therefore, Swellengrebel insisted on a local investigation of anophelines and their behaviour before starting a malaria sanitation programme. And even then he considered a sanitation in a new location as an experiment. Given the uncertainty of its outcome, the effects of such a programme had to be carefully monitored and additional measures taken if required.

Swellengrebel's recommendations have only partly been put into practice. A detailed pre-investigation was more or less common practice; the reports on such investigations in Tanjung Periuk, Solo, Tegal each run well into the 50 to 100 pages.

Far less has been written on vector-bionomics after implementation of the sanitation measures. The results of a sanitation were commonly evaluated through its effects on the mortality rate and the spleen index (malaria causes enlargement of the spleen; the spleen index is the percentage of the population with enlarged spleens).

Change in mortality rate and spleen index are a measure for the total effect of a sanitation programme; they do not, however, give information on the effects of the individual measures on vector density or breeding behaviour. The sanitation experiment then becomes a black box exercise.

The shortcomings of this black box approach became apparent in 1938, when a serious outbreak of malaria occurred in Tanjung Periuk, the harbour of Jakarta. A whole series of articles appeared in the Medical Journal of the Netherlands Indies, with opposite views on the cause of the epidemic and indeed also questioning the soundness of the basic control strategy. The Head of the Central Malaria Bureau even requested that the editorial board submit articles related to malaria problems to his office before publication, 'to avoid unnecessary scribbling' (Overbeek, 1938).

This is in sharp contrast with the confidence that radiates from an article by his predecessors, 'Malaria control in the Netherlands Indies'. (Walch & Soe-

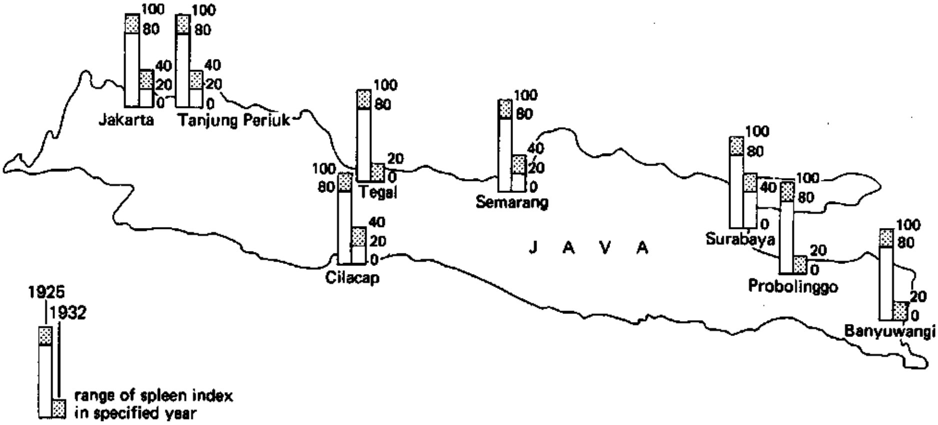


Fig. 5.2 Decrease of spleen index in seaports and coastal towns of Java in the period 1925 – 1932.

silo 1935). They presented a map (Fig. 5.2) which shows a remarkable decrease of the spleen index in the seaports and coastal towns of Java in the period from 1925 to 1932.

After presenting these results the authors then said: ' ... *we wish to emphasize that the improvements have been obtained through anti-larval measures. It is our belief that the results ... entitle us to the statement that measures of this kind are highly suitable for conditions as prevailing in many localities of our archipelago*'.

In retrospect, it seems correct to say that the epidemic in Tanjung Periuk in 1938 and the resulting confusion among the malariologists in no way subtracts from the validity of malaria control by species-sanitation: when concentrating on the main breeding sites of the main vector an occasional epidemic should not come as a surprise. The 1938 events do bring out clearly the shortcomings of exclusive reliance on the spleen index as an evaluation criterion. This has been pointed out by Kuipers in his dissertation of 1937 and in an article entitled 'The one-sidedness of our malaria control effort' in issue No. 40 of the 1939 Volume of the Medical Journal for the Netherlands Indies (in Dutch). A detailed account of Kuipers' work is given in Chapter 6.

Table 5.1 lists anti-larval measures and their effects, in those locations for which records could be found. The list is by no means complete, as can be seen by comparing the map in Figure 5.3 that corresponds with Table 5.1 and Figure 5.4, that has been taken from a publication by the Netherlands-Indies Medical and Sanitary Service in 1929 and shows all locations with extensive sanitation works.

The remainder of this chapter presents a more detailed account of specific malaria-control activities listed in Table 5.1. It starts with the sanitation of Sibolga, because many of the technical measures for the control of coastal malaria have been applied there. Then it discusses the anti-larval measures taken in marine fish ponds, which were a major source of coastal malaria. This is

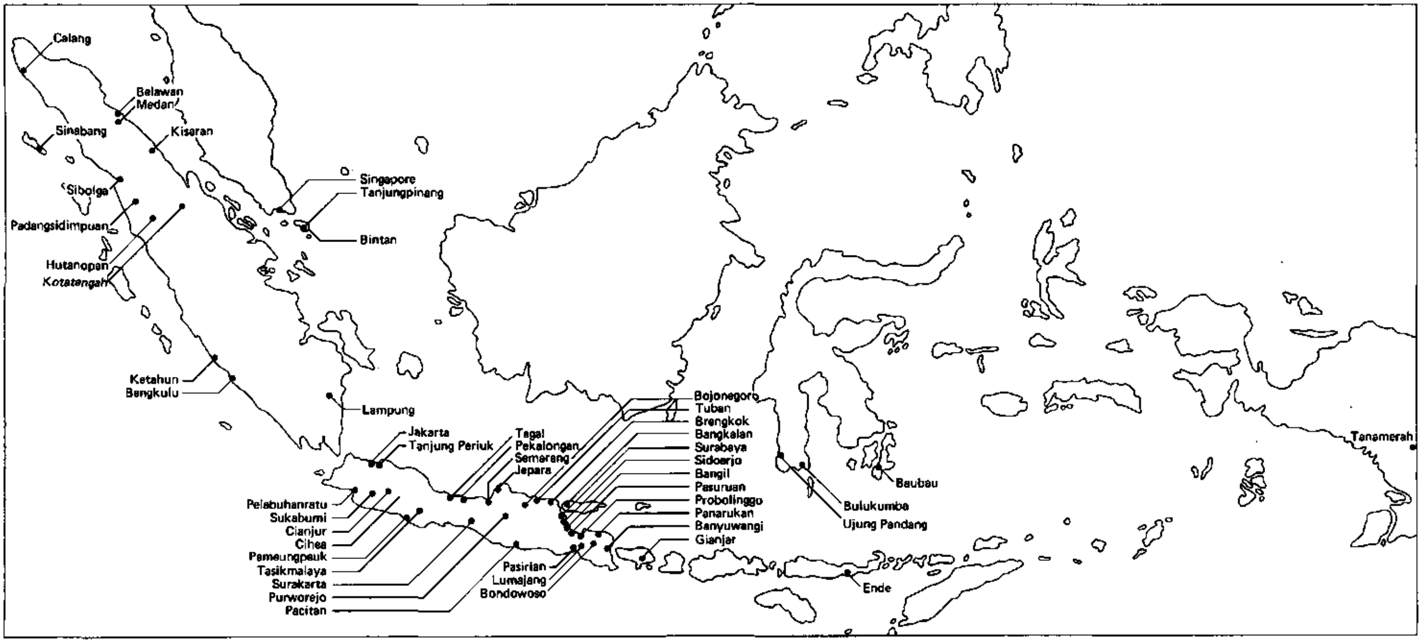


Fig. 5.3 Locations in the Indonesian archipelago, where sanitation measures described in Table 5.1 were implemented.

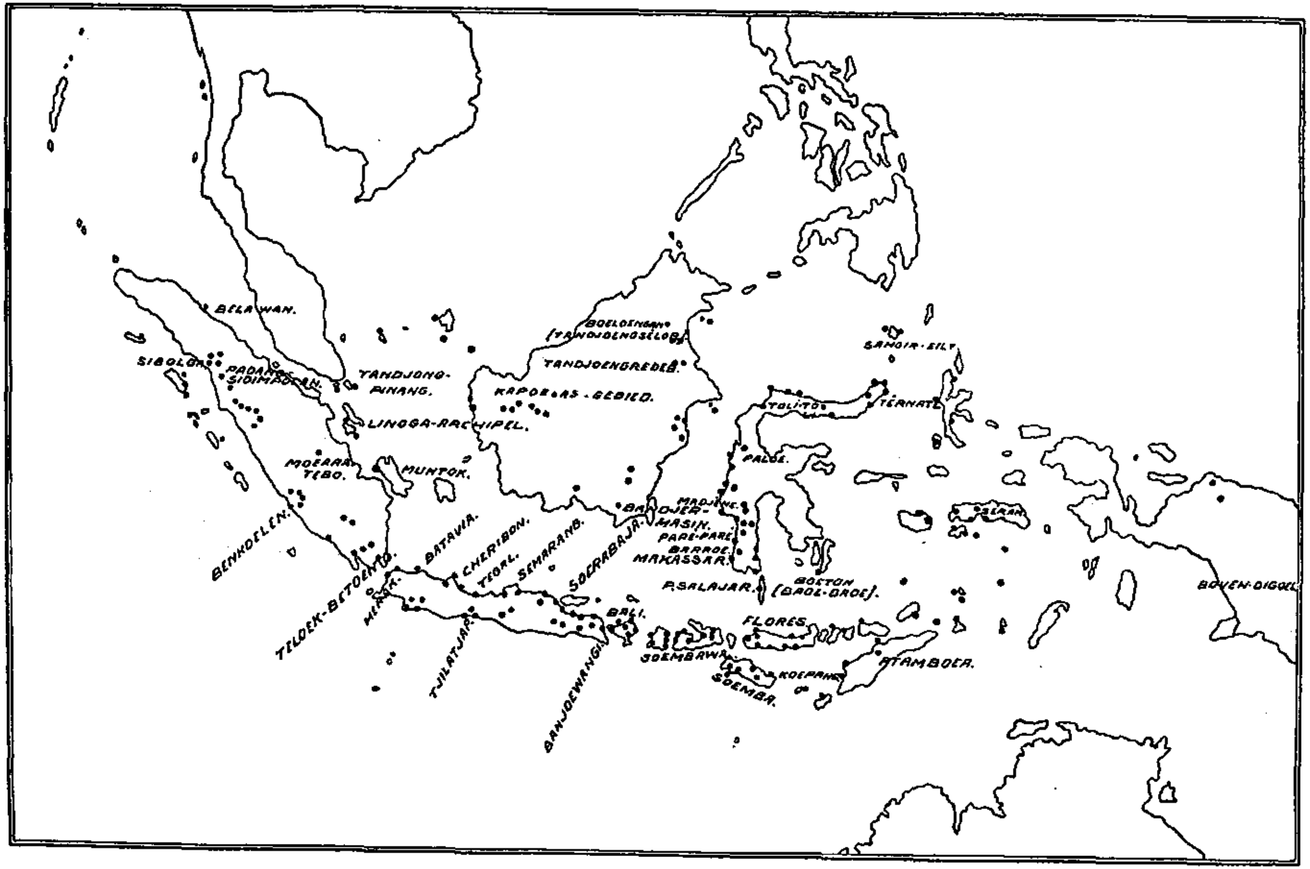


Fig. 5.4 Locations where extensive sanitation works were carried out. Reproduced from: Netherlands Indies Medical and Sanitary Services. Control of Endemic Diseases in the Netherlands Indies. Weltevreden, 1929.

Table 5.1 Sanitation measures in the Indonesian archipelago and their effects.

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Bangkalan	coastal zone W-Madura	?	brackish swamps	drain swamps and after lowering water table reclaim into ricefields	no data	Anon. 1934 p.104-105
Bangil	coastal town E-Java	*sundaicus*	brackish water collections in tidal zone	construct flood dike	no data 1943	Kuipers
Banyuwangi	coastal town E-Java	*sundaicus*	marine fishponds; brackish water collections in tidal zone	give up fishponds and restore tidal action by cutting bunds; fill in depressions and raise surface level above spring tide level;construct dikes and drain diked area through tidal valves; construct lined drains in residential areas	reduction in spleen index 1926 80-90% 1930 < 20%	Essed 1932 Kuipers 1943
Baubau	coastal town SE-Sulawesi	?	coastal swamp	drain and fill swamp, requiring 150 000 man-days of obligatory (unpaid) service	reduction in spleen index 1922 100% 1923 33%	van Hasselt 1925
Belawan	seaport of Medan, Sumatra	?	brackish pools due to construction activities in mangrove forest	hydraulic fill immediately after cutting forest;ban on cutting mangrove within 2 km of harbour and villages	reduction in spleen index 1919 > 80% 1930 < 20%	Schüffner & Hylkema 1922
Bengkulu	Javanese settlement SW-Sumatra	*hyrcanus*; *sinensis*	poorly maintained irrigation canals; fishponds	(proposed): improve irrigation system; maintenance of field canals to be paid by govt; temporary stop on influx of new settlers	no data	Anon. 1933 p.105-111

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Bintan	oil depot on island South of Singapore	*maculatus*; *sundaicus* & others	stagnant water collections after unskillful site-clearing, e.g. cutting mangrove forest	evacuate and treat patients; provide mosquito nets; fill depressions and level; larvicide remaining water remaining water collections	reduction of parasite index after measures but second epidemic due to carelessness	Pflugbeil 1933
Bojonegoro & Bordowoso	E.Java, interior	*aconitus*	rice fields	trials with intermittent irrigation	no data	Kuipers 1943
Brengkok	village N.coast E.Java	*sundaicus*	stagnant rainwater on uncultivated, saline ricefields	drain fallow fields by cutting bunds	no data	Kuipers 1934
Bulukumba	S.Sulawesi	*sundaicus*	lagoon	fill lagoon	no data	Kuipers 1943
Calang	military camp on coast NW Sumatra	*sundaicus*	lagoons	drain lagoons by driving steel pipes through sandbar	camp freed of malaria within four months	Mulder 1936
Cianjur	village irrigation system in W.Java interior	*aconitus*	ricefields that remain inundated after harvest;field ditches;fish-ponds & -fields	install technical irrigation system;one rice crop per year and drain fields after harvest;'hygienic exploitation' and confinement of fish cultivation to an area of 300 ha	no data	Overbeek & Stoker 1938 Anon.1935 p.387-392

Table 5.1 Continued

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Cihea	irrigation system in W. Java interior	*aconitus*	wet ricefields after harvest; poorly maintained field ditches	improve drainage system; rice cultivation and irrigation supply only from October-May and drain all fields immediately after harvest;irrigation dept. to clean field ditches (with subsidy from health dept.)	reduction in spleen index: 1919 80-100% 1932 0- 20% increase in agricultural production	Mangkoewinoto 1923 Koorenhof et al 1933
Ende	coastal town on Flores	?	lagoon	fill lagoon	no data	Kuipers 1943
Gianjar	rice land interior S.Bali	*aconitus; minimus*	ricefields	intermittent irrigation (9 days wet,3 dry) in field trials reduced larvae density by 75%; trial led local administration to making intermittent irrigation obligatory in Bali and Lombok	no data	Smalt 1937
Hutanopan	Sumatra interior	*sundaicus*	fresh-water fishponds	drain all fishponds and ban fish cultivation within 3 km of towns and villages	reduction in spleen index: 1917 80-100% 1930 20- 40%	Soesilo 1938
Jakarta	capital, N.coast W.Java	*sundaicus*	marine fishponds	'hygienic exploitation' of ponds	reduction in spleen index: 1917 80-100% 1932 20- 40%	Walch & Soesilo 1935
Jepara	fishing village N.coast C.Java	*sundaicus*	marine fishponds	rehabilitation and re-allotment of 120 ha of poorly maintained fishponds; provision of supply canal 1500 m long,9 m wide	no data	Anon. 1934 p.99-100

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Ketahun	Sumatra W.coast	*hyrcanus*	fresh-water fishponds	trials on 'hygienic exploitation' of fresh-water ponds, introducing weed eating (*Puntius javanicus*) and larvae eating fish (*Hapolichus panchax*)	no data	Soesilo 1938
Kisaran	rubber plantation interior Sumatra	*maculatus*; *sinensis*	in sunlit water collections after clearing forest	drain rubber plantation and land within 800 m of dwellings; maculatus control requires extra measures, e.g. drug treatment or evacuation of patients	strict supervision needed to contain malaria	Doorenbos 1931
Kotatengah	fibre plantation interior Sumatra	*sundaicus* & other	all types of water collections	(proposed) sanitation of all breeding sites	company abandoned site	Kothe 1933
Lampung	'Senembah' Tobacco Co. SE.Sumatra	*sinensis*	water collections in newly opened rice fields	trials with intermittent irrigation and fast-maturing rice varieties; introduction of larvae-eating fish; move settlement camp	no data	Walch 1924
Lumajang	S.coast E.Java	*sundaicus*	lagoon	drain lagoon with 80-m-long tunnel (diam. 1.20 m) through rocky coastline	no data	Kuipers 1943
Pacitan	S.coast E.Java	*sundaicus*	silted-up river	construct 2-km-long canal connect silted-up river with larger river	no data	Kuipers 1943
Padangsidimpuan	Sumatra	*sundaicus*	fresh-water	same as in Hutanopan		

Table 5.1 Continued

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Pameungpeuk	S.coast W.Java	*sundaicus*	lagoon;poorly drained ricefields;poorly maintained irrigation canals;fishponds	plant shade trees along lagoon and river stretch along the coast; employ extension workers to explain dangers of breeding sites	not very successful	Anon. 1936 p.256-258
Pasuruan	coastal plain E.Java	*aconitus*	ricefields	draining-off residual product from sugar factory into irrigation water reduced density of aconitus larvae in ricefields	Health Dept. allowed Co. to continue practice	Soesilo & v.d. Hout 1932
Pasirian	rubber Co. in hills near P., E.Java	*aconitus*; *maculatus*	swamps, drains and brooks after clearing forest	drain swamps; plant shade trees of type *Albizzia*, which reinforces embankments and prevents growth of weeds	spleen index from 94 to 46%, also due to strict supervision	Anon. 1934 p.388-389
Pekalongan	N.coast C.Java	*sundaicus*	stagnant pools in disturbed mangrove forest after road construction	connect stagnant pools by digging ditches; provide culvert under road to restore tidal action	no data	Anon.1935 p.388-389 Kuipers 1943
Pelabuanratu	S.coast W.Java	*sundaicus*	lagoons	plant leguminous cover crops as green manure to promote growth of shade trees on sandy soil	not very successful	Anon. 1934 p.98-99
Probollingo	N.coast E.Java	*sundaicus*	marine fishponds	give up fishponds and restore tidal action by cutting bunds	spleen index in 1932 <20%	Walch & Soesilo 1935
Purworejo	S. coast C.Java	*sundaicus*	silted-up river mouth	construct breakwaters into sea	no data	Kuipers 1943
Semarang	N. coast C.Java	*sundaicus*	fishponds;brackish water collections in tidal zone	gradual filling in of fishponds and low areas with dry material e.g. town refuse	spleen index in 1932 still 40-60%	Walch & Soesilo 1935

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Sibolga	trade centre N.W.coast Sumatra	*sundaicus*; *sinensis*; *aconitus*; *maculatus* & other	brackish water collections in tidal zone (silted-up river mouth,stagnant rainwater on saline soil);depressions with seepage from	fill in edge of swamp and construct embankment;raise surface of seaside area 0.15 m above spring-tide level; replace open drains with closed or semi-closed drains;hillfoot drains; river training and construction of piers	spleen index 1912 98% 1917 50% 1922 2% mortality 1912 80/1000 1919 18/1000	Nieuwenhuis 1923
Sidoarjo	500ha marine fishponds in E.Java	*sundaicus*	marine fishponds	upgrading of 2335 m of supply canal through village cooperation	no data	Schuster 1935
Sinabang	timber Co. on island W.Sumatra	various vectors	swamps;timber curing basins;stagnant water in depressions	drain and fill terrain and swamps; larviciding;screen houses;drug drug treatment of patients	reduction in mortality 1914 80/1000 1918 14/1000	Van Voorthuis 1920
Surakarta	interior, C. Java	*aconitus* & other	stagnant water in sand pits in empty flood channel	prohibit excavation of sand from flood channel (not enough water in dry season to flush channel)	no data	Brug & Walch 1927
Sukabumi	tea estates in hills S.W.Java	*maculatus*	brooks and gullies after clearing forest	plant shade trees (*Tithonia diversifolia*) along watercourses and gullies	not enough support from population	Anon. 1934 p.97-98
Surabaya	N.coast E.Java	*sundaicus*	marine fishponds; water collections in tidal zone	fill fishponds and depressions with material excavated for harbour construction;build flood dike	spleen index in 1930 : 20-40%	Kuipers 1943
Tanamerah	prison camp interior Irian Jaya	*bancrofti*; *punctulatus*	brooks and water collections after clearing forest	install drainage system;spray remaining water collections with oil product	favourable effects prevented closing down of camp	Mooij 1932

Table 5.1 Continued

Location	Description	Anopheles	Breeding site	Measures	Effects	Reference
Tanjungpinang	small island S.E. of Singapore	*maculatus*	stagnant water in drains and depressions	install open drains with cemented floor and lining of loose coral stones; reservoirs to allow periodical flushing flushing of drains	no data	Anon. 1929
Tanjung Periuk	seaport of Jakarta	*sundaicus*	marine fishponds; brackish water collections in harbour, nearby villages and wastelands	'hygienic exploitation' of fishponds; various suggestions by different authors about causes of 1938 malaria epidemic and required measures	spleen index 1932 20-40% epidemic in 1938	Overbeek 1939 Kuipers 1939 Marwits 1938 Priester 1939
Tasikmalaya	district E.Java interior	*aconitus*	poorly maintained rice fields, ditches and fishponds	cooking in huts prevented mosquitoes from entering;malaria increased due to house improvement scheme aimed at eliminating rats (animal hosts of *Pasternella pestis*)	malaria epidemics with high mortality in many villages in district	Grootings 1938
Tegal	N.coast C.Java	*sundaicus*	lagoon;water collections in tidal zone (e.g.borrow pits at at Chinese cemetery)	fill lagoon, low areas and pits; river training and construction of piers into the sea	spleen index 1919 80-100% 1932 0- 20%	Walch & Soesilo 1935
Tubanbetung	N.coast E.Java	*sundaicus*	marine fishponds; water collections in tidal zone	deepen fishponds;fill pools and pits; trials with intermittent irrigation	no data	Kuipers 1943
Ujung Pandang	S.Sulawesi capital	*sundaicus*	lagoon;pools and pits in tidal zone	construct breakwaters into sea at rivermouth; fill pools and pits	no data	Kuipers 1943

followed by a case-study on malaria control in rice fields; in the Cihea plain malaria was controlled by restricting the period in which irrigation water is supplied. Health departments often blame irrigation engineers for causing malaria; as an antidote the case of Tasikmalaya describes how malaria increased dramatically after implementation – by the Health Service – of a house improvement scheme.

5B – An early sanitation: Sibolga

Introduction

One of the earliest sanitations in Indonesia took place in Sibolga, from 1915 to 1919. Sibolga was the administrative and trade centre of the regency Tapanuli on the west coast of Sumatra (Fig. 5.3).In 1912 the health situation had deteriorated to the point where it threatened the economic viability of the town. The mortality rate for that year in the living quarters near the market place was 8 %.

Dr. W.Th. De Vogel, as Head Inspector of the Medical Service was sent to Sibolga, to conduct a thorough local investigation prior to drawing up the sanitation plan by the Public Works Department. He was accompanied by Dr.N.H. Swellengrebel, to help him with the determination of the anopheline species (see also Chapter 4). Swellengrebel was particularly interested in finding *Nyssorhynchus willmori*. Dr. Malcolm Watson had discovered in Malaya that this species was responsible for malaria in the rubber plantations in the hills, where they breed in fast flowing streams (De Vogel, 1913).

Breeding sites

Sibolga lies on a bay, at the mouth of a small river and is surrounded by steep foothills (Fig. 5.5). The river has created a narrow valley, that starts at a distance of some 2 km from the sea at an altitude of 20 to 30 m. above sea level. The highest native residential area of Sibolga -kampong Barangan – is located here. At 600 m from the sea, the river valley passes into a coastal plain of some 900 m wide. The European residential area and administrative buildings were located on the river's left bank. The commercial centre and native living quarters – pasar Sibolga -was located between the administrative centre and a large tidal swamp. De Vogel and Swellengrebel searched all water collections for mosquito larvae:

- the highest larval density was found in the swampy area bordering on pasar Sibolga. This area was used for dumping waste products from a coconut plantation and also town refuse from pasar Sibolga. The refuse, together with the swamp vegetation prevented seawater from flowing in and out, thereby creating isolated water collections with large numbers of larvae of the species *An. sundaicus*,
- no larvae were found in the tidal swamp itself,

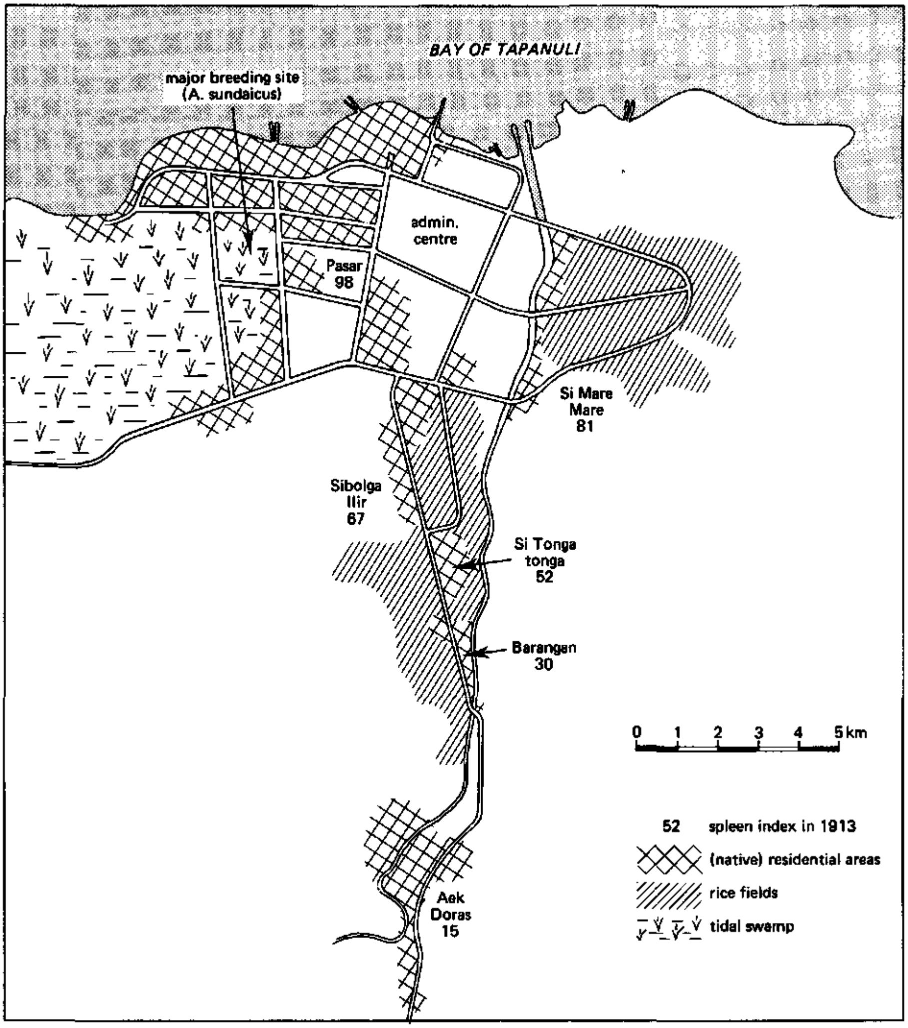


Fig. 5.5 Map of Sibolga.

- only a few larvae were found in the European area; the researchers however did find various species of adult mosquitoes in their guest house (*An. sundaicus, An. rossii, An. sinensis*). Their assumption was that these mosquitoes came from the rice fields just across the river. – all rice fields contained mosquito larvae, but more Culex than anophelines (*An. rossii, An. sundaicus*),
- in spite of intensive searching, no larvae were found in the fast flowing streams that run into the river Aek Doras, nor in the river itself.

Table 5.2 Spleen index in Sibolga

Name area	No. of children examined	No. of enlarged spleens	Spleen index
Pasar Sibolga	218	214	98 %
Si Mare-Mare	42	34	81 %
Sibolga Ilir	66	44	67 %
Si Tonga-Tonga	60	31	52 %
Barangan	122	37	30 %
Aek Doras	100	15	15 %

Spleen index survey

The results of a spleen index survey in each of the native residential areas among children aged 1-12 is given in Table 5.2.

Interpretation of findings

Based on the above findings, De Vogel explains the upsurge of malaria in 1912 as follows:

1. The dumping of refuse in the tidal swamp near the market place caused an increase in production of mosquitoes; this led to an increase of malaria in the commercial center of Sibolga.
2. Persons who lived in other residential areas but came to the commercial centre for work or entertainment became infected there and carried the disease back to their own residential area.
3. The increase in the infection reservoir in the native living quarters and the presence of anopheline mosquitoes in the rice fields led to an increase in malaria.
4. There is a correlation between the increase in malaria and the number of mosquitoes; this reflected in the proportional relationship between spleen index and size of the rice land bordering on each residential area.

Sanitation plan

De Vogel recommended elimination of all breeding sites through improved drainage. He did not enter into specifics on how the drainage problems needed to be resolved, this being a matter for the Public Works Department. De Vogel made it quite clear, however, that he strongly objected to an earlier plan to fill in the tidal swamp. These plans had been put forward by a previous administrator, who saw the swamp as the cause of malaria in Sibolga; he was backed by the Public Works Department, not in the least because the plan provided the additional land needed for the expansion of Sibolga's port facilities. According to De Vogel filling the swamp was not necessary for health reasons. He recommended to plan the extension of the harbour on the other side of the river and to acquire the additional land by transforming the rice fields there into building sites.

De Vogel's recommendations on this issue have not been taken up. Part of the swamp has been filled and the harbour authorities obtained their additional land where they wanted it – at the expense of the Health budget. In his report of 1919 on the implementation of the sanitation works in Sibolga, Nieuwenhuis does admit that filling the swamp had not been really necessary, but he puts it in such a way as to suggest that this fact was only discovered after completion of the works, without mentioning De Vogel's objections (Nieuwenhuis, 1919).

In 1917, when the sanitation works were already in progress, Swellengrebel did another larval survey. This time he did find larvae in and near the streamlets running down from the hills; not *Nys. willmori* but *An. maculatus* and *An. karwari*. Given the fact that the larvae were only found in higher country near areas with a low spleen index, Swellengrebel concluded that these species were not dangerous so that no additional sanitation measures were needed. Some later authors concluded from this that the sanitation works of Sibolga were aimed exclusively at *An. sundaicus* and therefore should be considered a species-sanitation (e.g. Soesilo, 1936).

Costs and effects

Figure 5.6 presents annual and cumulative costs of the sanitation works, and their effect on the mortality rate in pasar Sibolga. (source: Kuipers, 1937). Table

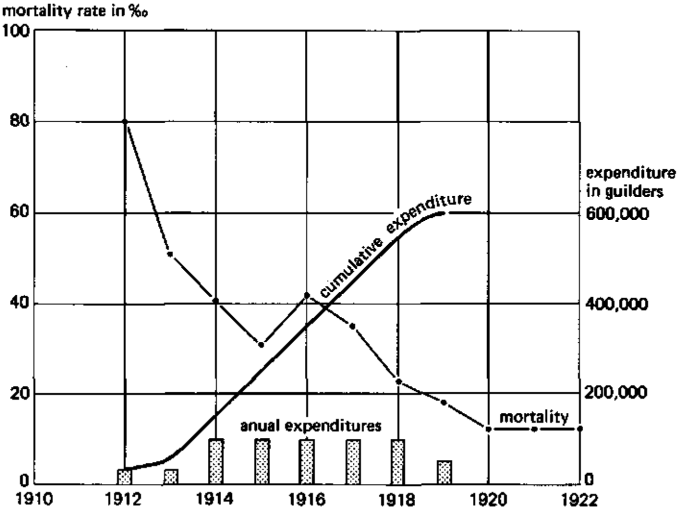


Fig. 5.6 Annual and cumulative cost of sanitation works in Sibolga and the effects on mortality.

Table 5.3 The effects of the sanitation works on the spleen index for pasar Sibolga and the three other native residential areas (Source: Nieuwenhuis 1919).

Name area	spleen index Apr-May 1913	spleen index Dec 1917-Jan 1918
Pasar Sibolga	98 %	50 %
Sibolga Ilir	67 %	25 %
Barangan	30 %	10 %
Aek Doras	15 %	10 %

Table 5.4 Annual trade figures for Sibolga (in Dutch florins)

	1903	1911	1918
Value of imports	1,228,641	2,351,333	4,429,400
Value of exports	742,042	1,776,931	4,790,700

5.3 gives the effects of the sanitation works on the spleen index for pasar Sibolga and the three other native residential areas. (source: Nieuwenhuis, 1919).

To put the costs of the sanitation works into perspective, Table 5.4 gives the annual trade figures for Sibolga. When looking at these figures and comparing them with the total cost of the sanitation works – Dfl. 650,000 – two things stand out:

1. The willingness to spend more than one third of the annual export value on a sanitation programme indicates the economic importance of malaria control in those days.
2. The investment in the sanitation works seems to have done the economy of Sibolga a lot of good.

5C – Marine fishponds

Introduction

Cultivation of fish in artificial ponds in the coastal zone of northern Java has been practised for centuries. The earliest reference is a Javanese code of law from around 1400 AC, which specifies punishment for stealing from a marine fishpond (Reijntjes, 1926).

In 1864 the agricultural inspector Van Spall investigated both fresh and salt-water fishpond cultivation practices of local farmers. Marine fishponds in Java at that time occupied an area of 33,000 ha. Van Spall recommended the govern-

Photo 8a Sibolga: the native quarters (pasar) and the bay of Tapanoeli, seen from a nearby hill. (Scource: Nieuwenhuis, 1919)

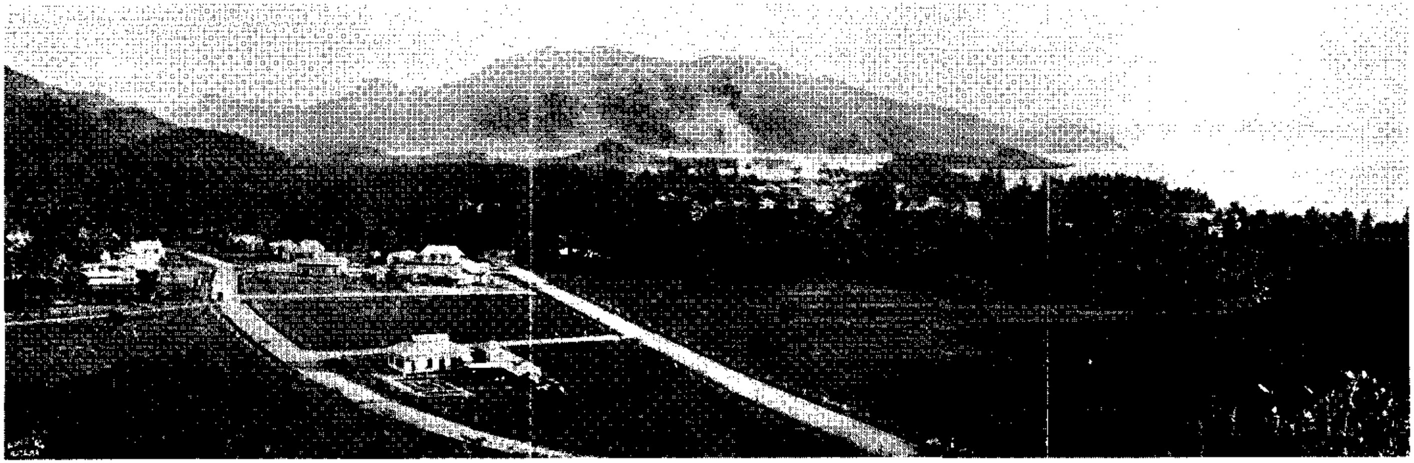


Photo 8b Sibolga: the European quarters under construction, seen from a nearby hill. (source: Nieuwenhuis, 1919)

ment to actively support the expansion of the cultivated area, by transforming mangrove forest into fishponds. This would provide extra food, income and tax revenue, and improve health.

By 1926 marine fishponds occupied an area of 55,000 ha, producing more than 17 million kilogrammes of fish with a market value of almost 7 million guilders. The Health Service however, was not at all happy with the expansion. In a manual for government officials on malaria matters, published by the Health Service in 1925, Rodenwaldt wrote:

'Concerning the large population centres on Java's Northern coast, we are confronted with a fatal error. Here one has propagated the establishment of fishponds in the mangrove coastal zone, which was held responsible for malaria, in the conviction that by doing so the zone would be made safe. At present we know that *An. sundaicus*, the most dangerous malaria vector of the Netherlands-Indies, breeds in these fishponds which are therefore the cause of heavy endemic malaria in coastal settlements. It is the task of the hygienist to try and eliminate these marine fishponds from the surroundings of human settlements. The matter is further complicated by the fact that *An. sundaicus* has been found capable of flying very long distances, which means that all fishponds within at least 3 km from human settlements need to disappear. Tens of years will be needed to accomplish this task and even then it remains to be seen whether in certain regions economic considerations will not prevail over hygienic ones. One lesson however has to be learned from the results of biological and hygienic studies of the last ten years: that in the Netherlands-Indies under no circumstances it can be permitted that new fishponds are established in the coastal zone, or ponds that have been given up are taken into production again.'

In spite of Rodenwaldt's strong objections, the area of fishponds increased further from 55,000 ha in 1926 to 82,000 ha in 1941.

This case study examines how opinions on the relation between malaria and marine fishponds changed over the years and the effect of these changes on the control measures.

Extensive breeding of anopheline mosquitoes

In a malaria survey in the capital Jakarta, Kiewiet de Jonge (1908) found that the mortality rate in the second half of the year 1907 among the local population in the district Pendjaringan near the coast was three to four times higher than in the other districts of the city. Also, the percentage of people with enlarged spleens was much higher in the coastal districts.

Kiewiet de Jonge then searched for breeding sites of anopheline mosquitoes. He found them almost everywhere: in rice fields in all parts of the capital – which was in fact more a collection of villages – in the marine fishponds, in numerous puddles, wheel ruts, hoofprints, near wells, wash-places, so that he exclaimed: 'yes, where didn't we find anopheline breeding sites!'

In his report, Kiewiet de Jonge considered the following control measures:

1. Elimination of all breeding sites
2. Construction of mosquito proof houses
3. Evacuation of the unhealthy town districts
4. Drug treatment of malaria patients

Kiewiet de Jonge considered the alternatives 1, 2 and 3 unfeasible. He recommended the local administration to set up a programme for the distribution of quinine – free of charge – to all malaria patients. The administration provided funds and made Kiewiet de Jonge responsible for the implementation of the programme. From his report of 1908, it is apparent that Kiewiet de Jonge considered the programme as a temporary solution at best, and also that he was rather disappointed by the lack of responsiveness from the population.

Jakarta sanitation project 1913

In 1913, the Public Works Department began an ambitious sanitation project in the capital. Since its foundation in 1610, Jakarta had been an unhealthy place. The Dutch founders had considered the location amidst swamps a strategic advantage. After Dutch fashion, a network of canals was put in place in the mid 17th century.

In 1699 there was a large volcanic explosion of mount Salak, 60 km south of Jakarta. Subsequent floods carried enormous amounts of eruption material, which blocked the canals and drains and created evil-smelling swamps. In the 18th century, several attempts at improving the situation by diverting floodwaters away from the city failed.

In order to escape the poor hygienic conditions in the old city, a new administrative and residential area was built on higher grounds, early in the 19th century. After the exodus of the Europeans, the sanitary conditions in the lower city deteriorated even further. By 1910, three centuries after the foundation of the city, the health condition was considered no longer acceptable.

The estimated cost of the sanitation works that began in 1913 was 4 million guilders. The major components were (Van Breen, 1913):

- flood diversion works,
- construction of a drainage and sewerage system,
- groundwater level control,
- elimination of stagnant water.

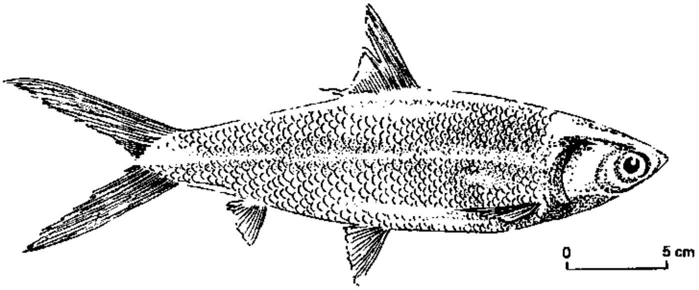
Although the works would reduce the number of mosquito breeding sites, the plan was not specifically aimed at malaria control. The rice fields and the marine fishponds, in which Kieweit de Jonge had found anopheline larvae, remained unaffected.

Marine fishponds: breeding sites of malaria vectors

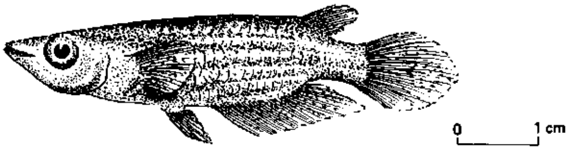
Already five years later, the chief designer of the 1913 sanitation plan made an urgent request to the administration for allocation of additional 1.6 million guilders for the expropriation and reclamation of the fishponds in the coastal zone of Jakarta, and to allocate annually a sum of 25,000 guilders over a period of 30 years, for pumping costs and gradual filling of the area with sludge from dredging operations in the Jakarta harbour and waterways.

This change of ideas was brought about by the outcome of the malaria investigations of Van Breemen and Sunier in 1917 and 1918, which were widely published. The following is based on a summary of their research conclusions which were an integral part of the advise of the Health Committee to the City Council of Jakarta (Anonymous 1919):
'In the summary below we briefly indicate what we at present know for with certainty about the relationship that exists here in Batavia [=Jakarta] between the marine fishponds and the spread of malaria.

a. In Batavia spleen index and mortality are the highest, and indeed very high, in the marine fishpond zone and gradually decrease from there to the south [cf. Fig. 5.9].
b. Larvae of the very dangerous malaria transmitting mosquito *Myzomyia ludlowi* [*An. sundaicus*] were found, with very few exceptions, in the marine fishpond zone only and mainly in the fishponds themselves.
c. Breeding-sites of other anophelines, which do not play a role here, were found all over Batavia. In these breeding-sites, however, no *ludlowi* [*sundaicus*] larvae were found.
d. In locations south of the fishpond zone with high spleen indices, where many *ludlowi* [*sundaicus*] mosquitoes were caught in the houses, we could not find any *ludlowi* breeding-sites.
e. The fish cultivated in the marine fishponds [*Chanos-chanos*, see Fig. 5.7] is vegetarian and feeds on submerged water plants which grow close to the surface. These water plants grow best when salinity is around 20 o/oo; growth decreases at higher salinity levels.
f. In addition to the cultivated fish, the marine ponds often contain enormous quantities of a small fish [*Haplochilus panchax*, see Fig. 5.7] which in the literature on malaria control is mentioned as one of the best destroyers of mosquito larvae.
g. In spite of these larvae-eating fish, the ponds which contain the water plants mentioned under e. – and also the overgrown banks of the ponds – produce a large number of mosquitoes, varying from a few up to several hundreds per square metre. In absence of larvivorous fish, mosquito production figures as high as 6000 per m2 per night have been observed.
h. The production of mosquitoes decreases with increasing salinity and stops completely when salinity in the ponds is considerably higher than seawater.



Chanos - chanos (Bandeng)



Haplochilus panchax (Kepala tima)

Fig. 5.7 *Chanos-chanos*, the cultivated fish in the marine fishponds, and *Haplochilus panchax*, an effective larvivorous fish.

i. The level of salinity at which mosquito production stops is so high that it is not even reached in a year with a less pronounced dry season. This indicates that stopping mosquito production through maintaining a high salinity level in the ponds is not feasible.

...From the above it should be clear for everyone that the actual source of heavy endemic malaria in Batavia is located exclusively in the brackish water zone and specifically in the marine fishponds‘.

The researchers, and with them the Health Committee, recommended the City Council of Jakarta as follows:

‘Short of moving Batavia to a location outside the sphere of influence of the brackish water zone, there is only one permanent and effective solution: to fill the fishponds and reclaim and bring under cultivation the entire brackish-water zone north of Batavia.’

In their summary report the researchers indicated that various parties had asked whether it would not be possible to exploit the fishponds in such a way that they are unsuitable as breeding sites for the malaria vector. For instance, by getting rid of the water plants near the surface, which provide shelter from larvae-eating fish. The difficulty involved here – as was pointed out by the researchers – is that the cultivated fish depend on these water plants for adequate growth. They mentioned the idea of conducting trials on artificial feeding of the cultivated fish, yet warned strongly against such attempts:

‘Even if such a way of exploitation were technically possible, it remains questionable whether fishpond owners could be made to adopt the new methods. And apart from that, exploitation of the marine fishponds in such a way that they no longer present a danger to public health would require permanent close supervision. ... the undersigned are of the opinion that from a public health point of view such attempts to "run with the hare and hunt with the hounds" are totally unacceptable. Only a radical and permanent clearing of all the water collections in the brackish water zone can save the population of Batavia from the paralysing pressure of endemic malaria with certainty and forever.'

The words of the researchers did not fail to make an impression on the City Council of Jakarta. They adopted the proposal for a radical and permanent solution and requested the government for funds to implement the works as part of the sanitation program that had started in 1913.

The government was slow to react and perhaps not without reason: not only was implementation of the plans very expensive, it also meant loss of a high protein popular source of foods, loss of income and job opportunities for the owners of the ponds, and loss in tax revenue. It was not until 1928 that a sum of any significance became available for malaria control in the marine fishponds in Jakarta. The time lag provided the opportunity for the initiators and those opposed to their plans to get together.

An appeal from East Java

E.J. Reijntjes – inspector of the inland fisheries department in Surabaya, East Java – wrote an article on malaria and fishponds in the agricultural journal 'Teysmannia' in 1922. Reijntjes disagreed entirely with the researchers in Jakarta on the crucial issue of the type of plants the cultivated fish feeds on. As indicated in the above paragraph, the researchers in Jakarta claimed that the water plants, which float near the surface and provide shelter from the larvivorous fish, are essential for adequate growth of the cultivated fish. Hence, their conclusion that fish cultivation and breeding of malaria mosquitoes go hand in hand.

Reijntjes, however, conducted experiments which indicated that the cultivated fish feed mainly on the bluegreen algae that develop at the bottom of the ponds.

Reijntjes allowed water plants to develop in one of two otherwise similar ponds. He then stocked the ponds with an equal number of fish. Two months later, the fish in the pond without floating plants had gained most in weight, while the mass of water plants remained untouched. The number of fish in the pond with the water plants was then doubled. After two months there was still an abundance of water plants, while the fish had lost weight.

Reijntjes pointed out that in East Java the fish were cultivated in ponds with hardly any plants at the water surface. The common practice there was to drain the ponds for a few days every month to expose the bottom to sunlight, which stimulated the development of the bottom algae and killed the floating water plants. Subsequently the ponds were filled with seawater. By applying this method in Jakarta, Reijntjes felt, it would be possible to combine the interests of fish cultivation and malaria control. The method depends on adequate water management in the ponds, which requires a system of drainage and supply canals. As a first step, Reijntjes recommended trials on improved water management in the fishponds of Jakarta.

Unfortunately, the appeal from East Java took a long time to reach the researchers in Jakarta and the trials only started six years later.

Experiments in pond-water management

Unaware of the practices in East Java and lacking funds for the implementation of the radical and permanent solution they favoured, the malariologists in Jakarta started looking for less costly control measures; later on they initiated the very type of trials that they had warned against earlier.

A low cost method was to give up fish production and simply cut away a few metres of the dikes of the fishponds, providing free access to the seawater. The tidal movement then would render the ponds unsuitable as breeding sites for the malaria vector. Dr. Mangkoewinoto had successfully applied this method in neglected fishponds at Probolinggo (East Java) in 1921.

Van Breemen tried this method on a fishpond complex at Tandung Periuk – the harbour of Jakarta – in 1923 and again in 1924, with very poor results. It appeared that the tidal amplitude at Jakarta, which is about 1 m at spring tide against 2.5 – 3 m in East Java, was too small to suppress the production of floating algae and therewith breeding of mosquitoes.

After this failure, Van Breemen conducted an experiment on an area of 10 ha of fishponds in which he achieved a clean water surface by overstocking the ponds. While the productivity of the ponds was lower than usual, the experiment demonstrated that it was possible to produce fish without producing mosquitoes.

The leader of the Central Malaria Bureau at that time was Rodenwaldt, who was very much opposed – as Van Breemen had been – to any form of 'hygienic exploitation' of the fishponds, on the grounds that it would be impossible to adequately supervise such activities.

Inventory of exploitation methods

Mid 1927 Walch was appointed leader of the Malaria Bureau. He immediately called for an inventory to be made of the various methods of fishpond exploitation in the archipelago, and their effects on malaria (Walch & Schuurman, 1929). This study brought into contact – for the first time – the malariologists from Jakarta and the fisheries inspector Reijntjes from Surabaya. Reijntjes took them to the district of Pasuruan (East Java), which represented the type of 'hygienic exploitation' he had described in his article of 1922. They witnessed how the mass of floating green algae in the centre of the ponds turned into whitish powder after the ponds had been drained and exposed to sunlight for a day or two, while the fish remained in a 0.3 m deep and 1.5 m wide ring channel.

(The researchers from Jakarta were quite impressed: in the course of their own attempts at obtaining a clean water surface they had once had a few hundred men working for two days to clear the green algae from a single pond.) After the green algae were killed, a shallow layer of water was maintained for several days, which again under the influence of sunlight provided a suitable medium for the development of blue green algae on the bottom of the ponds. After this, ponds were filled again with seawater.

The malariologists found the fishponds in the district free of floating algae and the villages full of healthy children. This favourable impression was confirmed by a spleen index survey. Higher spleen indices encountered in a few villages could be explained by local imperfections, such as:

- ponds with too shallow water depth, which allowed regeneration of floating green algae; the remedial action required was deepening of these ponds;
- ponds that were supplied by rivers rather than directly from the sea could often not be drained in the rainy season because of high water levels in the river. This resulted in poor development of blue-green algae on the bottom while production of floating green algae remained unchecked and was even stimulated by the lower salinity levels. Remedial action here was digging a combined drainage-supply canal directly to the sea.

The excursion to East-Java convinced the malariologists that the 'Pasuruan method' of fishpond exploitation was worth trying in Jakarta.

Photo 9 Banjoewangi: Fishpond with floating algae (before sanitation in 1926) in which *An. sundaicus* (*An. ludlowi*) was breeding in enormous numbers. (source: Essed, 1928)

Photo 10 Banjoewangi: The same spot (as in photo 9) 3 years after sanitation, showing a mangrove forest where tidal movements take place in a perfect way. (source: Essed, 1928)

In Semarang, on the north coast of Central Java, the researchers came across another exploitation method: fishponds were not drained monthly, but daily, under influence of the tide. This practice had developed without any guidance from the fisheries department, and also resulted in a water surface that was free of floating algae. The malariologists were quite pleased with their 'discovery'. First because the 'Semarang method' proved that the concept of 'hygienic exploitation' was possible with about the same tidal amplitude as in Jakarta. And second, because such exploitation was accomplished without any supervision.

The inventory took the malariologists also to Probolinggo and Banyuwangi, both in East-Java, where as a malaria control measure fishponds had been abandoned to the sea. Their main observations were that this method did not really provide a low cost solution because of the compensation payments that had to be made to the owners of the fishponds, and not even a permanent one, because additional canals had had to be dug to ensure sufficient tidal action and continuous surveillance was needed to keep farmers from rebuilding the dikes and resume fishpond cultivation.

'Hygienic exploitation' after all

Reijntjes' recommendation of 1922 – of trying the 'Pasuruan method' in Jakarta on an experimental basis – was finally put into practice in 1928. A fishpond area of 60 ha due north of the city centre and west of the old harbour canal was selected. The objective of the experiment was explained to the owners of the ponds in a meeting that was also attended by the burgomaster (mayor) and the Regent of Jakarta. In the case of a lower than usual fish production as a result of the new exploitation method, the owners would receive compensation. The owners agreed to cooperate and preparations started in 1928. These involved:

- replacing two narrow, winding and overgrown supply ditches by a 7 m wide canal; the capacity of this canal was sufficiently large to fill the ponds in two days time;
- constructing a main sluice at the entrance of the supply canal;
- installing a new intake sluice for each of the 23 ponds;
- levelling the bottom of the ponds and where necessary raising the bottom elevation between 0.1 to 0.3 m above low tide level;
- digging of a ring channel in each pond.

The works were executed by the Technical Department of the Ministry of Public Health and completed in two-and-a-half months.

The trial

The first difficulty was to get the owners to stock their ponds with fish. Normally they would not do so until a fair amount of green floating algae had developed. By 20 November 1928, all 23 fishponds were finally stocked. To stimulate development of blue-green algae, the water level was allowed to vary daily with the tide, as in the 'Semarang method'. But after this, the researchers wanted to maintain the water level as high as possible, to suppress the development of floating green algae, which they saw as the source of malaria and the pond owners as the food source their fish couldn't do without.

Walch, Van Breemen & Reijntjes (1930) provide details of their dealings with individual owners and their actions in individual ponds. It suffices here to say that by implementing the principles of the 'Pasuruan method' they managed to obtain a water surface without floating algae and also free of mosquito larvae, while producing a sufficient quantity of fish to make exploitation economically viable.

From the production data until the end of 1929, the researchers calculated that the first, second and third harvest gave the owners an average return on working capital of 23%, 108% and 189% on a yearly base. In their calculations of working capital, they included an annual rent of Dfl. 210 per ha, which was not actually paid by the owners in the experiment.

FIG. 1. OVERZICHTSKAART VAN HET VISCHVIJVERGEBIED BIJ BATAVIA.
(*Map of the fishpond area at Batavia*).
Schaal (*Scale*) 1:100000.

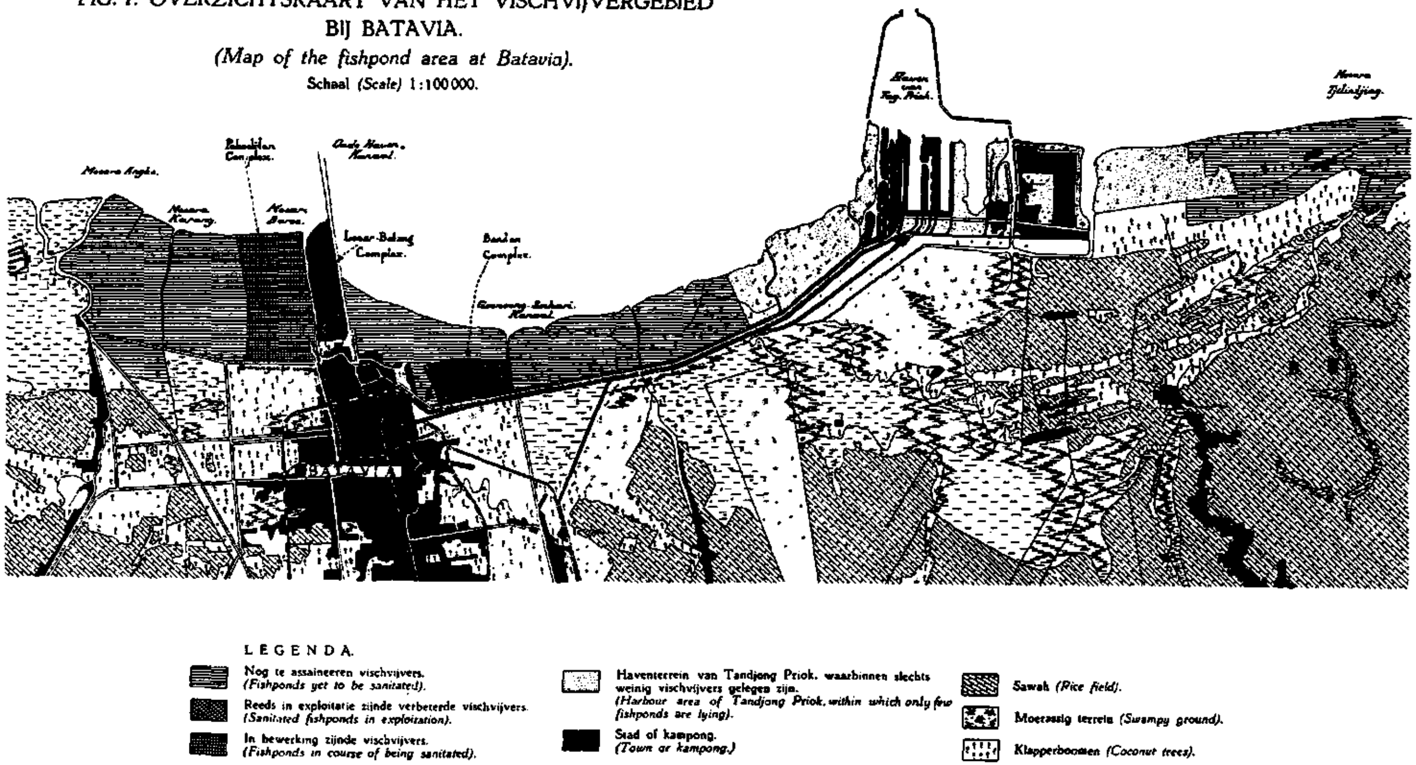


Fig. 5.8 Map of the fishpond area at Jakarta (formerly Batavia), reproduced from Walch *et al.* (1930).

New sanitation plan

Based on the outcome of the experiment, the researchers recommended sanitation of all fishponds in a 4 km long zone north of Jakarta. Figure 5.8 is reproduced from the researchers' report and gives a map of the fishpond area. Unlike in the experiment, the ponds would have to be expropriated and then rented back to the owners. The reason for this was that most ponds were long and narrow, which made them unsuitable for digging of ring channels, so that reallotment was necessary to obtain ponds with a suitable shape. The researchers estimated the cost of sanitation of all 1000 ha of fishponds at Dfl. 5,600,000.

In the period 1928 – 1932 an area of 291 ha of fishponds was actually sanitated, at a cost of Dfl. 2,000,000. Due to the worldwide recession, no more funds were available for the sanitation of the remaining 700 ha.

Effects of 'hygienic exploitation' on malaria

In 1931 the Malaria Bureau conducted a survey to evaluate the effects of the sanitation programme (Van Hell, 1931). Figure 5.9 gives the spleen index for the various quarters of Jakarta, with the figures between brackets referring to Van Breemen's survey of 1917. Apparently Van Breemen and Walch had been

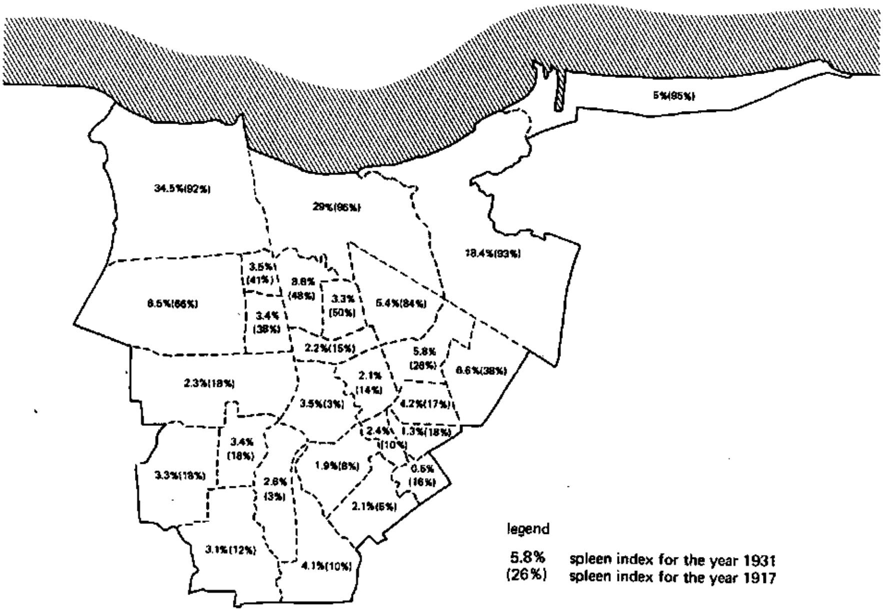


Fig. 5.9 Map of Jakarta, with spleen index for the various quarters.

too busy in 1928 with grasping the finer points of fish cultivation to think of conducting a benchmark survey on the malaria situation in Jakarta. This makes it difficult to say with certainty that the considerable improvement in the spleen index in all quarters of the town was due to the hygienic exploitation of the fishponds. Quarters closest to the sanitated ponds, however, showed the best improvement.

After hygienic exploitation of the fishponds began, the overall mortality rate in Jakarta also decreased substantially, from a stable 39 per thousand in the period 1925 – 1929 to 27 per thousand in 1931. It is furthermore remarkable that only a few data on mosquito density, species composition etc. are available. It is not possible to relate the reduction in malaria incidence to lower mosquito biting rates or infection indices.

Effects of 'hygienic exploitation' on fish production

Markus (1941) reported that while productivity in many fishpond areas remained high (500 kg/ha/year) under hygienic exploitation, it decreased to as low as 50 kg/ha/year in others. Markus found that high productivity was related to ponds with a black, homogeneous, soft mud with a high organic matter content. Low productivity was associated with brown to grayish, heterogeneous, often cloddy mud low in organic matter. Frequent drying of the mud layer appeared to reduce the organic matter content.

Vaas (1947) reported that to improve the productivity of the ponds they were

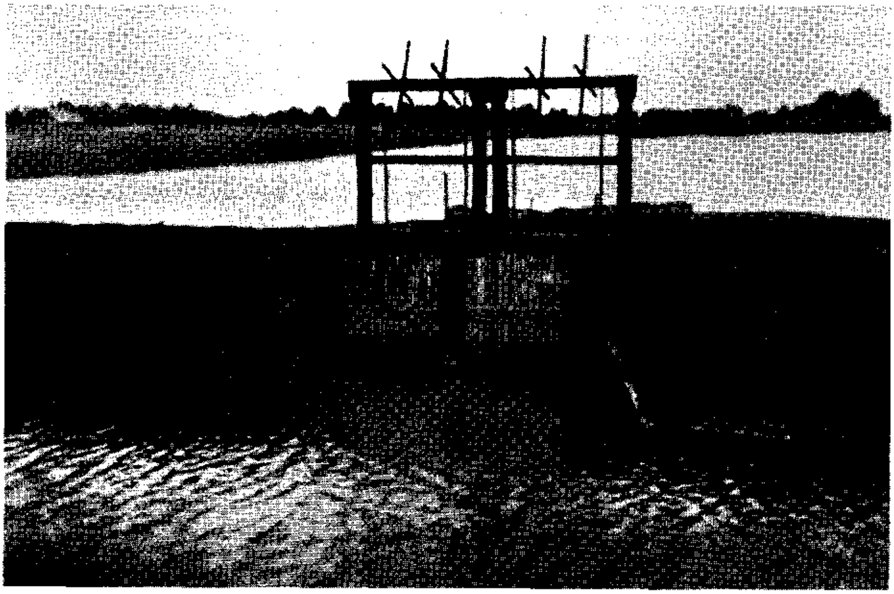


Photo 11 Fishpond after treatment. Each fishpond is provided with a sluice; by means of supply canals, discharging into a main canal, in connection with the sea, it is possible to drain and to refill every fishpond separately. Water surface clean; no algae.

no longer drained completely and fertilized with a compost made out of weeds from the pond and vegetation from the banks. Vaas recommended planting of leguminous crops on the banks, to be incorporated into the compost as a green manure. He did not indicate how successful the above measures were in restoring productivity of the fishponds.

5D – Cihea: a case of integrated rural development avant la lettre

Introduction

The Cihea irrigation project took 40 years to build, from 1854 to 1894. After a short period of high productivity, yields went down and many fields remained uncultivated because the population was too ill with malaria to grow rice. It took a joint effort by the Irrigation and Medical Services, the Department of Agriculture and the local administration to emerge from the swamp that the Cihea irrigation project had become. After many difficulties, a regulation was introduced in 1919, that restricted planting dates and periods in which irrigation water was supplied. Once the farmers' reluctance to this 'plant- and water regulation' had been overcome, rice production increased and malaria was reduced to an acceptable level.

Irrigation Development

The relatively dry plain of Cihea is located West of Bandung, Java, about 300 metres above sea level. In 1854, the Regent of Bandung conceived the plan of making a canal to divert water from the Cisokan river (Elenbaas, 1893). The Regent had an open eye for the prosperity of his people and used his privilege – the right of ordering the population to provide unpaid labour – for constructing irrigation canals. Because of the deep and steep-walled gorge created by the river, it took a long time to find a suitable diversion point. In spite of an input of 50,000 labour days, the population only managed to construct the first 1,300 m in the period 1865-1868. They stopped working on the project altogether in 1874, when the Regent died. In the same year, a local official from the colonial administration put forward a proposal to complete the works with Government assistance. In 1877, the Governor of the Preanger Regencies ordered the Irrigation Service – which had not been involved so far – to do what we would now call a pre-feasibility study. This was followed by a detailed design and cost-estimate. In 1884 the Government decided not to proceed, because it deemed the expected cost of Dfl. 212,000 – or alternatively Dfl. 116,000 plus 317,000 days of statute labour – too high . From these figures we can calculate that the cost of labour was valued at Dfl. 0.30 per day. This corresponds well to the daily wages of Dfl. 0.28 paid to Javanese workers on the tobacco plantations in Sumatra in 1889. For comparison, the starting base salary for European staff at such a plantation was Dfl. 200 per year, which could increase to Dfl. 400 after six years of service. Total income could be considerably higher due to profit sharing, up to Dfl. 2,000 per year (Janssen, 1914).

In 1888, in an attempt to alleviate poverty in the area, the Governor proposed the project anew. In 1891, the Government allocated a sum of Dfl. 312,852 for the implementation of the works 'in free labour' , i.e. not using statute (unpaid) labour. The first and second section were completed in 1894, and people began to migrate into the plain. They could only obtain land, however, in the parts that had not been brought under irrigation yet, as speculators had already taken possession of the irrigable land. Then the works stagnated, because the allocated funds had been used up. Many of the immigrants left again, because they feared that the Government would not complete the works. In 1896 the Government allocated another Dfl. 143,050 , but also counted on 69,900 days of statute labour to complete the works. To avoid having to work without pay, more people left the plain. Much of the land sold by the emigrants came into the hands of speculators again, who lived in the towns of Bandung and Cianjur.

In 1904 the irrigation works were completed, at a total cost of Dfl. 933,843 and 120,000 days of statute labour. The primary canal was 17.2 km long, with a capacity of 7 m^3/s , the total length of the secondary canals was 35.4 km and that of the tertiary canals 267.4 km. No less than 255 structures were build, among those 4 tunnels and several aqueducts. The total irrigable area was 5202 ha, which means that the cost of irrigation development amounted to Dfl. 180,–/ha (Koorenhof *et al.*, 1933/34).

Malaria Investigations

In October 1911, the tea company Tiedeman & Van Kerchem – owners of a tea plantation East of the Cihea river – addressed a petition to the Governor General of the Dutch East Indies, requesting him to have such measures taken as required to improve the health situation on their plantation , 'also for the benefit of the local population'. In response, the Chief Inspector of the Health Service for West Java – Dr.W.J. van Gorkom – visited the estate from 17-19 December 1911. He examined the native workers and their family members who lived on the estate and found a spleen index that was not exceptionally high: 37.5% for the factory workers and 42.5% for the estate labourers; he found no patients with excessively large spleens. The estate's administrator claimed that malaria was brought to the estate by temporary workers from the Cihea plain. From a survey in which he examined 635 persons from 7 villages in December 1911 and another 4110 persons in 12 villages in August 1912, van Gorkom found a spleen index well over 50% in most villages, and a high number of patients with excessively large spleens. The spleen index for children was much higher, with an average of 79%. Van Gorkom paints an overall gloomy picture of the Cihea plain: unhealthy looking people, high infant mortality, houses and villages in poor state of repair, weed-covered and ill-maintained irrigation ditches, fishponds and rice fields. According to the local Civil Service, many fields remained uncultivated because of the lack of labour, which again was caused by malaria. Van Gorkom described this situation as a 'circulus vitiosus' – the vicious circle

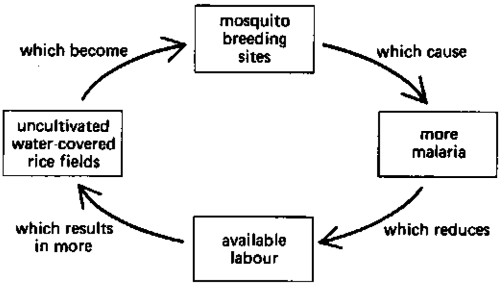


Fig. 5.10 *Circulus vitiosus*.

indicated in Fig. 5.10 (Gorkom 1913).

To break the cycle, van Gorkom recommended the local administration:

- to stop the irrigation supply to fields which are not cultivated;
- to improve the physical drainage system;
- to ascertain that fishponds are kept clean;
- to promote the use of mosquito bednets and of quinine;
- to distribute quinine to the needy at no cost whenever there is an upsurge of malaria.

To the tea company Tiedeman & Van Kerchem he recommended:

- to employ temporary workers only after a medical examination;
- to introduce systematic quinine prophylaxis for their workers;
- to set up their own company medical service rather than relying on government measures.

Five years later, in 1917, Van Gorkom's successor – Van Lonkhuyzen – visited the Cihea plain, together with S.T. Darling, from the Rockefeller Institute. Their main interest was hookworm disease; yet they also looked at various Anopheline species – Van Gorkom had only made a distinction between anophelines and other mosquitoes. Based on the high number of *An. aconitus* caught in native houses – and its reputation as a malaria vector in other countries – they arrived at the preliminary conclusion that *An. aconitus* was the main vector. Infectivity studies of the vector, however, were not done at that time.

Subsequently a government doctor, Mangkoewinoto, was sent to the plain for a more thorough investigation. Table 5.5 indicates the various species caught in houses. Only *An. aconitus* was found to be infected, which confirmed the earlier hypothesis of this species being the principal vector.

The preferred breeding site appeared to be the inundated, uncultivated and weed-covered rice fields. Ditches with luxurious grass hanging into the water also produced large quantities of *An. aconitus* larvae.

Mangkoewinoto found that the spleen index in the villages had increased considerably since 1912. The percentage of rice fields that remained uncultivated had also increased (Fig. 5.11). According to Mangkoewinoto, very little had

Table 5.5 Numbers of malaria mosquitoes and their larvae found in houses, ditches and ricefields in the Cihea plain.

	No. of Anopheles caught in houses		No. of larvae found * 1919 **	
	1917	1919	ditches	ricefields
A. aconitus	163	1155	3845	555
A. rossi	126	8	1	7
A. punctulatus	1	6	-	3
A. kochi	4	8	3	74
A. fulginosus	25	3	83	34
A. barbirostris	-	24	55	640
A. sinensis	26	44	71	467

* No. of larvae found by same number of people in same time span;

** Mangkoewinoto mentions that larval search in 1919 was done when many ricefields were already being drained.

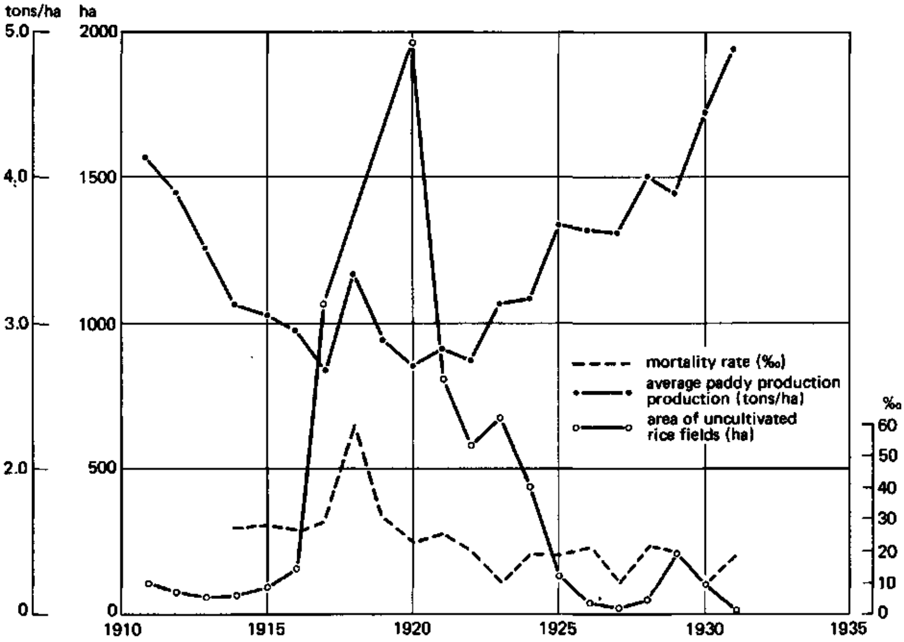


Fig. 5.11 Fluctuations in area of uncultivated ricefields, paddy production, and mortality rate in the Cihea plain in the period 1910-1931.

been done about the actions recommended by Van Gorkom; in 1917 the plain still looked like one big swamp.

At that time, the local representative of the colonial administration was negotiating with the sugar company Handels Vereeniging Amsterdam (H.V.A.), who had offered to bear the costs of a sanitation programme, provided it could plant sugar cane in the plain and build a factory. In his report of 1917, Mangkoewinoto supported these proposals and said that large scale sugar cultivation was the best and most rational way to control malaria in the Cihea plain. In spite of strong support from the administration and the Health Service, the plan did not materialize. According to Mangkoewinoto because H.V.A. only wanted the best plots of land; according to Koorenhof *et al.* (1933/34) because H.V.A. after further study had concluded that sugar cultivation was not economically feasible because of adverse soil and climatic conditions. On the basis of his findings Mangkoewinoto proposed the following measures to combat malaria in the Cihea plain:

1. Complete drainage of rice fields after harvest.
2. Simultaneous planting of rice fields.
3. Cleaning of irrigation and drainage ditches.
4. Distribution of quinine to population whenever there is an upsurge of malaria.

Mangkoewinoto explains that measures 1, 2 and 3 had in fact already been put into effect by the Irrigation Service for other reasons than malaria control. Drainage of rice fields after harvest was considered necessary to reduce root rot, which was assumed to be caused by continuous submergence of the soil. Simultaneous planting and cleaning of farm ditches was required for a proper water distribution.

The local irrigation superintendent was reported to be quite taken with Mangkoewinoto's conclusion that not only the inundated rice fields represented a health risk, but also the poorly maintained farm ditches: this provided him with another good reason for persuading farmers to clean the ditches. The superintendent was facing great difficulties in introducing the water regulations; for fear of his own safety he did not go into the plain unarmed.

In an attempt to achieve better cooperation from the farmers Mangkoewinoto, together with the local administration and the irrigation superintendent, organized a demonstration of his mosquito research for the village leaders and landowners. He showed them various anopheline species and their larvae, infected mosquito stomachs, blood slides etc. and explained to them the transmission mechanism of malaria and the importance of the proposed measures for the well-being of the region.

'Plant and Water Regulation' and the Irrigation Service

Mangkoewinoto's recommendations of 1919 were not much different from those of Van Gorkom in 1912. Why the Irrigation Service had not acted upon Van Gorkom's recommendations to improve drainage and stop the irrigation supply to uncultivated rice fields? The answer can be found in the annual reports on the Cihea irrigation project from the Department of Civil Works (Anonymous 1914-1922).

The 1914 report mentions... 'preparatory fieldwork for the already authorized works for improvement of drainage and for the collection of data required for better water management'.

Report 1915: 'Since the completion of the works in 1904, water management has been the responsibility of the local administration; no specific regulation for water distribution exists, nor is there a cropping plan; everyone plants as he sees fit...'

'... of course it is not possible under those circumstances to achieve proper water distribution; this results in inefficient water use.'

'In the reporting period a start was made with the enlargement of the drainage canals and removal of weirs built in them by the farmers, and with the digging of new drainage canals.'

'The reason to improve drainage in the Cihea plain was the report of the Health Service Inspector of 24 October 1912...'

'A field survey indicated that the majority of rice fields could be drained simply by cutting through the bunds, but farmers did not make the effort. In other places, imperfect drainage is the result of poorly maintained farm ditches or building of weirs across drains by farmers. Only in a few places imperfections of the main drainage system caused the swampy conditions.'

'Because of very poor permeability, drainage of the soil requires closely spaced farm ditches. Construction of the ditches is beyond the capacity of the sparse population in the area. Much could also be achieved by deep soil tillage, but again the farmers will not do this themselves. Therefore it seems appropriate to open up the area for cultivation of sugar cane, also as a means of improving the health situation.'

Report 1916: '... the superintendent of irrigation reported in December of this year on the findings of his studies concerning the operation of the irrigation system; this report can serve as the basis for a water distribution regulation.'

Report 1917: '... this year a start was made with a preliminary water regulation, for which several discussions were held with the local administration and the population. The need for a plant and water regulation had been felt for a long time, but attempts at introduction were always opposed by the farmers, who could not be persuaded to put some regularity in their time of planting. Because of the low population density there are not sufficient labourers available for preparing all the fields in a short time. The result is that farmers in the area are planting throughout the year.'

'... farmers prefer to keep their fields submerged, because the heavy clay soils produce deep cracks upon drying out and then need to be inundated for a long time before they can be cultivated again. As a result of continuous submergence, the soil is not sufficiently aerated [which was assumed to cause root rot (Koorenhof *et al.*, 1933/34)]. It also appears that constant inundation affects the health situation. A medical investigation indicated that not less than 98 percent of the population suffer from malaria. As a result, the number of population in the area is decreasing.'

'... from the above it will be clear that a water regulation is absolutely necessary. In the reporting period a preliminary regulation was introduced with the objective of having an official regulation by 1918, which will be strictly enforced.'

'The tertiary irrigation units are divided into two groups, red and blue. The red will receive water from November 1, the blue from February 1. Each group will have 3 months for land preparation and planting.' [The red and blue units are dispersed over the entire area to allow labourers and plough animals to move through the area without having to travel long distances; Koorenhof *et al.*, 1933/34]

Report 1918: 'The introduction of the plant and water regulation met with great difficulties. The farmers, who are accustomed to planting when they please did not keep to the regulatory planting periods.'

'In view of problems with food supply, the local administration decided to start the irrigation supply to the first group in August rather than in November. Although there was an ample supply of irrigation water – about 3.5 l/sec/ha – land preparation was difficult because the soil had developed deep cracks through which a lot of water was lost. In addition, the farmers were reluctant to plant so early and did not start land and nursery preparation until the end of the year. The preliminary plant and water regulation must be considered a failure.'

Report 1919: 'Based on the experience in 1918 it was decided to start the irrigation supply to the first group on 15 September and the second on 1 December. Although in places there was some opposition from the farmers, it appeared the regulation was more readily accepted. By December 70 percent of the fields had already been planted or was being prepared. This was the result of the efforts of the irrigation superintendent and the wholehearted support received from officials of the local administration.'

Report 1920: 'On February 1, and every 2 weeks thereafter, the irrigation supply was reduced by 1/6 and finally stopped on April 15. After this date only so much water was supplied as to meet the requirements for drinking, bathing, washing and watering of non-rice crops. Fish cultivation was restricted, for health reasons. The same procedure was followed for the second group, with gradual reduction of the irrigation supply starting on April 1.'

'The Health Service made available an amount of Dfl. 4,000 for the maintenance of tertiary irrigation and drainage ditches. With this amount a total of 62 km of ditches was restored to design profile and regularly maintained afterwards. Due to this improvement, the favourable weather conditions, and the interruption of the irrigation supply health conditions during the reporting year were favourable.'

Report 1922: '... the planting of rice proceeded smoothly; it can be noted with satisfaction that the initial opposition against the plant- and water regulation by now has completely disappeared.'

The 'State Sanitation Farm'

In 1919, the Director of Agriculture announced in the Peoples' Council – the Parliament of the Netherlands-Indies – that the Government considered the establishment of large-scale rice farms to alleviate the national food shortage. An agriculturist was sent to California to study methods of mechanized rice farming (Anonymous, 1921). In the same year, the Government requested the Civil Service in Cianjur to purchase 1000 ha of rice land from the population in the centre of the Cihea plain – where drainage conditions were worst and the people suffered most from malaria – with the objective of improving agricultural practices and the health situation of the farmers.

Koorenhof *et al.* (1933/34) say that at that time many small farmers left the area, selling their land at prices around Dfl. 10.- or less, while the Government had to pay Dfl. 140.- per ha.

Of the 1000 ha, 71 ha was used as experimental fields for growing non-rice crops – cassava, maize, cotton, groundnuts. The objective was to identify a dry season crop with very low water requirement, which could help to reduce the economic loss of growing only one rice crop, without creating a health hazard. The remaining land was rented to local farmers for rice cultivation; tenants could obtain loans: Dfl. 10.- after land preparation, another Dfl. 10,– after planting and Dfl. 5.- after each weeding. All loans were repayable in rice.

Local contractors built mosquito-free houses for European and local staff, 50 cottages, a small hospital, warehouses and stables, for a total amount of Dfl. 75,000. Also, equipment was bought for mechanized rice farming, including tractors.

An agriculturist was appointed as manager and a medical technician from the Health Service was stationed permanently on the farm, with a local Government doctor visiting once a week.

The manager immediately took up improving the drainage system; in the first year 20 km of canals was constructed and another 100 km in the following years. All depressions in the terrain were drained and the ban on construction of new fishponds strictly enforced.

To prevent illegal rice cultivation in the dry season, the water supply for domestic use was channelled from the main irrigation canal directly into the drains going to the villages. When this method proved successful on the sanitation farm, it was generally applied on the Cihea plain.

The experiments with second crops and with mechanized rice cultivation both produced unfavourable results. Yields were minimal and the machinery could not cope with the heavy and marshy soils of the Cihea plain. As an alternative, the sanitation farm tried to promote animal traction. The experimental fields were turned into pasture land and in 1922 the Government provided Dfl. 60,000 for the purchase of breeding-cattle. The results of the breeding programme were not very good either. The sanitation farm then concentrated its research activities on rice cultivation: fertilizer and crop variety trials.

By 1930, the state sanitation farm, in spite of its high initial cost, achieved an annual return on investment of 6 %.

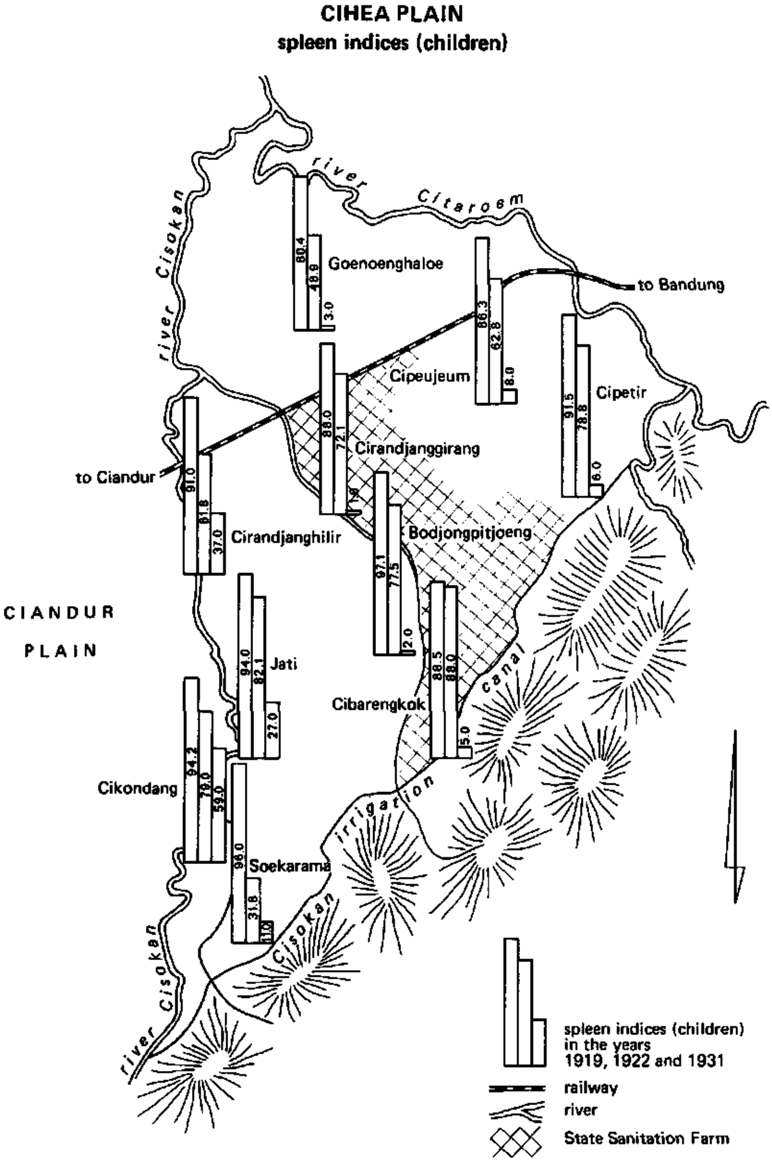


Fig. 5.12 Location of State Sanitation Farm and spleen indices for ten villages in the Cihea plain in the years 1919, 1922 and 1931.

Results and conclusions

In the period from 1919 to 1932 the population increased from 13,223 to 24,493. Due to increased productivity the per caput rice production increased from 470 kg in 1917 to 660 kg in 1932 (Koorenhof *et al.*, 1933/34). The increase in rice productivity is the result of higher yields and decreasing area of uncultivated rice fields (Fig. 5.11).

Mortality rate in the Cihea plain decreased from about 30 per thousand around 1920 to values below 20 per thousand in 1930. The spleen index for the whole of the plain decreased from 90.7% in 1919 to 15.9% in 1931. Figure 5.12 shows the spleen index for children in ten villages in the plain for the years 1919, 1922 and 1931. Although this reveals significantly decreasing spleen indices, in 1931 malaria still prevailed in the western part. This was attributed to the malarious areas in the Cianjur Plain, on the other side of the river Cisokan. There, no 'plant and water regulation' had been implemented because the indigenous irrigation systems did not provide sufficient water control. But, in the light of the results achieved in the Cihea plain, it was decided to replace the village-type systems with a 'technical' irrigation system – with separate canals for irrigation and drainage – and to introduce a similar 'plant and water regulation'. The irrigation works for an area of 12,680 hectares started in 1937 (Anonymous, 1937).

5E – House improvement and malaria

Introduction

An article with this title appeared in the communications of the Civil Health Service in 1938. It was presented by J.W. Grootings, government physician and regional director of plague control at Tasikmalaya. Plague had been present in the Netherlands-Indies since the world epidemic of 1895. It soon disappeared from Sumatra and Sulawesi, but persisted in Java, rising and falling in great epidemic waves which caused 207,666 known deaths from plague in the period from 1911 to 1936. The disease is essentially one of rats and is transmitted by fleas – mainly *Xenopsylla cheopis*. Humans living in close contact with rats can become infected when they are bitten by infected fleas.

In the country districts, a campaign of house improvement was implemented, with as its goal the alteration of existing houses, or construction of new houses, in such a manner that facilities for rat nesting were eliminated. Double walls are abolished, bamboos used in building are sealed at each end, or replaced by wooden beams, the use of tiles to replace thatch is encouraged, and regular house inspections are made. Wilcocks (1944), in an article on medical organization and diseases of the Netherlands Indies, says: '*The Dutch have carried out this campaign without compulsion, but with the aid of a small bonus for each completed house, and report astonishing success; by the end of 1938 no less than 1,525,364 houses had been improved. The unexpected effect of this activity in cau-*

sing an increase in malaria has been referred to above.'

Wilcocks refers to his section on malaria, where he says:
'*In recent years there has been an increase in malaria in those areas in which the house improvement campaign for the suppression of rats has been pressed. The reason for this is that in the process of house improvement breeding places are created, small pools and puddles where earth has been taken, unless great care is exercised. Much of the house improvement is done by the natives themselves, and supervision from the point of view of malaria is not easy.*'

In his article, Grootings observes the same relation between house improvement and malaria as Wilcocks does, but comes with a totally different explanation.

Sakit woneng

The area Grootings reported on consists of the Regencies Tasikmalaya and Ciamis, located in the interior of West-Java. Contrary to what Wilcocks said, the house improvement scheme was on a compulsory basis. Begun in 1933, the scheme by 1938 had been completed in five sub-districts, was almost completed in two, and in implementation in another two. Among the population, there was general consent that house improvement caused malaria; they even called the disease – which had not been common in the region – by the name 'sakit woneng' ('sakit' = disease; 'woneng' after Dutch 'woning' = house).

Malaria investigations

Since the house improvement scheme still needed to be implemented in many other sub-districts, Grootings felt he could not ignore popular opinion and therefore started an investigation into the matter, with the help of the Provincial Health service of West-Java, the Central Malaria Bureau, and the local administration.

Figure 5.13a gives the mortality curve for the years 1931 through 1937 for 8 sub-districts, and on the same time scale the progress of the house improvement scheme in that sub-district. Figure 5.13b presents the curves for the sub-districts where the house-improvement had not yet been implemented. The location of the sub-districts, with the implementation sequence of the house improvement scheme is indicated in Figure 5.14.

Comparison of the mortality curves learns that house improvement effectively controlled plague. With respect to malaria, Grootings made the following observations:

1. All curves show an increase of mortality to an unprecedented level* during and after house improvement
2. In most cases, the mortality curve reaches its peak when 90 to 100% of the houses has been improved
3. The increase in mortality after house improvement occurs in every season of the year.

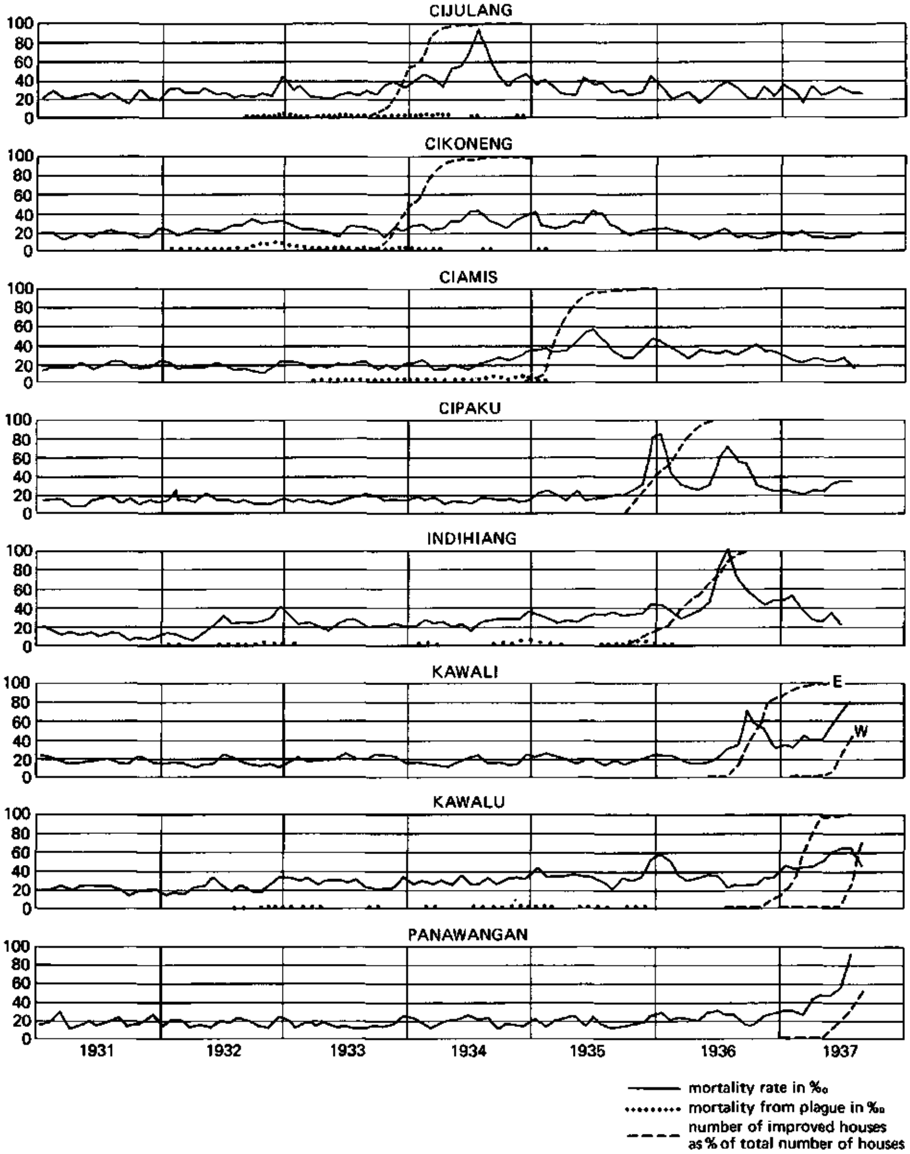


Fig. 5.13a Mortality curves for the period 1931-1937 in 8 sub-districts with house improvement.

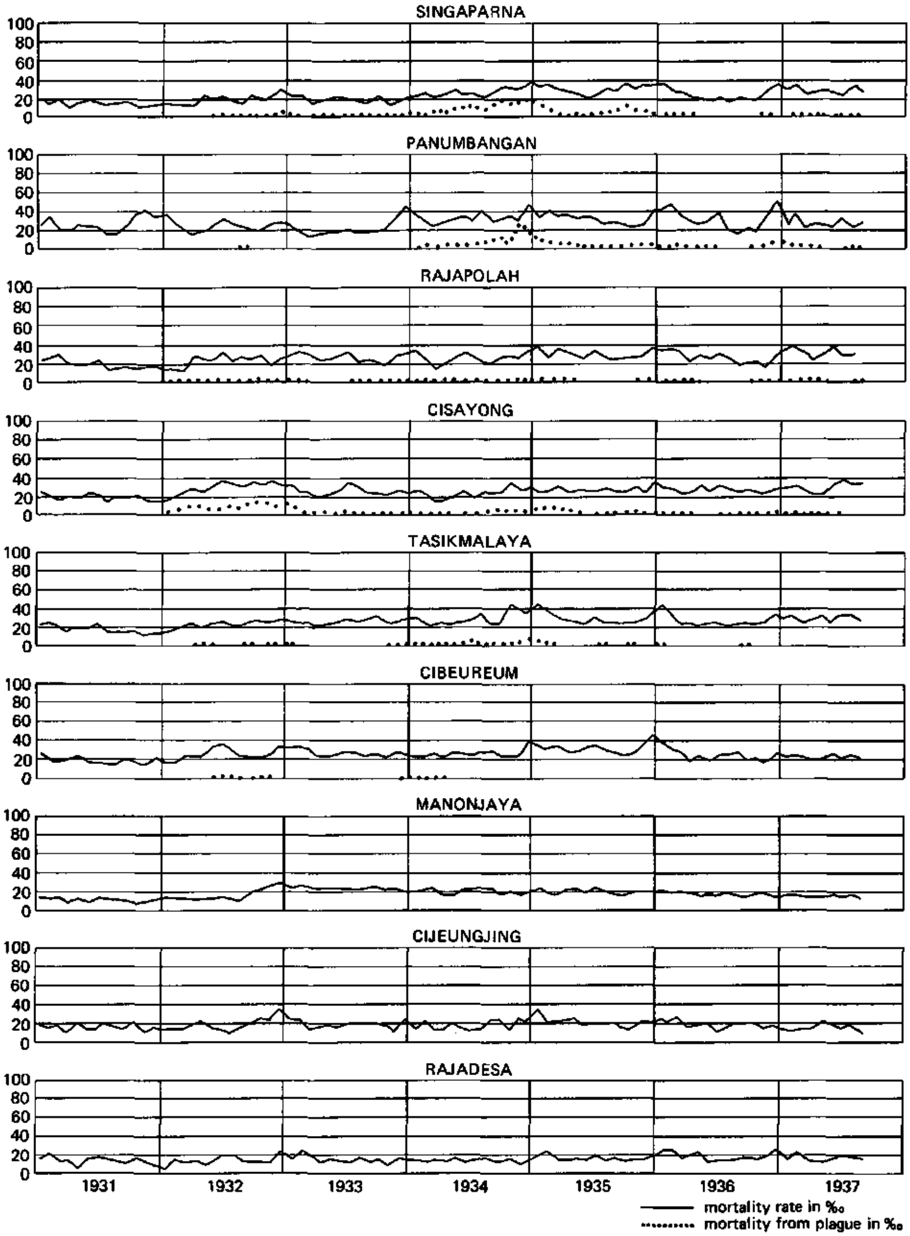


Fig. 5.13b Mortality curves for the period 1931-1937 in 9 sub-districts without house improvement.

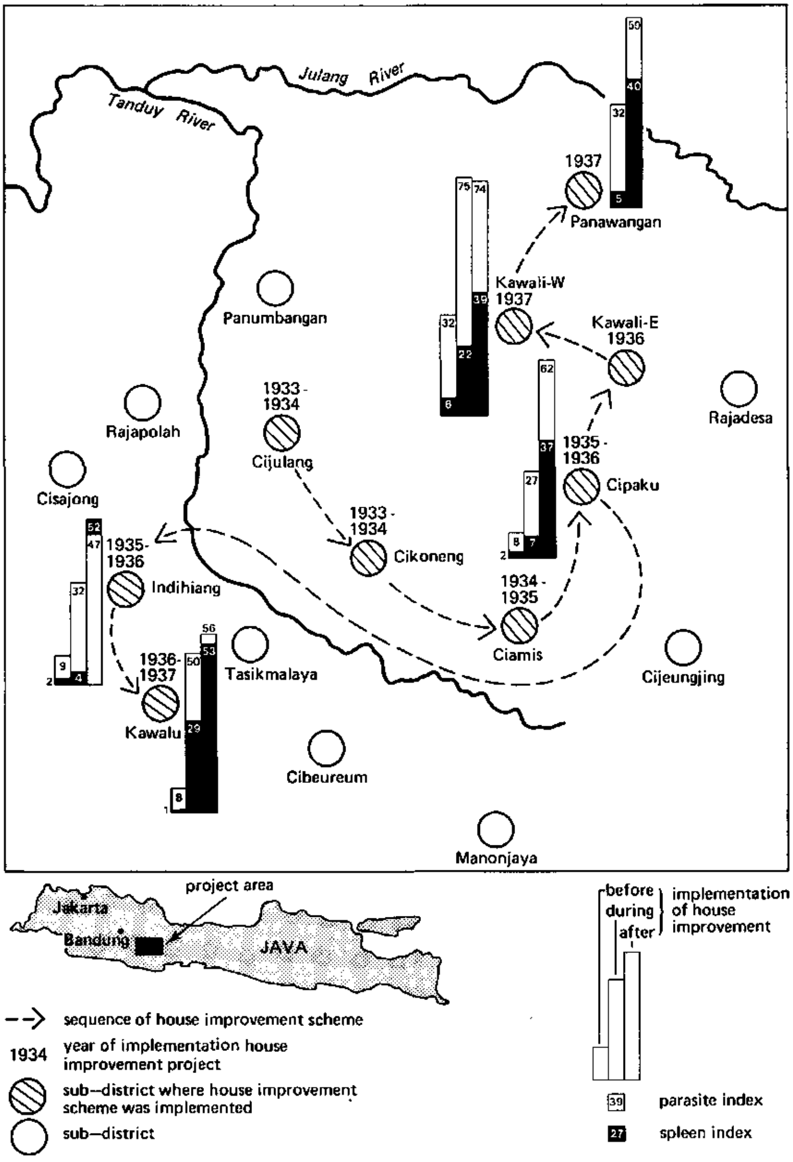
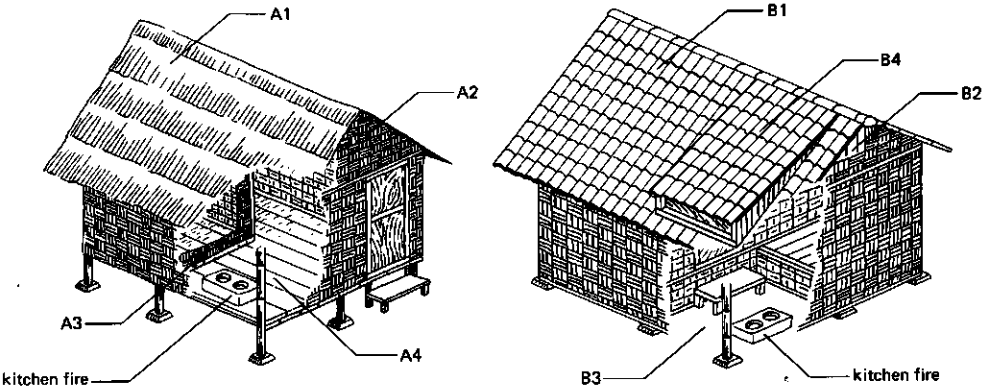


Fig. 5.14 Effects of house improvement programme on spleen indices in sub-districts of the regencies Tasikmalaya and Ciamis.

* From Grootings' curves, I have calculated the average of the maximum mortality rates in the 17 sub-districts as recorded before house improvement; this was 38 per thousand. The average of the peak mortality rate recorded after house improvement in the 8 sub-districts is twice as high: 77 per thousand. This



BEFORE IMPROVEMENT

A1 thatched roof
A2 no ventilation between ceiling and walls
A3 partition between kitchen and bedroom only halfway across the room and not reaching to ceiling
A4 kitchen smoke enters freely into rest of the house

AFTER IMPROVEMENT

B1 tiled roof
B2 ventilation through open space under roof
B3 kitchen entirely seperated from bedroom
B4 kitchen smoke leaves house through smoke hole in the roof

Fig. 5.15 Main characteristics of houses before and after improvement.

indicates that Grootings was justified to speak in terms of 'an increase of mortality to an unprecedented level'.

Grootings also determined spleen and parasite indices – before, during and after house improvement – in a number of sub-districts. It appeared that malaria was present at a very low level before the house improvement scheme and increased sharply thereafter. The results of the survey are indicated in the map of Figure 5.14. The map also shows that the malaria epidemic advanced parallel to the implementation of the house improvement scheme in the various districts, while passing by the neighbouring districts without house improvement.

The following species of anopheline mosquitoes were found indoors in all sub-districts:

An. aconitus
An. subpictus
An. barbirostris
An. kochi
An. hyrcanus
An. fulginosus

Of those, only *An. aconitus* appeared to be infected in all sub-districts; in Kawalu also infected *subpictus* and *hyrcanus* were found.

From this, Grootings concluded that *aconitus* was the main vector. *Aconitus* breeds in poorly maintained rice fields, ditches and fishponds, which were present in all sub-districts.

Kitchen smoke

Grootings' investigations supported popular belief that house improvement led to malaria. Why was this so ?

As is apparent from Figure 5.15, houses before improvement were imbued with smoke from the kitchen fire, whereas after improvement kitchen smoke no longer entered the house. Grootings' hypothesis was that the unimproved houses – because of the smoke – were unattractive for mosquitoes and difficult for them to enter, while after house improvement there was no more smoke to keep the mosquitoes away and the houses became easily accessible through the ventilation openings.

To test this hypothesis Grootings conducted mosquito surveys in villages where a house improvement program was in progress. Table 5.6 lists the number of mosquitoes found in improved and unimproved houses in the same neighbourhood, at the same moment, during an equal period of time by an equal number of searchers.

The fact that on average the ratio mosquitoes to houses was more than three times higher for the improved houses appears to support Grootings' hypothesis that the unimproved, smoke-stained houses were less attractive for mosquitoes to enter than the improved houses.

Grootings' recommendations

Apart from quinine distribution to the population – which had already been implemented – Grootings recommended sanitation measures in his article which are very similar to those implemented in the Cihea plain (c.f. Case study Cihea):

- keep irrigation and drainage ditches free from vegetation;
- in village irrigation schemes: cut and burn rice straw after harvest;
- in technical irrigation schemes: plant rice only once a year and stop irrigation supply after harvest;

Table 5.6a Mosquito survey in houses that had not been improved.

Sub-district	No. of houses	No. of mosquitoes	No. of *An. aconitus*
Ciamis	817	129	*
Tasikmalaya	467	125	42

Table 5.6b Mosquito survey in improved houses.

Sub-district	No. of houses	No. of mosquitoes	No. of *An aconitus*
Ciamis	793	713	*
Tasikmalaya	313	316	135

* Due to an organizational error the number of *An. aconitus* caught was not counted separately for unimproved and improved houses in Ciamis; of the total of 842 mosquitoes caught, 668 (79 %) were *An. aconitus*.

- keep the water surface of fishponds permanently free from vegetation;
- promote the use of larvivorous fish (*Haplochilus panchax*) and weed-eating fish (*Puntius javanicus*) as an anti-larval measure in fishponds.

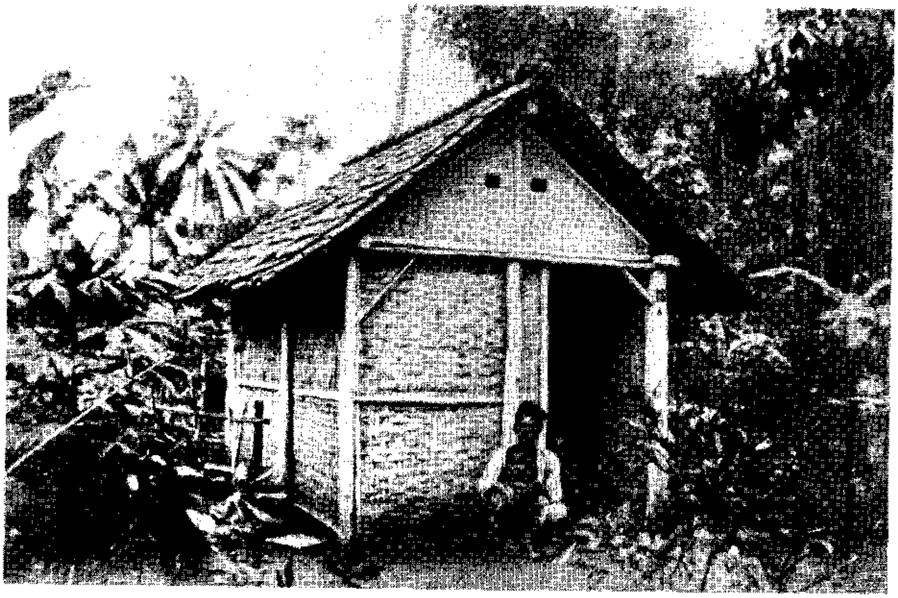


Photo 12 House after improvement.

Chapter 6

Dr. Ir. J. Kuipers – Civil engineer and malariologist

W.B. Snellen

Introduction

In 1938 a malaria epidemic occurred in Tanjung-Periuk, the harbour of Jakarta. It provoked a whole series of articles in the medical journal for the Netherlands-Indies [Geneeskundig Tijdschrift voor Nederlandsch-Indië], with opposite views on the cause of the epidemic and sometimes reflecting a concern about the efficacy of the malaria control effort.

In issue no.47 of the 1938 volume, Van Der Eyden wrote on the strategy of malaria control. In his view the knowledge of malaria epidemiology in the Netherlands-Indies stagnated, in spite of millions of guilders spent on sanitation measures, the establishment of a powerful Malaria Bureau, and countless entomological studies. The reason for this stagnation, he said, was the lack of appreciation for the genius of Ronald Ross as the founder of malaria epidemiology. On the basis of the chapters 'Laws which Regulate the Amount of Malaria in a Locality' and 'Laws which Regulate the Number of Anophelines in a Locality' from Ross' book 'The Prevention of Malaria' (1911), Van Der Eyden concludes: '*Where there is a lot of malaria, the responsible breeding site is always close by, usually within several hundred metres. Even though the mosquitoes sometimes fly as far as 5 km, malaria seldom spreads further than 750 m from a breeding site. Therefore, a sanitation measure is always adequate provided all breeding sites within 750 m from settlements are cleared.... The cause of the epidemic in Tanjung Periuk therefore are the poorly maintained drains with stagnant water and other water pools within the harbour area.*' (Van Der Eyden 1938).

The director of the Central Malaria Bureau sent a letter to the editor on account of Van Der Eyden's article (Overbeek, 1938). Overbeek stated that while clearing of breeding sites within 750 m from settlements may have worked against *An. maculatus* in the Malay States, this did not mean the same principle could be applied to control *An. sundaicus*. As just one example, he recalled the research of Van Breemen in 1917, who in 3 native quarters in Jakarta found spleen indices of 66%, 40-50%, and 84%, while the distance to the closest breeding sites was 3 km.

The source of malaria in Tanjung Periuk, Overbeek wrote in his letter and later in a more elaborate article (Overbeek, 1939), was a swampy area south of the dock-system. But without doubt, he said, the marine fishponds at some 1.5 km from the harbour had also contributed to the epidemic.

Overbeek ended his letter requesting the editors that articles on malaria issues may be seen by the Malaria Bureau prior to publication, 'so as to avoid unnecessary scribbling.'

Two articles in support of Van Der Eyden's conclusion appeared in issue No.17 of the 1939 volume, both by shipping companies' physicians based at Tanjung Periuk (Marwits, 1939; De Priester, 1939). Marwits observed a striking correlation between the number of malaria cases on board of ships after having docked in Tanjung Periuk, and the mooring place the ship had occupied. There were no malaria cases on board of ships of the 'Rotterdam Lloyd' which moored on the far end of dock no. 2. Whereas ships of the 'S.M. Nederland' that moored on the same dock – but some 600m closer to a road along which breeding sites and larvae of *An. sundaicus* had been identified – had up to 40 malaria cases in a crew of 300. As a control measure, ships of the 'S.M. Nederland' were no longer allowed to stay overnight at the landside end of the quay and were moved some 200 to 400 m away from the road before nightfall. After this measure no more malaria cases were reported.

Marwits connected the upsurge of malaria with the slackening of maintenance of the drains and premises during the last few years. De Priester presented malaria curves for the native settlements at Tanjung Periuk, and arrived at the same conclusion.

Issue No.40 of the 1939 volume of the journal reports on a lecture given to the malariologists in Jakarta by a civil engineer, Kuipers, who accused the malariologists of a one-sided approach:

a1. They do ask, why is there malaria ?
a2. Yet they do not reflect on why there was no, or less, malaria.

b1. They do take measures against a malaria epidemic
b2. But they do not use the laws by which it is governed.

c1. They search for proof of vector production in a breeding site
c2. But they do not specify the relation between mosquito production and the occurrence of malaria

d1. They do say: we found larvae in this breeding site
d2. But they do not explain the absence of larvae in other sites.

Kuipers supported his view with a diagram (Fig. 6.1), which indicated the names of the scientists who had studied the malaria problem in the Tanjung Periuk area, the various breeding sites (f = fishponds; d = drains; s = swamps) they held responsible for it, and whether or not they had taken the questions a1, a2, b1, b2, etc. into account (y = yes; n = no; p = partially).

Kuipers was head of the Sanitation Bureau at Surabaya. He was responsible for water supply and sanitation projects in East Java; this also included technical measures for malaria control. He had received a doctorate from the University of Amsterdam in 1937 on a dissertation-in Dutch- 'Mathematical-statistical Investigation of Observations on Anopheles in The Netherlands and on Java' under the supervision of Professor Swellengrebel (for a discussion on Swellen-

	f	f	f	f	d	d	d	s
a1.	y	y	y	y	y	y	y	y
a2.	n	n	p	n	n	n	n	n
b1.	y	y	y	y	y	y	y	y
b2.	n	n	n	n	n	n	n	n
c1.	y	y	y	y	y	y	y	y
c2.	n	p	y	n	y	p	p	p
d1.	y	y	y	y	y	y	y	y
d2.	n	p	n	n	p	n	n	n
	B 1918	R&E 1922	B 1926	O 1938	R&E 1922	P 1939	M 1939	O 1939

B=Van Breemen;R&E=Rodenwaldt & Essed;O=Overbeek;P=De Priester;M=Marwits

Fig. 6.1 Kuipers' diagram on approach of malaria research in Indonesia (see text for explanations).

grebel's work refer to Chapter 4). His dissertation was an attempt at quantifying the relationships between environmental factors and the potential mosquito productivity of a breeding site.

In his lecture -and in his dissertation- Kuipers claimed that these relationships had practical significance for the control of malaria through species sanitation.

The minutes of the discussion following Kuipers' lecture suggest that the malariologists did not readily accept his ideas. Shortly after, World-War II started and when it was over there was DDT. Kuipers then used his mathematical-statistical insights to improve the design criteria for urban drainage systems. These criteria are still applied in the Netherlands today.

This chapter describes how Kuipers developed his theory of vector production potential, his criticism of the traditional malaria control strategy and how his insights might be used in new malaria sanitation programmes.

Kuipers' early work: Brengkok

In Brengkok – on the northern coast of East-Java – a sudden outbreak of malaria occurred in 1933, claiming many lives. Some years earlier, an investigation had identified *An. sundaicus* as the malaria vector and the marine fish ponds as the major breeding site. As a sanitation measure, the 'hygienic exploitation method' had been implemented: periodical drainage of the ponds to destroy the floating algae that provide food and shelter to the larvae of the vector species.

Knowing that *An. sundaicus* breeds in sun-lit brackish pools, Kuipers conducted a field survey to detect all locations where such pools might occur (Fig. 6.2). As a next step, for each of those potential breeding sites, he checked whether there had been any changes or abnormalities, which might explain a sudden increase in vector production.

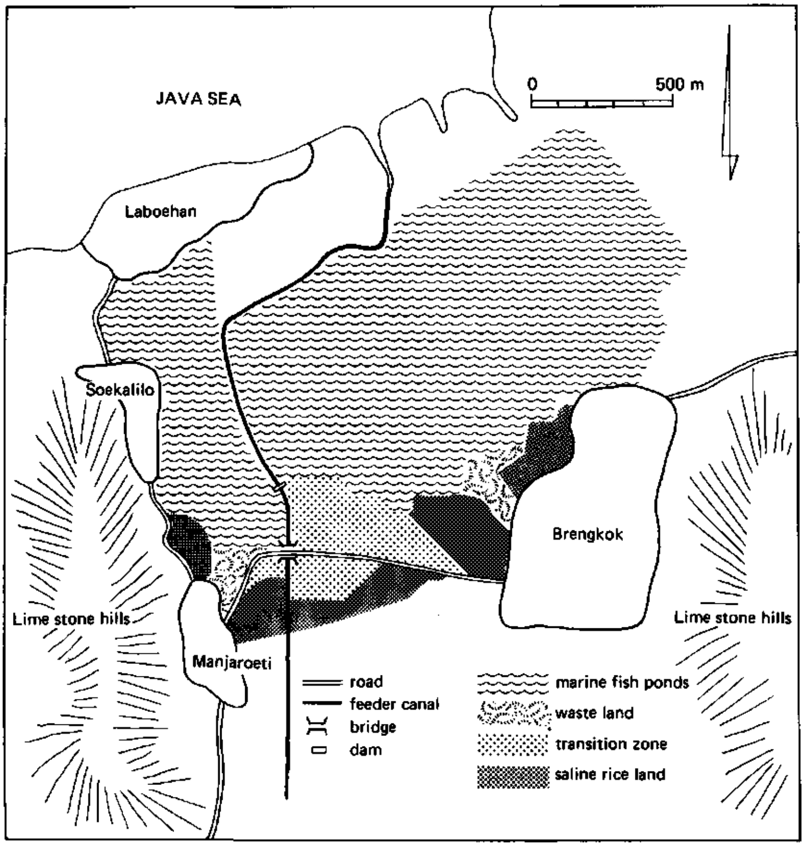


Fig. 6.2 Potential breeding sites for *Anopheles sundaicus* near the village of Brengkok, East Java, Indonesia.

It appeared that the saline rice fields had not been planted that year, because the monsoon rains were late and irregular at the start. In normal years, the shade from the rice plants and the regular dilution of the impounded water with rain would make the rice fields unsuitable breeding sites for the vector. But when the fields remained uncultivated and with irregular rainfall, sun-lit brackish pools could have developed.

Kuipers used meteorological records and soil characteristics to produce a 'ponding curve'. From the ponding curve he derived a theoretical vector density curve (Fig. 6.3). The correspondence of the maxima and minima of the vector density curve and that of the mortality curve was taken as evidence that the saline rice fields had caused the epidemic.

Because there were no larvae, Kuipers could not check the validity of his vector production model in the field. Due to an organizational mistake in the distri-

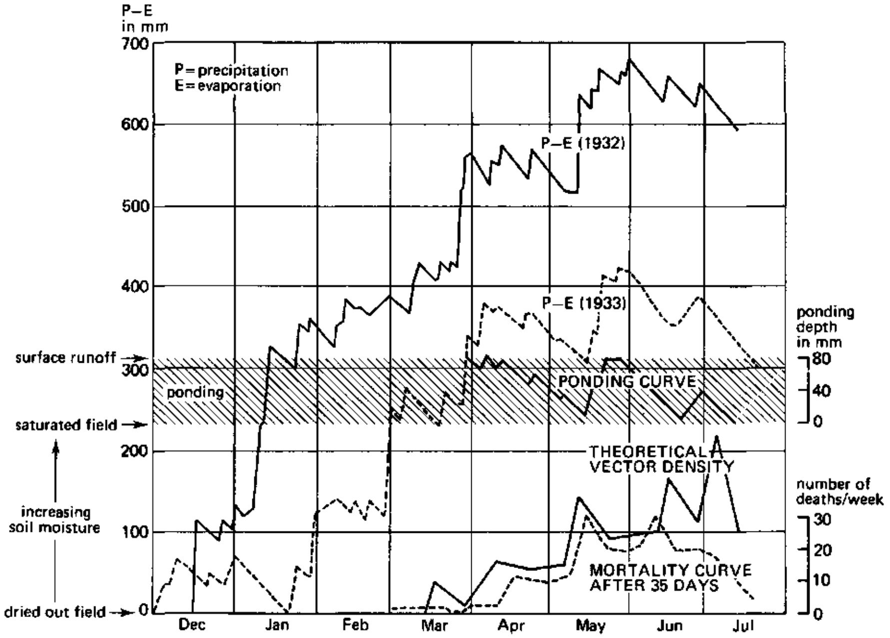


Fig. 6.3 Mortality curve, theoretical vector density, and the ponding curve in saline rice fields near Brengkok, derived from data on rainfall, evaporation and soils.

bution of anti-malaria drugs, many more deaths occurred than would have normally been the case. This meant that Kuipers could check his production curve against a mortality curve.

For the above reasons, the Brengkok approach could hardly be recommended as a new strategy in malaria control. The experience, however, did convince Kuipers of the usefulness of studying the interrelationship between the variation pattern of the relevant environmental factors, vector production and the resulting malaria.

Kuiper's dissertation

In the Brengkok case, Kuipers used a purely theoretical vector production model, which he could not verify in the field for lack of larvae. In his dissertation of 1937 Kuipers presented quantitative vector production models, which were based on field data that had been collected by other malaria researchers.

In The Netherlands, Van Der Torren had determined larval densities of two varieties of *Anopheles maculipennis*. The malaria vector was *An. maculipennis var. atroparvus*; the other variety – *messeae* – did not transmit malaria. The disease had been endemic in The Netherlands for centuries. [The last epidemic was in 1946, with 15,000 malaria cases, in spite of house spraying with DDT. The last recorded case of indigenous malaria was in 1958].

The disease had always been associated with brackish water. The availability of a large volume of fresh water – after construction of a 42 kilometer long dike separating the former Zuiderzee from the sea – presented the possibility of reducing the salt content of the surface water in the province of North-Holland, where most of the malaria occurred. In an attempt to predict the effect of such a malaria control measure, Van Der Torren collected over 1,000 larvae and water samples during the summers of 1934-1935. He observed that:

- each of the two varieties are found in both fresh and brackish water;
- highest densities of *atroparvus* are found within the range of 1,500 – 2,000 mg chloride per litre;
- highest densities of *messeae* occur at 0 – 500 mg Cl/l.

From the above findings, Van Der Torren concluded that after letting in fresh water and reducing the chloride content below 750 mg/l, malaria could be expected to disappear.

Kuipers challenged this conclusion, on the grounds that there were other factors beside chloride content that determined the *atroparvus – messeae* equilibrium. He used multiple regression equations, with y representing larval density, x_1 the chloride content and x_2 through x_5 factors that he based on Van Der Torren's records on type and composition of vegetation.

$$y = a + b1\,x_1 + b2\,x_2 + b3\,x_3 + b4\,x_4 + b5\,x_5$$

From Kuipers' calculations, it appeared that the value of the chloride regression coefficient (b1) was indeed much smaller than some of the other coefficients.

Multiple regression analysis in Kuipers' days required countless hours of calculating, which could explain why Kuipers did not take the trouble of testing the statistical reliability of his results.

Recalculation of the regression coefficients confirms that some of the other factors (vegetation factors) were more important than the chloride content. At the same time, it appears that the calculated values lack statistical significance. As an example, Figure 6.4 presents the equation and relevant statistical information based on the data collected in June 1934.

$y =$	$-7.6 +$	$0.005\,x_1 +$	$0.08\,x_2 +$	$0.12\,x_3 +$	$0.08\,x_4 +$	$0.08\,x_5$
st.dev. of coeff.	8.0	0.003	0.24	0.16	0.17	0.17

R Squared = 0.16

y = larval density
x_1 = chloride content (mg/l)
$x_{2\text{-}5}$ = vegetation factors

Fig. 6.4 Multiple regression equation which describes (changes in) larval density as a function of (changes in) chloride content and vegetation factors.

Indonesia

The investigations of Van Breemen in 1918 and 1919 had indicated the marine fishponds of Jakarta as the major breeding site of the malaria vector *An. sundaicus*. Sunier investigated the fishponds north of Jakarta in 1917-1919; Rodenwaldt & Essed studied the ponds east of the harbour at Tanjung Periuk, in 1921-22. The investigators found that the larval density of *sundaicus* was influenced by several environmental factors:

- tidal movement
- salt content of the water
- abundance of vegetation in the ponds
- rainfall

They produced numerous graphs and tables in an attempt to establish the relationships between these factors, but finally produced only qualitative – and sometimes contradictory – statements.

Kuipers produced regression equations for each set of data obtained in the earlier investigations, in order to obtain an objective and quantitative measure for the relative importance of the various environmental factors and their effects on larval density (Fig. 6.5).

From those regression equations, Kuipers concluded:

a. Because of the similarity of the two equations, the environmental factors which determine larval density of *An. sundaicus* in the fishponds of Jakarta are essentially the same as those in Tanjung Periuk;
b. Vegetation has a more pronounced effect on larval density than has salt content;
c. Rainfall has little effect on larval density.

Mosquito production

Most malaria investigators used larval density as a measure to assess the relative importance of a breeding site. These were determined by taking at random a

Jakarta	$y = 0.25 - 0.007\ x_1 + 0.68\ x_2 - 0.0007\ x_3$
T.Periuk	$y = 0.16 - 0.006\ x_1 + 0.45\ x_2 + 0.0004\ x_3$

y = observed larval density (as a fraction of maximum density)
x_1 = salt content (o/oo)
x_2 = vegetation factor
x_3 = monthly rainfall (mm)

Fig. 6.5 Regression equations for fishponds at Jakarta and Tanjung Periuk.

Larvae: $y_1 = 0.48 - 0.011\ x_1 + 0.45\ x_2 - 0.0005\ x_3$
Mosquitoes: $y_2 = 0.98 - 0.004\ x_1 + 0.57\ x_2 - 0.0026\ x_3$

y_1 = larval density (as a fraction of maximum observed density)
y_2 = mosquito production (as a fraction of maximum observed production)
x_1 = salt content (o/oo)
x_2 = vegetation factor
x_3 = monthly rainfall (mm)

Fig. 6.6 Comparison of adult and larval sampling.

fixed number of scoops from the water surface, using a hand-held pan. Ultimately, of course, it is not the larvae but rather the mosquito emerging from it that transmits malaria. Some investigators therefore preferred to use emergence traps, suspended above the water surface. Sunier had used both methods in his investigations of the Jakarta fishponds. From a series of 31 observations in which both methods had been used simultaneously, Kuipers produced the regression equations given in Figure 6.6.

On the basis of the above relations, Kuipers calculated the seasonal variations in larval density and mosquito production. From these calculations he concluded that in the middle of the West monsoon season, when rainfall is high and salt content is low, mosquito production in the marine fishponds of Jakarta would fall to zero.

None of the regression coefficients in the above equations, however, have statistical significance. By excluding regression on salt and vegetation, we can derive the following equation, which is statistically significant and describes the transformation of larvae into mosquitoes, as influenced by rainfall:

$$y = 0.62 + 0.51\,x_1 - 0.0029\,x_2$$

with y = mosquito density (as a fraction of maximum)
x_1 = larval density (ibidem)
x_2 = monthly rainfall

This equation tells us that even with maximum larval density ($x_1 = 1.0$), the Jakarta fish ponds do not produce mosquitoes when monthly rainfall exceeds 390 mm. With an average monthly rainfall in the wettest month (January) of 330 mm, this would mean that Kuipers' prediction of no mosquito production in the middle of the West monsoon is only true for wetter than average years.

Kuipers' criticism

Kuipers' criticism on the malariologists in the Netherlands-Indies can best be explained on the basis of the activity schedule for a sanitation programme (Table 6.1).

Table 6.1 Kuipers' criticism of the traditional malaria control strategy.

ACTIVITY	METHOD	CRITICISM KUIPERS
1. Health monitoring	1. Weekly collection and processing of mortality statistics	1. Detection of problem is always late
2. Local medical investigation; if malaria epidemic : drug distribution		2. Drug distribution is always a step behind epidemic
3. Malaria investigations		
3.1 Identify vector species	3.1 Detection of parasites or infected glands in anopheline mosquitoes caught in or near houses of infected persons	3.1 Vector may no longer be present at time of the investigation
3.2 Identify breeding sites	3.2 Larval finds of the confirmed vector species	3.2 Larval findings only represent situation at time of observation
3.3 Identify breeding sites	3.3 From general experience and from field observations of larval densities and various environmental factors	3.3 Because of many factors involved, interpretation of field observations is tends to be subjective
4. Planning sanitation programme		
4.1 Decide which breeding sites to include in programme	4.1 No standard procedure;based on previous experience	4.1 No objective criteria
4.2 Select sanitation measure	4.2 No standard procedure;consider breeding sites within vector's flight distance	4.2 No objective criteria
5. Implementation of sanitation		
6. Evaluation		
6.1 Short term evaluation: If SI high, repeat 3. If SI low, continue with 1.	6.1 Conduct spleen index (SI)surveys in first few years after implementation of sanitation measures	6.1 Spleen index surveys alone do not provide a test for validity of assumptions made under 4.1 and 4.2
6.2 Long term evaluation:	6.1 As indicated under 1.	6.2 Evaluation procedure does not always provide information that is needed for identification of cause of new malaria upsurge.

When conducting a species sanitation, the following questions need to be answered:

A. Which is the local vector?
B. Where does it breed?
C. What does it take to make breeding sites unsuitable for the vector?
D. Which breeding sites have to be included into the programme to achieve the maximum reduction in malaria with minimal cost?

Because of the many uncertainties involved, Swellengrebel had insisted from the very start that every species sanitation should be considered an experiment and its results carefully monitored, so that additional measures could be taken as required. Table 6.2 indicates how this recommendation was put into practice: by spleen index surveys and evaluation of mortality rates. Kuipers' main criticism on this way of monitoring was that action could only be taken after an upsurge of malaria occurred, without giving information on why it occurred and on the type of additional measures required.

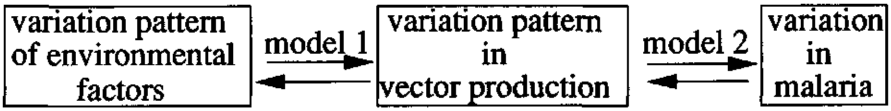


Fig. 6.7 Interrelationships between environmental factors, vector production and malaria (after Kuipers, 1937).

Improved activity schedule

The case of Brengkok taught Kuipers the importance of studying the dynamic interrelationships between environmental factors, vector production and malaria. These interrelationships are schematically presented in Figure 6.7

Kuipers' dissertation indicated a method of producing model 1. In his later work, he gave a mathematical expression which relates vector production and malaria (Kuipers 1939).

Table 6.2 presents an improved activity schedule for the preparation of a malaria sanitation program, using Kuipers' insights. In the early stage of a sanitation program, the models are largely based on general knowledge, for lack of location-specific information. Yet, the models can help identify the source of malaria, select the intervention measure, and provide a quantitative base for the design of the sanitation project.

The quantitative base also allows evaluation of each of the assumptions made in the design stage. And comparison of field data with the data predicted by the model allows adjustment and refinement of the models, thereby providing feedback and improving the quality of existing information.

In conclusion, Kuipers' ideas of 50 years ago give us some indications on how to set up a malaria sanitation project in such a way that it becomes a process of on-going improvement. Kuipers' theory was apparently nowhere put into practice but his ideas about the use of models to predict the effect of malaria control measures were later, albeit in a different way, widely followed. Twenty years after Kuiper's dissertation, Macdonald (1957) published his now famous work 'The Epidemiology and Control of Malaria', which until today forms the

Table 6.2 Improved activity schedule for planning, implementation and monitoring of a malaria sanitation programme, based on Kuipers' writings.

Step 1 Identify vector species (taxonomic and parasitological investigations)

Step 2 If only qualitative information on breeding habits of confirmed vector species available :

> On the basis of breeding habits and available data on relevant environmental factors, establish list of all locations in the area which are capable of producing a set of environmental factors suitable for breeding of the vector . Based on available data on fluctuation of environmental factors, indicate for each potential breeding site in which period of the year (or under which special circumstances) this site will be dangerous.

Step 3 Verify results of step 2 by larvae sampling in all water collections

Step 4 In major breeding sites, determine fluctuations in larvae/mosquito densities through the seasons and record relevant environmental factors.

Step 5 From the observations in step 4, produce mathematical models, which describe larvae/mosquito densities as a function of the relevant environmental factors.

Step 6 Compare mathematical models from various breeding sites;combine models for breeding sites which have similar characteristics, if statistically warranted. Identify causes for discrepancies. Desired outcome : consistent models, for each type of breeding site.

Step 7 Using records of relevant environmental factors as input, calculate seasonal fluctuation of mosquito production for the major breeding sites. Compare these theoretical mosquito production curves with malaria records. Use degree of correspondence of mosquito production curve and malaria records as a criterion to evaluate the importance of various breeding sites (in addition to field survey / larval sampling).

Step 8 Comparison of fluctuation in total vector production from the breeding sites within flight distance of the area that needs to be protected, and the fluctuation in malaria can provide an indication of the reduction in vector production that is required to bring the incidence of malaria down to an acceptable level.

Step 9 Differentiate between 1. sites which produce vector mosquitoes for a major part of the year, and 2. sites, which only produce vector mosquitoes under exceptional circumstances. Major engineering works for vector control should only be directed at sites listed under 1. For sites listed under 2. , it is better to set up an early warning system and to take action only when a combination of environmental conditions that is conducive to vector breeding occurs.

Step 10 For sites listed in step 9 under 1., identify the environmental factor that can be easily manipulated and which modification will have a major effect on vector production. The quantitative model will help to identify the relevant environmental factor and to quantify the effects of its manipulation. Also, calculate the cost of implementing the environmental measure for each major breeding site.

Step 11 Based on required reduction of vector production (step 8) and the effect of the environmental management measures on vector production in each of the major breeding sites (step 10), and taking into account the cost , determine the mix of measures and breeding sites that will achieve the required reduction in vector production at the lowest cost.

Step 12 Implement trial sanitation programme, consisting of engineering measures for vector control in breeding sites listed in step 9 under 1. and an early warning system and action plan for those listed under 2.

Step 13 Monitoring and evaluation :
1. For sites where measures have been implemented
a. Evaluation of measure : does measure effect relevant environmental factors as expected If not, adjust measure, as required.
b. Evaluation of change in vector production by larvae sampling in individual breeding sites: does change in environmental factors reduce vector production as predicted by model ? Adjust model, as required.

2. For other sites : estimate mosquito production by larvae sampling ;does early warning system predict upsurge of vector production as intended ? If not, identify causes and adjust model.

3. From 1 and 2 above, determine fluctuations in (actual)total vector production and check whether required reduction has been achieved.

4. From observations of no. of malaria cases, produce curve showing fluctuations of malaria incidence;check whether required reduction has been achieved.

5. Compare fluctuations in incidence of malaria as predicted by model (after making adjustments as explained above) with no. of actual recorded cases. Identify causes for discrepancies, and adjust model.

basis for the way malaria control is being approached worldwide. Although beyond the purpose of this review, a study on the effectiveness of Kuiper's approach along the lines of Macdonalds model would be worthwile, particularly to assess the possibility of using 'species sanitation' as the control method of choice.

Chapter 7

Malaria control in Indonesia since World War II

S. Atmosoedjono

Introduction

Trials using DDT to control malaria were implemented by Indonesian and Dutch workers in West Java shortly after the second world war. It was intended to suppress high population densities of *Anopheles aconitus* in inland rice field areas and *An. sundaicus* in coastal brackish-water localities.

The infant parasite rate (IPR) or transmission index (TI) was reduced from 22% to 0% in estates of North Sumatra while overall parasite rates (PR) were reduced from 23% to 4%. It was observed, however, that DDT had little impact on the vector species population as a whole and densities remained the same. It was believed that mosquitoes entering sprayed houses to seek a blood meal could not survive, and died shortly after exposure. With infection or reinfection prevented, malaria transmission ceased.

Encouraged by those results, in 1951 the Malaria Institute in Jakarta supported by the International Cooperation Administration (ICA) and WHO launched DDT spraying operations in various inland and coastal areas of Java, South Sumatra, Northern Central Sulawesi and Ambon (Maluku). This Malaria Control Program (MCP) covered areas with spleen rates of 50% or greater. A WHO Malaria Pilot Project was established during the same year in Cilacap, Central Java, and from 1952 onwards DDT house spraying was routinely implemented. By 1955, a five year plan was implemented aimed at protecting 30 million people living in malarious areas. At the same time observations in coastal villages near Semarang showed that the IPR did not decrease; the IPR for 1953, 1954 and 1955 was 5.8%, 0.2% and 5.4%, respectively. The discovery of DDT resistant *An. sundaicus* by Crendell in 1954 on the northern coast of Cirebon, West Java, helped to explain the sudden rise in IPR in Semarang. Chow & Soeparno (1956) observed in Semarang and Surabaya that *An. sundaicus* was 23 to 27 times more resistant to DDT than the susceptibles. To overcome the resistance problem, Dieldrin was introduced at a dosage rate of 0.5 gr/m^2 applied twice a year. The IPR dropped and *An. sundaicus* gradually disappeared from the northern coastal area from Java but still occupies the southern coast until today. Sundaraman (1958) assumed a pattern of gradual behaviouristic resistance because the species could be found in great numbers outdoors after spraying. It is suspected that differences in ecosystem between the north and south coastal areas and/or differences in vector bionomics play a role in the continued presence of *An. sundaicus* along the south coast.

Anopheles aconitus, a rice field breeder, developed resistance to dieldrin in various places in Java beginning in 1959 and doubled the resistance frequency to dieldrin and DDT in Central Java by 1962. East Java also showed the same resistance problem, but the species has been susceptible to DDT in West Java despite treatment did not differ in all three provinces. Also here the question of biological differences in *An. aconitus* of West Java and Central and East Java arose.

The studies of Van Thiel & Metselaar (1955) and Van den Assem (1959) showed that DDT was the insecticide of choice to control the *punctulatus* group in Irian Jaya. Metselaar (1957) observed that DDT could reduce parasite rates (PR) to 50% and sporozoite rates from 1.2% to 0.2%. Combined with drug administration the reduction of parasite rates was further accelerated; however, malaria transmission continued with *P. falciparum* predominant over *P. vivax* and *P. malariae*. The fast decline in natural immunity in *falciparum* patients was associated with an increase of gametocytes, a source for further transmission. *P. falciparum* infection would be the first to cease if transmission could be interrupted completely. Metselaar & Van Dijk (1958) presented data supporting Metselaars's statement that DDT and mass chloroquine drug treatment reduced but did not interrupt transmission completely and that parasite rates of *P. falciparum* were higher than that of other species. (Parasite rates of pre- and post-drug treatment: *P. falciparum* 17% – 1.8%; *P. vivax* 14% – 0.1%; and *P. malariae* 15% – 0.5%).

Malaria control programme 1952-1958, and malaria eradication programme 1959-1965

The development of insecticide resistance by various malaria vectors to DDT and dieldrin was followed by an acceleration of the Malaria Control Program (MCP) from 1952 to 1959. The protection of 17 million persons in the more readily accessible areas resulted in a marked decline of malaria.

The following data on the malaria situation and spraying operations in Cen-

Table 7.1 Malaria situation and anti-malaria spraying in Central Java 1953-1959

				Spraying Operation		
Year	Slides	Positives	SPR %	DDT (kg)	Dieldrin (kg)	Population protected
1953	7,626	1,810	23.73	5,214		21,515
1954	65,279	12,624	19.33	27,758		153,630
1955	23,994	3,700	15.42	75,272		477,068
1956	87,486	12,110	13.84	181,263	33,753	1,594,206
1957	197,280	15,009	7.60	349,232	236,927	5,062,550
1958	217,144	10,776	4.96		22,373	363,495
1959	59,842	426	0.71	start Malaria Eradication Programme		

Source: WHO/SEARO, 1987

tral Java is given in Table 7.1.

In 1959 the Indonesian Cabinet approved an agreement between the Republic of Indonesia, WHO and ICA (AID) to convert the control program to an eradication phase. The first ICA malaria eradication protocol was signed in January, 1959. It was planned to eradicate malaria from the entire country by 1970. The country was to be divided into 66 zones, each with an average population of 1.4 million, while each zone was divided into 20-40 sectors. In each zone the program was planned to go through three phases; pre-eradication, one year; attack period, three years; and surveillance, three years prior to maintenance. The National Malaria Eradication Service (NMES) was established in March 1959 and in July 1959 it was separated from the Malaria Institute and the directorship transferred to the Ministry of Health. The first spraying was done on November 12, 1959, in Kalasan, Yogyakarta by President Soekarno. This inauguration date of 12 November has been designated as the Indonesian National Health Day.

It was thought that after the first year of spraying the IPR should become zero, an indication of no transmission. Spontaneous cure among other age groups would take place when reinfection does not occur. After three years only a few cases would remain and radical cure treatment implemented for complete cure.

Spraying operations were conducted twice a year with DDT at 2 g/m^2 to cover all indoor sprayable wall surfaces. By 1963 a population of 64.6 million, representing the total population in malarious areas in 42 zones of Java, Bali and Lampung, had been protected by insecticidal coverage (Table 7.2).

Epidemiological evaluation

The impact of insecticidal spraying was evaluated epidemiologically by (a) malariometric surveys during the preparatory phase and early attack phase and (b) active and passive case detection with epidemiological investigations during the attack and consolidation phases.

The results of 1960-1962 malariometric surveys in 42 zones indicated that parasite rates of 2% or higher were found in the areas presented in Table 7.3.

Table 7.2 Coverage by DDT spraying, 1959-1963 Java, Bali and Lampung

Year	No.of zones Covered	Population Protected (Million)	DDT Used (m. ton)
1959	4	7,82	0,660
1960	12	12,37	1,903
1961	27	47,11	6,630
1962	40	61,00	8,231
1963	42	64,63	9,255

Source: Ministry of Health, Indonesia

Table 7.3 Results of malariometric surveys (1960-1962) in 42 zones.

Province	Zones with Parasite Rates >2%
South Sumatra	Lampung
West Java	Sikabumi, Cianjur, Garut, Tasikmalaya and Ciamis
Central Java	Semarang, Purworejo, Yogyakarta, Magelang, Purbalingga,Cilacap
East Java	Mojokerto, Madiun, Kediri, Malang
Nusa Tenggara Barat	Bali

Results of Epidemiological Surveillance carried out in some of the zones during 1960-62 are shown in Table 7.4.

With the exception of Serang, in West Java, the Slide Positive Rate (SPR) in most of the zones was less than 1%. The majority of the cases were classified imported and *P. falciparum* represented about 50%.

In most of 42 zones in Java-Bali and South Sumatra epidemiological surveillance involving active (ACD) and passive case detection (PCD) had begun by 1963. Results during the 1962-1968 case finding activities in Java-Bali are shown below (Table 7.5).

The Annual Blood Examination Rate (ABER) varied between 4.2% (1966), to over 9.0% (1965). To measure the impact of anti-malaria activities, the Slide Positive Rate (SPR) is considered a better parameter than the Annual Parasite Incidence (API). Because of year-to-year variation in the ABER and based upon the SPR, malaria incidence was considered lowest during 1965. The SPR steadily increased from 0.15% in 1965 to 0.53% in 1968. *P. falciparum* fluctuated from 32.4% to 49.4% in the years listed.

Table 7.4 Results of epidemiological surveillance, 1960-1962

Province/Zone (complete or partial)	Year	Blood slides examnd.	Pos. (SPR) %	Parasite species			Classification of cases			
				Pf	*Pv*	*Pm*	indigenous	relapse	imported	unclassified
Central Java **Yogyakarta**	1962	129,560	1063 (0,82)	567	484	12	52	481	316	143
NTB Bali	1962	36,598	30 (0,08)	14	14	2	0	27	3	0
Bali	1962	116,872	90 (0,08)	47	42	1	21	30	25	14
West Java **Serang**	1960	28,381	600 (2,12)	322	262	16	140	111	245	25
West Java **Serang**	1961	52,267	897 (1,72)	406	445	46	157	135	267	92
West Java **Serang**	1962	50,523	540 (1,08)	248	290	8	21	98	366	56
Jakarta	1961	80,782	180 (0,22)	116	59	5	26	21	83	43
Jakarta	1962	150,443	13 (0,01)	9	4	0	3	3	7	9
East Java	1962	66,023	34 (0,15)	19	15	0	0	1	28	5
Bonjonegoro	1962	59,778	18	4	9	5	4	4	5	5

Source: WHO/SEAR, 1987

Pf - Plasmodium falciparum; Pv - P. vivax; Pm - P. malariae

Table 7.5 Malaria profile Indonesia (Java and Bali)

Year	Population* (millions)	Bloodslides examined	ABER %	No. of positives	API %	SPR %	No. of *Pf* infections	SIR *Pf*(%)	*Pf* %
1963	59.5	3,827,073	6.43	5,846	0.10	0.15	2,862	0.07	48.96
1964	60.9	5,396,971	8.87	15,038	0.25	0.28	4,878	0.09	32.44
1965	62.3	5,726,015	9.19	8,862	0.14	0.15	3,325	0.06	37,52
1966	63.8	2,696,107	4.23	10,011	0.16	0.37	3,655	0.14	35.51
1967	65.3	3,905,974	5.98	14,601	0.22	0.27	7,216	0.18	49.42
1968	66.8	3,919,890	5.87	20,606	0.31	0.53	-	-	-
1969	68.4	4,551,866	6.66	97,553	1.43	2.14	38,630	0.85	39.60
1970	70.0	5,946,866	8.50	117,056	1.67	1.97	61,923	1.04	52.90
1971	72.0	5,655,066	7.85	72,829	1.01	1.29	38,835	0.69	53.32
1972	73.0	6,700,025	9.18	128,830	1.76	1.92	72,172	1.08	56.02
1973	78.0	7,383,731	9.47	346,233	4.44	4.69	109,797	1.49	31.71
1974	78.9	7,519,108	9.53	229,693	2.91	3.05	79,353	1.06	34.55
1975	81.8	8,209,125	10.13	125,166	1.53	1.51	44,351	0.54	35.43
1976	82.9	7,859,677	9.48	96,999	1.17	1.23	38,777	0.51	41.01
1977	84.9	8,084,880	9.52	110,553	1.30	1.37	42,981	0.53	38.88
1978	86.9	7,357,346	8.47	121,140	1.39	1.65	41,495	0.56	34,25
1979	85.6	8,020,612	9.37	78,825	0.92	0.98	37,015	0.46	46.96
1980	87.2	9,085,040	10.42	176,733	2.03	1.95	82,366	0.91	46.60
1981	88.8	9,121,890	10.27	124,637	1.40	1.37	56,324	0.62	45.19
1982	90.9	9,196,556	10.12	84,266	0.93	0.92	45,750	0.50	54.29
1983	99.6	9,197,340	9.23	133,626	1.34	1.45	64,077	0.70	47.95
1984	101.6	8,545,753	8.41	86,072	0.85	1.01	36,828	0.43	42.79
1985	103.7	8,483,868	8.18	47,673	0.46	0.56	18,300	0.22	38.39
1986	105.6	8,294,113	7.85	20,113	0.19	0.24	7,818	0.09	38.87

* Population: mid-year estimates of people living in malarious areas.
Source: WHO/SEARO, 1987

Resurgence of malaria, 1969-1973

Beginning in 1965 malaria had started a resurgence. The number of cases had increased from 8,862 in 1965 to 20,606 in 1968, with an SPR of 0.15% and 0.53%, respectively.

By the end of 1968 the NMES had been reorganized. It was integrated with the Directorate General of Communicable Diseases Control at headquarters level. This body was responsible for planning, management, funding, and provision of logistic support to the program through the malaria sub-directorate. At the provincial level it was integrated with the general health services under which the Inspector of Health was responsible for the program activities. The Regency Medical Office was responsible for administration of anti-malaria activities in the periphery. The same general organizational structure exists today. Even with this reorganization the malaria situation continued to deteriorate in Java-Bali. Malaria cases in 1973 had increased 16-fold from 20,606 in 1968 to 346,233 in 1973 (Table 7.5).

The malaria status, 1974-1985

The highest malaria incidence recorded from 1963 tot 1985 was in 1973 (Table 7.5). Malaria cases totaled 346,233 with an API of 4.4% and a SPR of 4.7%. However, the malaria situation started improving in 1974; subsequently a situa-

Table 7.6 Distribution of malaria cases, by province, 1983-1985

		1983			1984			1985	
Province	Cases	API %	ABER %	Cases	API %	ABER %	Cases	API %	ABER %
West Java	10,035	0.34	5.0	3,336	0.11	5.4	1982	0.06	5.1
Central Java	108,626	4.08	13.2	67,258	2.48	11.8	37788	1.37	11.6
East Java	13,375	0.44	10.2	14,407	0.47	10.1	7085	0.23	10.1
Bali	71	0.01	9.1	69	0.02	7.8	181	0.07	6.3
D.I. Yogyakarta	1,166	0.41	15.4	731	0.25	13.6	575	0.20	13.7
VKI Jakarta	353	0.14	0.1	287	0.11	0.1	62	0.01	0.1

Source: WHO/SEARO, 1987

tion analysis was conducted in July, 1976 and an in-depth evaluation was done in August, 1977. During the 1973-1985 period, the API declined from 4.4% to 0.4% and the SPR from 4.7% to 0.56%. However, the frequency of *P. falciparum* showed an increasing trend until 1982 (54.3%) but began a downward trend thereafter.

Malaria cases in Java-Bali

Malaria incidence was always higher in Central Java and East Java. The total cases during 1983-85 showed that 78.1% – 81.3% were from Central Java and 10.0% – 16.8% from East Java (Table 7.6).

Seventy-five of 90 sub-districts (Kecamatan[1]) in the provinces with high incidence during 1983 (API: 7.5%) were located in Central Java. By 1985 the number was brought down from 75 to 27 kecamatans.

Central Java: Table 7.6 shows the API decreased from 4.08% in 1983 to 1.37% in 1985. The ABER exceeded 11% for each of the three years. Malaria cases decreased from 108.626 in 1983 and 37,788 in 1985, a reduction of about 65%. Because *An. aconitus* was found resistant to DDT, fenitrothion replaced it and produced a direct and immediate impact in reducing transmission.

East Java: The ABER in East Java was above 10% from 1983-85, the malaria incidence and SPR increased slightly from 13,375 and 0.4% in 1983 to 14,410 cases and 0.43% in 1984, but decreased in 1985 to 7,085 cases with an SPR of 0.23%. The reduction of malaria cases was greater than 50% from 1983 to 1985. *P. falciparum* also declined from 63.6% of the total cases in 1983 to 47.8% in 1985.

West Java: Malaria cases and SPR had declined from 10,035 cases and 0.57% SPR in 1983 to 1,982 cases and 0.13% SPR in 1985. *P. falciparum* was reduced from 56.7% of the total cases in 1983 to 36.3% in 1985. Imported cases from

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[1] Kecamatan – administrative grouping of several villages.

the outer islands accounted for more than half of the cases.

Bali: During the period of 1983-1985 there was a slight reduction in the SPR from 0.15 % in 1983 to 0.11% in 1985. The SPR dropped from 0.7% to 0.03% in 1983 and 1985, respectively. *P. falciparum* was found to represent 32.6% of the total in 1985 and imported cases were 49.2%.

DKI Jakarta: PCD that was conducted in hospitals and health centers over this period. More than 80% of the total cases were imported and none was of local origin.

MCP status, 1985-1988

For the fourth Five Year Development Plan (REPELITA) 1984-1989 the MCP aimed to reduce the high malaria incidence subdistricts from 63 to 37 in HCI areas (API > 7.0%) to less than 1 per thousand population in Java-Bali. In the outer islands (Kalimantan, Sulawesi, Lesser Sundas, Maluku and Irian Jaya) the aim was to reduce malaria prevalence to less than 5% in the priority areas and to less than 15-20% in the remaining sites.

The implementation of malaria control activities in Java-Bali provinces have been different than those in the other islands in Indonesia. In Java-Bali priority was given to all the provinces, while in the outer islands the emphasis was given to transmigration projects, other socio-economic development areas and areas bordering with neighboring countries.

In Java-Bali, malaria control activities consisted of ACD and PCD, laboratory examination/confirmation, drug treatment, indoor residual house spraying, larviciding, biological control and limited environmental management.

For the outer islands, activities consisted of indoor spraying operations and malariometric surveys in the priority areas and treatment of clinical malaria cases in health centers.

A slight reduction of cases and API in 1986 from 20,127 and 0.19% to 19,309 and 0.18% in 1987 was followed by an increase in 1988 of 32,471 cases and 0.32%, respectively (Table 7.7). When the ABER approached 10% a more accurate malaria assessment could be obtained (Table 7.8).

The projected number of cases for 1987 and 1988 were 29,706 and 50,735, respectively, an increase of almost 71%. The SPR for 1987 was 0.27 and 1988 0.49. The increase of 13,162 cases was alarming. The main cause of increase of malaria cases in Java-Bali was attributed to a drastic reduction in DDT-

Table 7.7 Malaria status in Java-Bali, 1985-1988

YEAR	ABER	CASES	API/%	SPR/%	P.F.%
1985	8.18	47,673	0.46	0.56	38.39
1986	7.83	20,127	0.19	0.24	38.84
1987	6.50	19,309	0.18	0.27	42.30
1988	6.40	32,471	0.32	0.49	45.90

Table 7.8 Malaria in Java-Bali, when Annual Blood Examination Rate approaches 10%.

Year	ABER	Cases	ABER at 10% no. of cases
1985	8.18	47,673	58,279
1986	7.83	20,127	25,704
1987	6.50	19,309	29,706
1988	6.40	32,471	50,735

Source: Ministry of Health, Indonesia

Table 7.9 Malaria situation in Central Java, 1987-1988

Province	No. of cases 1987	No. of cases 1988	Percentage of case rise
West Java	2,159	4,972	130.3
Central Java	11,242	18,110	61.1
East Java	4,438	7,013	58.0
Bali	512	1,338	161.1
Yogyakarta	880	1,038	17.9
TOTAL	19,309	32,471	68.2

Source: Ministry of Health, Indonesia

indoor spraying from 421,000 houses in 1986/87 to 150,000 in 1987/88. The *P. falciparum* rate also increased from 42.3% in 1987 to 45.9% in 1988. The malaria situation in Central Java has always produced the greatest number of the cases; between 55% and 65% of the total cases in Java-Bali. A breakdown is given in Table 7.9.

The highest percentage rise in cases in Bali was 161.3% and in West Java 130.3%. Complete absence of indoor house spraying during 1987/88 caused the increase in both provinces. However, neither of the two provinces had an API of more than 0.6%. In 1988, the API in West Java and Bali were only 0.15% and 0.47%, respectively (Table 7.10). The overall *P. falciparum* rate increased

Table 7.10 Malaria situation in Java-Bali, 1986-1988

Province	1986 ABER	1986 CASES	1986 API	1986 *Pf.%*	1987 ABER	1987 CASES	1987 API	1987 *Pf.%*	1988 ABER	1988 CASES	1988 API	1988 *Pf.%*
West Java	4.7	1,964	0.06	34.47	4.5	2,159	0.07	34,65	3.8	4,972	0.15	42.1
Central Java	10.6	13,065	0.48	38.89	9.7	11,242	0.41	46.65	9.3	18,110	0.62	53.9
East Java	10.3	4,098	0.13	43.56	8.1	4,438	0.13	38.50	4.0	7,013	0.21	30.8
Bali	6.6	257	0.09	24.68	4.6	512	0.18	27.27	4.9	1,338	8.47	28.5
Yogyakarta	12.9	705	0.25	40.85	7.8	78	0.30	36.5	5.2	1,038	0.34	46.1
DKI Jakarta	0.1	37	-	35.13	0.1	0	0.01	44.8	-	-	-	-

Source: Ministry of Health, Indonesia

Table 7.11 Number of high case incidence kecamatans, 1983-1987

Province	1983	1984	1985	1986	1987
West Java	7	-	-	-	-
Central Java	75	36	27	9	9
East Java	8	8	8	-	-
Bali	-	-	-	1	1
Yogyakarta	-	-	-	-	-
DKI Jakarta	-	-	-	-	-
Total	90	44	35	10	10

from 31.2% in 1987 to 45.9% in 1988. *P. falciparum* rates in Yogyakarta showed the lowest, between 24-28%, whereas other provinces were between 30-53%, with Central Java being the highest in 1988 (53.9%).

High case incidence kecamatans in Java-Bali

One of the objectives of MCP during the fourth PELITA (1984/85-1988/89) was the drastic reduction of the number of HCI kecamatans (API more than 7.5%).

The number of HCI kecamatans decreased from 1983 to 1985, being 90, 44 and 38, respectively and to 10 in 1986 and 1987 (Table 7.11).

The following findings are a result of an epidemiological analysis of the HCI.

1. All HCI kecamatans were in inland *An. aconitus* areas.
2. In such kecamatans the foci of high malaria incidence were always in hilly slopes with perennial water flow and rice fields.
3. Perennial water flow from springs was responsible for providing clean and slow moving water in the rice fields throughout the year, which was suitable for *An. aconitus* breeding.
4. Farmers utilize the availability of water throughout the year to plant rice.
5. The above factors support *An. aconitus* breeding for a longer period and over a wider area thus creating areas highly favourable for malaria transmission.

Malaria situation in the outer islands

The overall malaria situation in the outer islands was not well known because of the very limited malaria control measures attempted in the priority areas of transmigration projects and socio-economic development areas. Most information is based upon parasite rates by malariometric surveys in the priority areas and clinical malaria cases by percentage and slide positivity rates from health center data.

Malariometric Surveys (MS): In the past MS have been conducted in priority

Table 7.12 Malariometric surveys in the outer islands, 1969 – 1988

	Year	Blood Slides examined	Numbers positive (%)	Parasite rate (%)
Pelita I	1969	25,503	3,950	15.5
	1970	67,983	8,265	12.2
	1971	82,709	12,546	15.2
	1972	159,596	15,033	9.4
	1973	120,930	11,270	9.3
Pelita II	1974	159,182	14,907	9.9
	1975	148,058	10,946	7.4
	1976	100,914	6,808	6.7
	1977	65,655	3,585	5.5
	1978	193,004	8,353	4.3
Pelita III	1979	155,892	6,558	4.2
	1980	466,355	19,283	4.1
	1981	559,657	20,303	3.6
	1982	594,926	30,689	5.2
	1983	450,619	13,310	2.9
Pelita IV	1984	698,316	31,618	4.8
	1985	405,374	17,697	4.3
	1986	259,518	11,162	3.7
	1987	266,120	15,193	5.7
	1988	105,372	7,245	6.8

Source: Ministry of Health, Indonesia

areas in order to determine the impact of DDT spraying operations and in non-operational areas to determine the base-line endemicity. Therefore, the data poorly represent the entire malaria situation in these provinces (Table 7.12). Of the 21 provinces, 14 had priority areas with parasite rates in excess of 2%. Provinces with high malaria rates have been: North Sulawesi, Central Sulawesi, Nusa Tenggara Timur, Maluku, Irian Jaya and East Timor. The overall *P. falciparum* percentage was between 35-55% between 1986 and 1988.

Clinical Malaria Cases: During 1986-88 there were 8 provinces which had a malaria prevalence of greater than 10% of the total outdoor populations. Higher clinical malaria prevalence was present in the eastern-most group of provinces. The data are presented in Table 7.13.

Passive Case Detection: There were 14 provinces which reported an SPR more than 20% between 1986 and 1988.

Table 7.14 shows a number of the tests conducted against four drugs with the highest failure percentage to S-P (Fansidar) 91.7%. The one case to be resistant to S-P was found in Dili, East Timor during 1988.

P. falciparum Resistant to Chloroquine: In 1988, of the 27 provinces only Yogyakarta has not yet reported any resistant cases. Provinces with well established and wide-spread *P. falciparum* resistance to chloroquine were Irian Jaya, Central Java, East Kalimantan, West Java, East Timor and Lampung, Sumatra. Problem foci were present in 105 kecamatans, in 62 kabupatens[2] in 26 provinces (Table 7.15).

P. falciparum Resistant to Mefloquine: Tests have been conducted since 1983 against mefloquine. During 1983-88, 475 cases of *P. falciparum* in 35 kecamatans were tested against mefloquine; two cases have so far been found to be resistant one in Kupang, NTT in March 1986 and one in Irian Jaya in February 1987.

P. falciparum Resistant to Quinine: 45 in vitro tests conducted during 1987 and 1988 in South Sulawesi, Riau, West Java and Timor Timur did not reveal any case of *P. falciparum* resistance to quinine.

P. falciparum Resistant to Amodiaquine: All but one of eighteen cases of *P. falciparum* so far tested against amodiaquine were found resistant.

Table 7.13 Clinical malaria cases and slide positivity rates (SPR), 1969 – 1988 (21 Provinces)

Year	Clinical Malaria	Blood slides examined	Positive	SPR %
1969	441,152	17,541	6,971	39.7
1970	704,850	13,936	5,030	36.1
1971	516,052	114,055	50,377	44.2
1972	566,906	261,654	94,013	35.5
1973	650,007	335,248	136,774	40.8
1974	740,177	240,498	90,478	37.6
1975	774,602	318,641	78,234	24.5
1976	747,555	358,093	73,486	20.5
1977	635,676	217,858	52,805	24.2
1978	579,756	236,203	51,962	22.0
1979	1,075,658	358,427	87,105	24.3
1980	1,241,403	488,616	130,279	26.7
1981	756,771	353,788	90,730	25.6
1982	1,214,496	410,946	104,814	25.5
1983	831,824	421,631	84,268	19.9
1984	1,395,389	456,290	105,416	23.1
1985	1,036,528	228,088	44,057	19.3
1986	1,009,841	179,719	36,368	20.2
1987	1,418,101	421,695	108,337	28.0
1988	1,158,514	262,095	77,095	29.4

Source: Ministry of Health, Indonesia

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[2] Kabupaten – administrative grouping of several kecamatans.

Table 7.14 Status of *P. falciparum* sensitivity/resistance to drugs. Tests Conducted in 1988

Test	No. Tested	Resistant	Sensitive	Failure	R %	F %
Chloroquine (in vitro)	48	21	6	21	77.7	43.7
Chloroquine (in vitro)	28	12	15	1	44.4	3.6
Mefloquine (in vitro)	42	0	20	22	0	52.4
Quinine (in vitro)	36	0	18	18	0	50
Amodiaquine (in vitro)	9	7	1	1	87.5	11.1
S-P (in vitro)	36	1	2	33	33.3	91.7

Source: Ministry of Health, Indonesia

Table 7.15 *P. falciparum* resistance to chloroquine by 1988.

	number of Provinces	number of Kabupatens	number of Kecamatans
Sumatra	8	16	23
DKI Jakarta	1	1	1
Java	3	12	28
Bali	1	1	1
Kalimantan	4	7	11
Sulawesi	4	10	13
Nusa Tenggara Barat	1	1	5
Nusa Tenggara Timur	1	2	6
East Timor	1	4	6
Maluku	1	1	2
Irian Jaya	1	7	13
TOTAL	26	62	105

Drug treatment in Indonesia

Presumptive Treatment

600 mg chloroquine – (adult dose) – to fever cases from ACD and PCD in Java-Bali.

In chloroquine resistant areas: in addition 45 mg primaquine – (adult dose)

Radical Treatment

P. vivax:	chloroquine 1,500 mg over 3 days and primaquine 75 mg in 5 days (adult dose).	
P. falciparum:	sensitive areas:	chloroquine 1500 mg – 3 days primaquine 45 mg – 3 days
	resistant areas: (kecamatan)	fansidar, 3 tablets, single dose primaquine, 3 tablets

In the outer islands, the majority of clinically diagnosed malaria cases were given 10 tablets of chloroquine to be taken in 3 days.

Prophylactic treatment consisted of 2 tablets chloroquine (adult) weekly in sensitive areas. Fansidar is no longer recommended for prophylaxis in resistant areas.

Vector control

Java-Bali: In Java-Bali and outer islands indoor residual house spraying (RHS) with DDT was the main strategy of vector control. In Java-Bali, larviciding, biological control and source reduction were applied in limited areas. Only 2% of the total houses in 1985/86 were under spraying coverage (Table 7.16). This decreased to about 1% in 1986/87 and 0.25% in 1987/88. The total number of DDT sprayed houses decreased from 649,650 to 239,848 to only 4,994 houses in 1985/86, 1986/87 and 1987/88, respectively. The number of houses sprayed with fenitrothion also decreased from 273,864, 184,507 and 130,248 during the same periods.

Residual Spraying in the Outer Islands: Until 1986/87 only 6% of the total houses in the outer islands were under insecticidal coverage. In 1987/88 the coverage was reduced to under 0.6% because of the drastic cut in the MCP budget that same year.

Larviciding Operation: In West Java, East Java, and Bali, larviciding operations were conducted in *An. sundaicus* areas. Fenthion at a dose of 1 cc/50 m^2 was applied on a weekly basis during April-October. Every year the coverage protected an estimated 0.7 million population. A total of 70 hectares of breeding sites were treated.

Biological Control: Breeding areas of *An. aconitus* in inland areas with high a case incidence were treated with larvivorous fish. During 1985/86 only four kabupatens in West, Central and East Java were included; this increased to 25 kabupatens in 12 provinces.

Table 7.16 Insecticide Spraying Coverage in Java-Bali, 1985-1988

Particulars	1985/86	1986/87	1987/88
Total houses (estimated)	21,176,600	21,592,000	22,028,000
Target for spraying (2 cycles)	1,011,500	561,000	105,000
Percentage targetted	2.3%	1.3%	0.24%

Environmental Management: Drainage pipes were constructed in suitable locations in order to reduce *An. sundaicus* breeding sites in West Java, East Java, Bali, Nusa Tenggara Barat, Nusa Tenggara Timur and East Timor in 12, 14, and 1 location for the years 1985/86, 1986/87 and 1987/88, respectively.

External support to the malaria control programme

The MCP continues to receive assistance from WHO, World Bank and USAID.

WHO: WHO supports the MCP with a long-term technical staff (malariologist-epidemiologist) which continues to assist and collaborate with the national authorities concerned in planning, implementation, field supervision, periodical evaluation, staff training and field research throughout the year 1988.

World Bank: World Bank assistance in South Sulawesi, Central Sulawesi and South-East Sulawesi under the Provincial Health Development Project during 1982-87 showed that the population protected was 89.2% and the reduction of malaria incidence was satisfactory from 140/1000 population in 1982 to 48.6/1000 population in 1987 (Dr. P.G. Kesavalu).

USAID: The USAID assisted MCP in 13 kabupatens of East Timor and 4 kabupatens in Nusa Tenggara Timur was terminated in December 1987. Field trials in NTT commenced in 1988 with the following objectives in order to reduce malaria prevalence:

1. Implementation of surveillance and chemotherapy through integrated service pool (POSYANDU);
2. To control malaria through the use of impregnated bed-nets;
3. To develop training materials on malaria and malaria control activities, i.e. posters, flip charts, laminated cards, slides and brochures.

Chapter 8

Discussion: relevance of the Indonesian experience for modern-day malaria control

W. Takken, W.B. Snellen and J.P. Verhave

From the above presented data (Chapter 5) it is evident that in many areas of Indonesia species sanitation directed against the most important vectors was successfully applied as a malaria control measure. This result was to a large extent due to Swellengrebel's realisation that vector control without proper knowledge of the bionomics of the vector might fail to achieve the desired objectives. His training as a zoologist allowed him to develop ecological methods of malaria control, away from the then widely practiced chemotherapy. This was quite unique within the primarily medically oriented Health Service of the Netherlands East Indies of the time. Many of the malaria control programmes reviewed in the previous chapters applied the principles Swellengrebel had laid down during his early pioneering research in Indonesia. The results demonstrate that species sanitation was a viable method of malaria control, provided it was applied according to the principles Swellengrebel had described. Nevertheless, by 1938 there was a serious discussion amongst malaria control workers in Indonesia on the reason why several of the previously successful vector control measures had failed to bring down the malaria incidence in Jakarta. Our study of the reports and publications of those days has taught us that the effect of the malaria control measures was nearly always judged on clinical evidence only (reduction of spleen index and parasite rate, Table 5.1), whereas apparently few scientists considered reduced herd-immunity as dangerous or bothered to continue studying the mosquito populations. Kuipers had stressed the importance of continuous ecological studies on the malaria vectors but it is unclear why his theory, based on empirical evidence, was not applied. It was therefore sometimes not known whether the results of vector control measures had indeed reduced or eliminated the target *Anopheles* species or perhaps the target species was replaced by another vector species because the environmental measures taken against one species created breeding sites favourable for other vector species. For instance the removal of vegetation for the control of *An. umbrosus* in Malaysia created favourable sunlit breeding sites for other anophelines (Bruce-Chwatt, 1985). It is unfortunate that this was not realised by the malaria control service, and perhaps even led to the discouragement of further use of this otherwise elegant way of malaria control.

Of the 46 projects listed in this review where species sanitation was applied, 26 concerned the control of *An. sundaicus* and 9 that of *An. aconitus*. This shows that these two species were considered the most important malaria vectors throughout the archipelago. The emphasis on these species may also have been caused by the fact that species sanitation could be readily applied on them and they occurred in areas where important agricultural and economic activities were taking place (large-scale rice production, fish production, construction of railways and harbours), whereas in areas that received less attention, malaria may have been equally serious, with vectors other than *sundaicus* and *aconitus*. In a recent publication (Kirnowardoyo, 1988) both *An. sundaicus* and *An. aconitus* are still considered important vectors in Indonesia and the emphasis on the control of these two species in the past and today seems therefore justified.

At least 19 of the 24 *Anopheles* species discussed in this review have been proven to be malaria vectors (Chapter 3C). Although we did not find a reference confirming the role of the remaining five species (*An. aitkenii, An. beazai, An. letifer, An. roperi* and *An. koliensis*), their role as vectors must be suspected and should be studied. For instance, in Papua New Guinea *An. koliensis* is an important malaria vector (G.B. White, personal communication) and therefore will most likely be a vector in the adjacent area of Irian Jaya. Kirnowardoyo (1988) states that 18 of the 80 *Anopheles* species found in Indonesia are vectors of malaria. Unfortunately, he does not refer to any of the malaria studies mentioned in this review and since his publication does not contain a species list, it is difficult to compare his statement with our findings. In 1975, the Centre for Disease Control Subdirectorate of Entomology initiated ecological studies on vectors of malaria and other vector-borne diseases throughout Indonesia. The results of these studies will provide valuable information, with which the role as malaria vectors of the 24 species mentioned in this review can be reassessed.

Another difficulty in assessing the importance of some *Anopheles* species as malaria vectors is the expanding knowledge on species-complexes (Service, 1988). This has led to a number of species being divided into groups of closely related siblings of two or more species, each with a different ecology. Of the salt and fresh water forms of *An. subpictus* sensu lato, apparently only the former is a vector (G.B. White, personal communication). This would explain why in some areas the species was considered a vector and in other areas not. The same may hold for other species, of which different breeding habits have been reported (e.g. *An. sundaicus*). It is likely that further studies will reveal the nature of these sibling complexes, adding even more species to the already long list of southeast Asian *Anopheles* species. At the time this paper went to press, we learnt that the *An. balabacensis* complex is now named the *An. leucosphyrus* complex, comprising *An. balabacensis, An. introlatus, An. leucosphyrus* A. and *An. leucosphyrus* B (Peyton, 1989). It was too late to include these changes in Chapter 3, but such changes reflect the continuous developments in the field of insect taxonomy. Obviously, a proper distinction between species, also within species complexes, is essential not only for the study of malaria epidemiology but also for the planning of malaria control strategies.

The data in Chapter 7 show that malaria is still a highly prominent disease in much of Indonesia today. For instance, on Java-Bali the malaria incidence rate in 1986 was almost similar to that of 1963. With an almost doubling of the population, a higher number of people is therefore suffering from the disease than some 30 years ago. The Malaria Control Programme is to be commended for an excellent surveillance system, which allows the monitoring of malaria epidemiology in much of the country on a year to year basis. Several problems are mentioned that prevent an adequate control of the disease. The increasing levels of drug resistance and insecticide resistance are the most important factors responsible for this, but we would like to add two more factors. Firstly, the 'malaria eradication era' (1955-1969) was directed against the malaria vectors, without paying attention to the ecology of the vectors. This has led to a nationwide shortage of vector ecologists capable of addressing the problem within an ecological context. Secondly, the general impression that malaria is a primarily rural disease has in many countries diverted attention to diseases which are more common in the urban areas, since these tended to receive more attention because of a rapid increase in urban populations and the improved standards of living there. Only in recent years rural development, including health care, has begun to receive more attention from central governments and donor agencies. Since then, there has also been a growing awareness that malaria is increasing worldwide and that without effective control measures this situation will deteriorate even more (WHO, 1990).

One of the conclusions of this review is the apparent discrepancy between the malaria control measures in Indonesia during the days of the Netherlands-Indies and those in use today. Most of the vector control measures that had proven to be effective in the Netherlands-Indies such as species sanitation were no longer in use by the early fifties, and emphasis of control had largely shifted from environmental measures to insecticide spraying, so much so, that the past control measures were only sporadically being considered as alternative control measures. We have not been able to discover when and why the malaria control service in Indonesia decided to abandon the environmental measures in use during the colonial days. It suffices to observe that occasionally in central Java *An. sundaicus* is still being controlled by management of fishponds (Kirnowardoyo, 1988).

It is generally agreed that effective malaria control can only be achieved through a multidisciplinary approach including drug-therapy, vaccination and vector control. The rapidly increasing drug-resistance makes the future use of this method uncertain unless drugs are developed that belong to a totally different chemical group than those presently in use. The recent discovery of an anti-malaria drug derived from *Artemisia* may be such a development (WHO, 1990). The development of malaria vaccines looks hopeful but the availability of such vaccines should not be expected in the near future (Marshall & Cherfas, 1990). Vector control is the most effective method for the prevention of malaria transmission and whenever possible this should be the general strategy of control programmes in combination with surveillance and chemotherapy. Whereas classical insecticidal spraying may still play an important role in malaria control, emphasis must be placed on integrated control with other than insecticidal measures because of the anticipated development of insecticide resistance which will nearly always occur under the classical larviciding and house-spraying techniques. Among the alternative measures presently under consideration are the use of insecticide impregnated bednets (this method is far less likely to lead to insecticide resistance than house spraying or larviciding), biological control with larvivorous fish and mosquito pathogens, and environmental measures. The latter are the subject of this review, from which it is apparent that most of the historical mosquito control measures based on environmental management are still applicable today. Where malaria control measures are required, detailed ecological information such as mentioned in Tables 3.7 and 3.8 should be collected for the vector species concerned. It can then be decided whether environmental measures can be considered. Table 3.9 shows that a large number of anophelines found in Indonesia qualify for this method of control and that often a combination of methods should be considered. However, it should also be mentioned that data collected 50 or more years ago should be assessed on their validity today. Environmental changes caused by the rapid increase in the human population may have affected the habitat as well as the behaviour of malaria vectors. The data from this review will facilitate the research required for such studies.

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