

Entomology of the filariasis control programme in Samoa,
Aedes polynesiensis and *Ae. samoanus*

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Abstract: The main strategy for elimination of filariasis is transmission interruption through mass drug administration (MDA) however, it is important to argue that knowledge of vector species distribution and biting density is important for the impact of an intervention. In this paper, first the epidemiology of lymphatic filariasis in Samoa is examined, followed by a description of the bionomics and transmission potential of the vector mosquitoes, *Aedes polynesiensis* and *Aedes samoanus*. Then the role of entomology in a MDA based filariasis elimination programme is examined.

INTRODUCTION

Lymphatic filariasis, a parasitic disease caused by *Wuchereria bancrofti* or *Brugia malayi*, (also known as elephantiasis) was eradicated from Japan in the 1970s by extraordinary hard work and enthusiastic efforts of scientists, politicians and communities (Sasa, 1976). However, globally more than 1 billion people in more than 100 countries are still at risk of contracting lymphatic filariasis; and there are over 120 million people already affected by the disease including over 40 million who are seriously incapacitated and disfigured by the disease. One-third of the people infected with the disease live in India, one third are in Africa and most of the remainder are in South Asia, the Pacific and the Americas (WHO, 1997).

In late 1870s, Sir Patrick Manson and other researchers determined the natural history of this disease including identifying the pathogen, microfilarial periodicity and transmission by mosquitoes (Rajan, 1999). Since that time, people in the differ-

ent parts of the world have tried to control this disease. Despite efforts for more than a century, the prevalence of infection continued to increase, mostly in tropical and subtropical countries where lymphatic filariasis is well-established.

Recent dramatic advances in techniques for diagnosis, surveillance, control and treatment, led an independent International Task Force for Diseases Eradication to identify lymphatic filariasis as one of only six infectious diseases considered to be "eradicable" or "potential eradicable".

Then in 1997, the World Health Assembly, adopted Resolution WHA50, 29 calling for the elimination of lymphatic filariasis as a global public health problem (WHO, 1997).

In March 1999, at back to back meetings of the SPC (Secretary of the Pacific Community) and WHO in Palau, Micronesia, the Ministers and Directors of Health endorsed the development and implementation of a comprehensive strategy to eliminate lymphatic filariasis in all 22 Pacific Islands Countries and Territories under the guidance of the global filariasis elimi-

nation programme (WHO and SPC, 1999; Ichimori, 2000).

Responding to this commitment, the Pacific Programme to Eliminate Lymphatic Filariasis (PacELF) was formed. It involves a package of approaches including blood surveys by rapid diagnosis antigen test, (ICT test card) MDA (Mass Drug Administration) with a combination drug regimen of albendazole and DEC (Diethylcarbamazine citrate), vector control, morbidity control and awareness campaigns (Ottesen et al., 1999; Phantana et al., 1999). This strategy was facilitated by the decision of SmithKline Beecham to donate all albendazole free-of-charge for as long as necessary to ensure the success of the elimination programme.

The first country to implement this new elimination campaign was Samoa in 1999; where there had been a long series of control activities with a unique operational strategy involving community-based approaches. Substantial operational research on both the parasitology and the entomology of filariasis had been carried out to provide a scientific basis for this control programme.

As the main strategy for elimination of the disease is transmission interruption through MDA of DEC and albendazole, some might argue that knowledge of vectors and vector control have little role in this program. In this manuscript, I will argue that, knowledge of vector species distribution and biting density is important for predicting the impact of an intervention. Furthermore, this paper will examine the role of entomology tools in the elimination programme, such as (I) PCR technology to detect vector infection as a monitoring tool and (II) the importance of vector control on the elimination programme.

In this case study, first the epidemiology of lymphatic filariasis in Samoa will be examined, followed by a description of the bionomics and transmission potential of the vector mosquitoes, *Aedes polynesiensis* and *Ae. samoanus*. Then I will examine

the role of entomology in an MDA filariasis elimination program.

Filariasis epidemiology and control in Samoa

There are two characteristic features of the epidemiology of filariasis in the Pacific area. I) The absence of *B. malayi* and, II) the occurrence of two distinct races of *W. bancrofti*, which differ in microfilarial periodicity: a nocturnally periodic race and a non periodic (or diurnally subperiodic) race.

According to the difference of microfilarial periodicity and in the local mosquito vectors, Sasa (1976) divided the Pacific into four ecological filariasis zone; Mcironesian, Melanesian, New Caledonian and Polynesian zones. Ramalingam (1968) demonstrated the diurnary sub-periodic microfilarial prevalence from American Samoa in Polynesian zone (Fig. 1).

Samoa is located in the Polynesia zone. This tropical country consists of two main islands (Upolu and Samoa) and has total population of 161,298 by the National census in 1991 (Samoa Department of Health, 1998). Diurnally subperiodic *W. bancrofti* is transmitted by *Ae. (Stegomyia)*

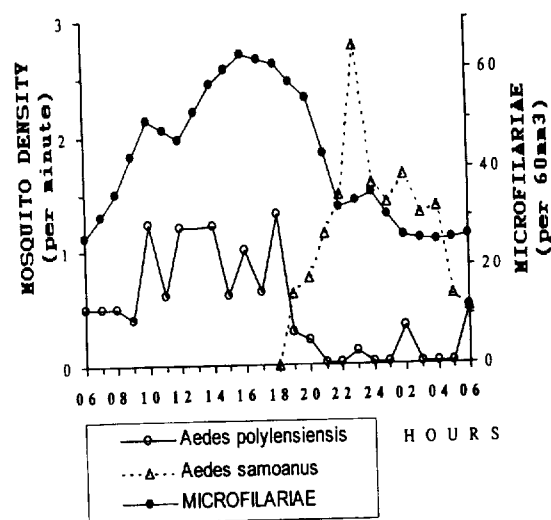


Fig. 1. The biting activity of *Ae. polynesiensis* and *Ae. samoanus*, and the microfilaria periodicity (by Ramalingam 1968).

Table 1. Microfilarial prevalence, mosquito infection and MDA in 1963-1987.

| Year | MDA*** | Blood survey* | | | | | | Mosquito infection* + | | | | |
|------|--------|---------------|--------------|--------------|------|-------|------|-----------------------|---------------|------------------|---------------------|------------------|
| | | Method* | No. Villages | No. examined | mf % | MfD** | Ag % | No. dissected | No. positives | Infection rate % | No. mos+ III larvae | Infective rate % |
| 1963 | | | | | | | | 407 | 34 | 8.35 | 12 | 2.95 |
| 1964 | | FP20 | | 2,077 | 21.1 | 19 | | | | | | |
| 1965 | | FP20 | 21 | 10,129 | 19.1 | 24 | | | | | | |
| 1966 | I | | | | | | | 2,381 | 17 | 0.71 | 1 | 0.04 |
| 1967 | | FP20 | | 42,697 | 1.63 | 2.7 | | | | | | |
| 1968 | | FP60 | | 5,371 | 1.32 | 4.8 | | 466 | 3 | 0.64 | 0 | 0 |
| 1969 | | FP60 | | 7,393 | 1.74 | 7.6 | | 865 | 4 | 0.46 | 0 | 0 |
| 1970 | | | | | | | | 578 | 2 | 0.35 | 2 | 0.35 |
| 1971 | II | | | | | | | | | | | |
| 1972 | | FP60 | | 6,361 | 0.24 | | | | | | | |
| 1973 | | FP60 | | 5,145 | 0.14 | | | | | | | |
| 1974 | | FP60 | | 30,272 | 0.33 | | | | | | | |
| 1975 | | FP60 | | 11,499 | 2.12 | | | | | | | |
| 1976 | | FP60 | | 3,649 | 1.43 | | | | | | | |
| 1977 | | | | | | | | | | | | |
| 1978 | | | | | | | | 6,702 | 56 | 0.84 | 18 | 0.27 |
| 1979 | | FP60 | 28 | 8,385 | 3.83 | 18.6 | | | | | | |
| 1980 | | | | | | | | | | | | |
| 1981 | | | | | | | | 1,758 | 17 | 0.97 | 5 | 0.28 |
| 1982 | III | FP60 | 27 | 10,361 | 5.25 | 20.2 | | 2,332 | 16 | 0.68 | 2 | 0.08 |
| 1983 | IV | | 27 | 9,627 | 4.17 | 9.4 | | | | | | |
| 1984 | | | 34 | 11,146 | 2.76 | 9.8 | | 5,206 | 3 | 0.06 | 1 | 0.02 |
| 1985 | | | | | | | | | | | | |
| 1986 | V | | | | | | | | | | | |
| 1987 | | FP60 | 26 | 13,708 | 2.33 | 9.2 | | | | | | |

* Finger prick blood smear with 20 mm³ or 60 mm³ blood

** The median microfilarial density

*** MDA I & II; DEC multiple doses (12-18 doses) treatment data from Sasa (1976)

MDA III, IV & V; DEC (6 mg/kg) single dose treatment data from Kimura et al. (1992)

† Data from Kimura et al. (1985b)

†† Data in 1963-1970 from Suzuki & Sone (1975), in 1978 from Samarawickrema et al. (1987) and in 1981-1987 from Kimura et al. (1992)

polynesiensis (Marks) and *Ae. (Finlaya) samoanua* (Grünberg) (Backhouse, 1963).

Filariasis in Samoa was known before the 1st World War as "Fe'e fe'e" (elephantiasis) or "Mumu". Sasa (1976) in his monograph on filariasis indicated that O'Connor in 1923 reported a microfilaria rate of 28.7% from American and Western Samoa. While Buxton (1928) demonstrated microfilaria rates of 23.7% and 41% for Upolu and Savaii, respectively.

Control activities against filariasis began in 1964. The microfilarial prevalence rate was 19.1% and median microfilarial

density was 24 in 1965 before the first MDA, which consisted of 18 doses (5 mg/kg) of Diethylcarbamazine citrate (DEC) (Table 1).

A new regimen for MDA using 12 doses (6 mg/kg) of DEC was conducted in 1971. This reduced the microfilaria rate further, to 0.14% by 1973. An MDA programme using DEC, with an annual single-dose drug regimen, commenced in 1982 and continued in 1983, and 1986. This regimen succeeded in reducing the mf prevalence from 5.25% in 1982 to 2.3% in 1987 (Kimura et al., 1992).

Another single-dose DEC mass treatment campaign was conducted, covering more than 80% of the Samoan population in 1993, 1994 and 1995. Subsequently, mass drug administration with a combination drug regimen, DEC (6 mg/kg) and ivermectin (200 µg/kg) was conducted in 1996 and in 1997. To monitor the intervention, blood surveys of 5,000 to 10,000 people from 20 to 30 villages were conducted each year before mass treatment campaigns. The finger prick method with 60 mm³ blood was used. In 1997, the rapid diagnosis filarial antigen tests (ICT filarial antigen Card Test) were also used as well as blood smears.

The overall mf prevalence rate on blood examination was 4.3% in 1993 and 1.1% in 1998 while the geometric mean microfilarial density (MfD) for the whole of Samoa was 11.8 in 1993 and 5.5 in 1998. Infectivity index (the estimated mosquito infection rate if everyone is equally exposed to mosquito bites) was 1.42 in 1993 and 0.22 in 1998 (Samoa Department of Health, 1998).

The latest phase of filariasis control project was inaugurated in 1999 with a new combination drug regimen of albendazole (400 mg/person) and DEC (6 mg/kg). The goal of this project is to stop the spread of infection, leading to elimination of filariasis from Samoa by 2005. The planned activities included mass treatment, blood surveys, mosquito control, health promotion, data analysis and training.

Mosquito fauna and vectors

Belkin (1962), in his comprehensive text on mosquitoes of the Pacific, listed 11 species of mosquitoes found or recorded in Samoa. These species were all classified to *Aedes* or *Culex* genus. Among these species, *Cx. quinquefasciatus* and *Ae. aegypti* were of European introductions, with the remainder probably all indigenous.

In 1976, Ramalingam collected 10 species of mosquitoes from Samoa. One species called *Cx. samoensis* recorded by

Belkin was not found in his study. Lately, WHO (1982) summarized 11 species of mosquitoes in Samoa. They are *Ae. aegypti*, *Ae. upolensis*, *Ae. polynesiensis*, *Ae. oceanicus*, *Ae. samoanus*, *Ae. tutuilae*, *Ae. nocturnes*, *Cx. quinquefasciatus*, *Cx. annulirostris*, *Cx. sitiens* and *Toxorhynchites amboinensis*.

Detailed studies on the mosquito fauna and the transmission of filariasis in Samoa were reported by Belkin (1962), Ramalingam and Belkin (1965) and Ramalingam (1968). Ramalingam (1976) reviewed the history of filariasis in Samoa. He mentioned that O'Connor (1923) was the first investigator to obtain fundamental information on the mosquitoes of Samoa and to study their relation to the transmission of filariasis. O'Connor also demonstrated that *Ae. polynesiensis* was the vector of subperiodic bancroftian filariasis in Samoa, confirming the earlier findings of Bahr (1912) in Fiji.

Besides *Ae. polynesiensis*, another species of the *Ae. scutellaris* group indigenous to Samoa, *Ae. upolensis*, as well as two species of the *Ae. (Finlaya) kochi* group, *Ae. samoanus* and *Ae. tutuilae* were shown to be naturally infected.

Suzuki and Sone (1975) concluded that the filariasis vector mosquitoes in Samoa were *Ae. polynesiensis*, *Ae. upolensis* and *Ae. samoanus*. However he also stated that, because it was hard to collect *Ae. upolensis* in and around villages, the role of this species in the transmission of filariasis seemed doubtful.

Although *Cx. quinquefasciatus* is susceptible to *W. bancrofti* and is vector of filariasis in many parts of the world (Sasa, 1976), Samarawickrema et al. (1992) concluded that *Cx. quinquefasciatus* was an inefficient vector of subperiodic *W. bancrofti* in Samoa.

Breeding places

Aedes (Stegomyia) polynesiensis is distributed widely in the South Pacific region, mainly in the Polynesian area; not

only in Samoa, but in Fiji, Wallis and Futuna, Tuvalu, Tokelau, Cook Islands, Tahiti and Pitcairn, (Belkin, 1962). In all four Samoan islands, *Ae. polynesiensis* is present. Its original breeding places were probably tree holes, and it still uses these widely wherever it occurs. It is very commonly found in coconut shells and husks, is frequently found in canoes, and utilizes artificial containers of various types. An unusual feature of the species is its ability to breed in restricted accumulations of water on the ground; it has occasionally been found breeding in crabholes.

On the other hand, *Ae. samoanus* is distributed only in Savai, Upolu islands in Samoa and Tutuila island in American Samoa. Belkin (1962) suspected that the original breeding sites of *Ae. samoanus* were the leaf axils of wild aroids and possibly of *Pandanus* as well.

Since the classic account by Buxton and Hopkins (1927), various workers have investigated the ecology and breeding sites of these vectors in the South Pacific islands, e.g. Burnet (1960) and Symes (1960) in Fiji; Jachowski (1954) and Bonnet and Chapman (1956, 1958) in American Samoa; Ramalingam (1968) and Suzuki and Sone (1974) in Samoa. Unfortunately, none of these reports provided the quantitative data needed for planning vector control measures.

Samarawickrema et al. (1992) identified the breeding sites of *Ae. samoanus* and assessed their productivity. They also investigated the larval habitats and output of *Ae. polynesiensis* throughout Samoa. Breteau and container indices for *Ae. polynesiensis* and *Ae. aegypti* fluctuated with the pattern of rainfall in two coastal villages and an inland bush village, but not in a coconut plantation community (Samarawickrema et al., 1993). The five main *Aedes* larval habitat types encountered were; 200 litre water-storage drums, discarded tins and bottles, coconut shells, automobile tyres and tree holes. *Ae. polynesiensis* preferred tree-holes but not water-storage drums. *Ae. aegypti* pre-

ferred drums and tyres. However mixed population of larvae of both species were common in any type of habitat. *Ae. polynesiensis* occurred perennially in drums and tree-holes.

Symes (1960) in Fiji and Suzuki and Sone (1974) in Samoa reported *Ae. polynesiensis* breeding in crab-holes. However, in the study of Samarawickrema et al. (1992), all crab holes sampled were found to be negative for *Aedes* larvae. Moreover, there was no difference in abundance of adults of *Ae. polynesiensis* between coastal areas where there were crab holes and inland villages (Samarawickrema et al., 1987a). Therefore it was inferred that crab holes were not such an important source of *Ae. polynesiensis* as to influence the adult mosquito population density in Samoa.

In Samoa, the screw pine *Pandanus* is cultivated for economic purposes and several species of *Aedes* mosquitoes (*Finlaya*) breed in its flooded leaf axils. Another filariasis vector *Ae. samoanus* also inhabits water in the leaf axils of *Freycinetia*, a forest creeper, as well as *Pandanus phytoelmata*, both plants belonging to the family Pandanaceae. In *Pandanus* axils, the immature stages of *Ae. samoanus* are associated with those of *Ae. (Finlaya) oceanicus* Belkin (1962) and *Ae. (Finlaya) tutuilae* (Ramalingam and Belkin, 1965), while in *Freycinetia* only *Ae. samoanus* was found (Suzuki and Sone, 1974). Ramalingam (1968, 1976) found *Ae. samoanus* in leaf axils of *Pandanus* in Samoa but not in American Samoa. *Ae. tutuilae* almost exclusively inhabits *Pandanus*, whereas *Ae. oceanicus* immature occurs in leaf axils of both *Pandanus* and *Colocasia*.

Samarawickrema et al. (1992) investigated the extent of breeding of *Ae. samoanus* in *Pandanus* leaf axils in Samoa and assessed its contribution to the overall population of adult of *Ae. samoanus*. This study showed that, among 23,049 mosquito larvae collected from Upolu, 77% were *Ae. samoanus*, whereas, out of 6,981 larvae taken in Savai'i only, 23.2% were *Ae. sam-*

oanus. *Ae. samoanus* was found to predominate in *Pandanus* in Upolu and *Ae. oceanicus* in Savai'i. However, the adult density of *Ae. samoanus* was higher in Savai'i and this was attributed to the large areas of forest with *Freycinetia* for *Ae. samoanus* breeding. In *Pandanus* in Savai'i the number of *Ae. samoanus* was negligible. In Upolu, with more urbanization and larger plantations, there was greater breeding of *Ae. samoanus* in *Pandanus*.

It was concluded that in the island of Savai'i, villages are never far from the large areas of natural forest with plentiful *Freycinetia* and the consequent abundance of *Ae. samoanus*. In Upolu, with the greater urbanization and more extensive plantations by a much larger human population, and with the gradual reduction of natural forest, *Ae. samoanus* has shifted its adaptation to *Pandanus* axils instead of *Freycinetia*. These ecological changes of host-plant association in Upolu might have implications for filariasis control.

Biting activity and parity

Belkin (1962) speculated that females of *Ae. polynesiensis* have become adapted to man for their blood source. The original hosts were undoubtedly birds, and possibly bats, since these were the only warm-blooded vertebrates available in the area before the arrival of man. Biting activity of *Ae. polynesiensis* is largely diurnal but shows a distinct peak in late afternoon and a lesser one in early morning.

In contrast, female *Ae. samoanus* were collected at night. On the basis of the abundance of this species in native villages in the interior, Belkin (1962) referred the statement made by Buxton and Hopkins (1927). It was probably because of the bite of this mosquito (*Ae. samoanus*) that the ancient Samoans used to protect themselves in a screen made of bark cloth (tapa), constructed like a rectangular mosquito net. It seems this species was the most nocturnal pest to the native human population.

Suzuki and Sone (1974) carried out observations by the human-bait collection method on the biting activity and seasonal prevalence of *Ae. polynesiensis* and *Ae. samoanus* in Samoa. There were two peaks of the biting activity of *Ae. polynesiensis*, one in the morning and another in the afternoon, of which the afternoon peak was usually higher. This mosquito species was, however, also found to be biting man at night under bright moonlight.

Aedes samoanus has the highest biting activity during the third quarter of the night. No difference was observed between the biting density at indoor and outdoor stations.

The two species were found to bite man throughout the year, and among the various climatic factors tested, seasonal changes in their biting density were correlated with the amount of precipitation. The observation of Samarawickrema et al. (1985) agreed with the findings of Suzuki and Sone (1974). *Aedes polynesiensis* density was low during the high rainfall months and increased immediately following them. *Aedes polynesiensis* was active throughout the day, with peaks at 8:00-9:00 hrs and 16:00-18:00 hrs. *Aedes samoanus* density showed no clear relation to rainfall and its highest peak time was 23:00-01:00 hrs.

They also studied age composition and survival of females. The nulliparous and parous populations of *Ae. polynesiensis* showed similar patterns of activity. The parous proportion of *Ae. polynesiensis* ranged from 36.3% to 59.5% and the epidemiologically significant 3 plus 4-parous proportion ranged from 1.0% to 6.7%. The parous proportion of *Ae. samoanus* was 37.9%-49.7% and the 3 plus 4-parous proportion 1.4%-2.6%.

Filarial infection in vector mosquitoes

Suzuki and Sone (1975) examined the infection rate of mosquitoes as a part of a post-control entomological evaluation of

the first round of MDA of DEC carried out during 1965–1966 in Samoa. They found that the infection rate had dropped from 8.35% to 0.61% in *Ae. polynesiensis* and 4.47% to 0.26% in *Ae. samoanus*. The infective rate changed from 2.95% to 0.07% in *Ae. polynesiensis* and from 0.26% to zero in *Ae. samoanus*.

Seven years after the second MDA 1971 with DEC, a transmission study was carried out in Samoa, over a period of 12 months in 1977–1978, by means of biting catches of *Ae. polynesiensis* and *Ae. samoanus* (Samarawickrema et al., 1987b). Mosquitoes were collected from four villages over the year. Overall infection and infective rates from a total 6,702 *Ae. polynesiensis* were 0.84% and 0.27 %, respectively, and the rates from a total 2,858 *Ae. samoanus* were 0.65% and 0.04%.

This study also demonstrated that transmission of filariasis was still occurring in Samoa after an MDA which reduced the mean mf rate in the whole country to 0.24%. The vector infective rates of this study were 2–3 times higher than those obtained by Suzuki and Sone (1975) surveyed in 1966–1967, clearly indicating resurgence of filariasis in Samoa.

Furthermore, Samarawickrema et al. (1987b) determined infection and infective rate of *Ae. polynesiensis* and *Ae. samoanus* in 47 villages throughout the islands of Samoa, Upolu, Manono and Savai'i during 1978–1979, and microfilaria rates were also surveyed in 28 of the villages. In Upolu, *Ae. polynesiensis* was apparently the major vector, because it was relatively more abundant in more cultivated and populated areas, along the northern coast of Upolu, except Apia town area. In Savai'i, *Ae. samoanus* predominated over *Ae. polynesiensis* except in "plantation" villages. Relatively high biting densities and infection and infective rates indicated that *Ae. samoanus* was not less important than *Ae. polynesiensis* as a vector in Savai'i.

Aedes samoanus preferred natural vegetation, in contrast to *Ae. polynesiensis* which was found near human habitations.

Higher mf rates were associated with villages where *Ae. polynesiensis*, rather than *Ae. samoanus*, was dominant, indicating that *Ae. polynesiensis* was generally a more efficient vector.

Kimura et al. (1992) showed the mosquito infection and infective rates following the single-dose MDA with DEC campaign: infections rates were 0.97% in 1982, 0.68% in 1983, 0.06% in 1984 and infective rates were 0.28% in 1982, 0.08% in 1983, 0.02% in 1984. Despite the large number of people exhibiting extremely low microfilarial densities after the second MDA campaign in Samoa. Bryan and Southgate (1976) demonstrated that *Ae. polynesiensis* is able to ingest and "concentrate" microfilaria from an ultra-low density of microfilariaemia.

Transmission experiments with *Ae. polynesiensis* and *Ae. samoanus* were carried out by Samarawickrema et al. (1985); the concentrating capacity of *Ae. polynesiensis* ranged from 0.70% to 4.74%. As microfilaria densities decreased, concentration increased. The microfilarial intake, the subsequent worm burden and concentrating capacity were less in *Ae. samoanus* than in *Ae. polynesiensis*. There was no evidence of any association between microfilarial density and concentration in *Ae. samoanus*. The average level of infective worm burden did not appear to affect the mortality of the vector (Samarawickrema et al., 1987b).

The epidemiological significance of low-density carriers was assessed in connection with the infectivity of vector mosquitoes (Kimura et al., 1985). The mosquito infectivity produced by the low-density carriers accounted for 2.16% of the total infectivity produced by all the carriers, suggesting that these carriers are not of major importance in the transmission of filariasis.

Entomological aspects for the filariasis elimination programme

Vector infection by PCR

Suzuki and Sone (1974) observed the relations of MDA coverage to mosquito infection rates and found that the drug distribution coverage was less in the districts with infected mosquitoes than in those where no infected mosquitoes were found.

The history of the filariasis control programme in Samoa is summarized in Table 1, showing mf prevalence rates and median microfilarial densities (MfD), along with mosquito infection rates and infective rates quoted from various sources. There is no correlation between mf prevalence and mosquito infection rate.

Regarding the sample size, since infection and infective rates in Samoa for 1963 to 1984 were all less than 1%, a large number of mosquitoes should be collected for statistical analysis. It is necessary to collect these large numbers of mosquitoes within a limited time period and area, if it is for monitoring purposes, which is very difficult in practice. Samarawickrema et al. (1987a) used 6,702 *Ae. polynesiensis* for their study; it took 18 months to collect this number of mosquitoes from two villages.

The necessary sample size may be less if PCR is available, however criteria of infection/infective rate for elimination remains to be determined. Although, as the Samoa data showed, active transmission can still continue with very low infection and infective rates. After achieving a 0.06% infection rate and 0.02% infective rate in 1984, mf positive cases among children age below 9 were found through mass blood surveys in 1993 (Samoa Department of Health, 1998), conclusive evidence of continued transmission.

The infection rate of mosquitoes by PCR can be useful for elimination evaluation to confirm zero infection among mosquitoes in situations such as Samoa, where there is a low mf prevalence and mf density, if the

collection of a large number of mosquitoes is practical.

Vector control for elimination

Chemotherapy is emphasized for elimination of lymphatic filariasis. Ottesen and Ramachandra (1995) explained that in order to interrupt transmission of lymphatic filariasis it was necessary either to eliminate (or reduce to very low levels) the microfilaraemia in humans or to control the mosquito vector effectively. Since efforts at vector control have proven expensive and difficult to sustain in the past, and since very effective drugs for control of microfilaraemia are now available, the focus of efforts to interrupt transmission was shifted to treating infections in human. However Ottesen (1999) also pointed that vector control should be implemented whenever feasible as a tool complementary to filariasis control programmes.

Evidence that vector control was feasible and affordable and had contributed to long-term decline was obtained in Zanzibar in Tanzania (Maxwell et al., 1999). They suggested that a combination of larviciding, simple environmental procedures and chemotherapy could markedly reduce filariasis transmission in any endemic area of Tanzania. The eradication of *W. bancrofti* has been achieved in the Solomon Islands by vector control, a classical insecticidal house-spray campaign aimed at achieving malaria eradication (Webber, 1975).

Vector control has played an effective supporting role for filariasis control and reduction of vector density can make an important contribution to achieving long-term sustainability of transmission interruption.

According to Samoa's experiences, the treatment of human subjects with microfilaraemia using DEC has not been successful in eliminating the mf from the peripheral blood. Often a low-density microfilaraemia persists which may not be

easily detected (Kimura et al., 1985a). It was confirmed that *Ae. polynesiensis* had capacity to concentrate microfilaria and transmission can still occur with low microfilarial cases (Samarawickrema et al., 1983). These studies all suggest that unless proper vector control is conducted to complement the effect of MDAs, transmission of filariasis is unlikely to be interrupted in the country.

Recently new combination drug regimen of albendazole plus DEC was established which has macrocidal in addition to the microcidal activities. In this case vector control is less important. If all adult worms and mf can be killed by MDA once a year, disease transmission will not continue.

Certain improved techniques for enhancing the effectiveness of vector control are now available, including insecticides-impregnated bed nets and curtains to limit host-vector contact. However, there are no standard vector control measures. Although methods will vary by village and by species of mosquitoes based on their bionomics, integrated approaches should be implemented.

The findings of studies in Samoa in breeding sites of *Ae. polynesiensis* indicate that the anti-vector measure, systematically targeted at the various breeding sites of *Ae. aegypti* and *Ae. polynesiensis* are an important component of the integrated control programme against vector borne diseases in Samoa. Another vector, *Ae. samoanus* has adapted to breed in *Pandanus* leaf axils, a plant of economic importance in Samoa, its leaf being used in the manufacture of mats and baskets. Only in a programme of integrated vector control, the periodic treatment of *Pandanus* leaf axils with larvicide by the village community promises effective control of *Ae. samoanus*.

In Samoa's case, since microfilariae appear in the blood for 24 hours and both the day biting mosquito, *Ae. polynesiensis* and the night biting mosquito, *Ae. samoanus* are vectors, chance of transmission is

doubled compared to nocturnal periodic parasites. *Ae. polynesiensis* can concentrate microfilariae and transmission can be possible with low microfilarial cases. If there are no macrocids, vector control is necessary to enhance the impact of transmission interruption by MDA and prevent re-surgence of parasites. The approaches for the control intervention can be integrated, however, the strategy and method of each of mosquitoes should be individually planned due to the different bionomics.

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REFERENCES

- Backhouse, T. C. 1963. Parasitology-*Wuchereria bancrofti* in Melanesia and Polynesia. In: Filariasis in the South Pacific. pp. 1-5, South Pacific Commission, Noumea New Caledonia.
- Bahr, P. H. 1912. Filariasis and elephantiasis in Fiji. *Lon. Sch. Trop. Med. Res. Mem. Ser.*, 1: 1-92.
- Belkin, J. N. 1962. The mosquitoes of the South Pacific (Diptera Culicidae). Vol. 1, 608 pp. University of California Press, U.S.A.
- Bonnet, D. D. and Chapman, H. 1956. The importance of mosquito breeding in tree holes with special reference on the problem in Tahiti. *Mosq. News*, 16: 301-306.
- Bonnet, D. D. and Chapman, H. 1958. The larval habitats of *Aedes polynesiensis* Marks in Tahiti and methods of control. *Am. J. Trop. Med. Hyg.*, 7: 512-518.
- Bryan, J. H. and Southgate, B. A. 1976. Some observations on filariasis in Western Samoa after mass administration of diethylcarbamazine. *Trans. R. Soc. Trop. Med. Hyg.*, 70: 39-48.
- Burnett, G. F. 1960. Filariasis research in Fiji 1957-1959. *J. Trop. Med. Hyg.*, 63: 153-162.
- Buxton, P. A. 1928. Researches in Polynesia and Melanesia. *Mem. Lon. Sch. Hyg. Trop. Med.* 2, 139 pp.
- Buxton, P. A. and Hopkins, C. A. 1927. Researches in

- Polynesia and Melanesia Parts I-IV (6). *Mem. Lon. Sch. Hyg. Trop. Med.* 1, 260 pp.
- Ichimori, K. 2000. PacELF: Regional update. *Filarial update*, 2(1): 12.
- Jachowski, L. A. 1954. Filariasis in American Samoa V. Bionomics of the principal vector, *Aedes polynesiensis* Marks. *Am. J. Hyg.*, 60: 186-203.
- Kimura, E., Penaia, L., Samarawickrema, W. A. and Spears, G. F. S. 1985a. Low-density microfilaraemia in subperiodic bancroftian filariasis in Samoa. *Bull. WHO*, 63: 1089-1096.
- Kimura, E., Penaia, L. and Spears, G. F. S. 1985b. Epidemiology of subperiodic bancroftian filariasis in Samoa 8 years after control by mass treatment with diethylcarbamazine. *Bull. WHO*, 63: 869-880.
- Kimura, E., Spears, G. F. S., Samarawickrema, W. A., Penaia, L., Sone, P. F., Pelenatu, S., Faaiuso, S. T., Self, L. S. and Dazo, B. C. 1992. Long-term efficacy of single-dose mass treatment with diethylcarbamazine citrate against diurnally subperiodic *Wuchereria bancrofti*: eight years' experience in Samoa. *Bull. WHO*, 70: 769-776.
- Maxwell, C. A., Mohammed, K., Kisumku, U. and Curtis, C. F. 1999. Can vector control play a useful supplementary role against bancroftian filariasis? *Bull. WHO*, 77: 138-143.
- O'Connor, F. W. 1923. Researches in the Western Pacific. *Res. Mem. Lond. Sch. Trop.*, 4: 57.
- Ottesen, E. A. 1999. Towards eliminating lymphatic filariasis. In: *Lymphatic Filariasis* (ed. T. B. Nutman), pp. 201-215, Imperial College Press, UK.
- Ottesen, E. A., Ismail, M. M. and Horton, J. 1999. The role of albendazole in programmes to eliminate lymphatic filariasis. *Parasitol. Today*, 15: 382-386.
- Ottesen, E. A. and Ramachandran, C. P. 1995. Lymphatic filariasis infection and diseases: control strategies. *Parasitol. Today*, 11: 129-131.
- Phantana, S., Sensathein, S., Songtrus, J., Klagrat-hoke, S. and Phonguin, K. 1999. ICT filariasis test: A new screening test for Bancroftian filariasis. *Southeast Asian J. Trop. Med. Public Health*, 30: 47-57.
- Rajan, T. V. 1999. Lymphatic filariasis: A historical perspective. In: *Lymphatic filariasis* (ed. T. B. Nutman), pp. 1-5, Imperial College Press, UK.
- Ramalingam, S. 1968. The epidemiology of filarial transmission in Samoa and Tonga. *Ann. Trop. Med. Parasitol.*, 62: 305-324.
- Ramalingam, S. 1976. An annotated checklist and keys to the mosquitoes of Samoa and Tonga. *Mosq. Sys.*, 8: 298-318.
- Ramalingam, S. and Belkin, J. N. 1965. Mosquito studies (Diptera, Culicidae). *Contrib. Am. Entomol. Inst.*, 1(4): 1-10.
- Samarawickrema, W. A., Kimura, F. F. S., Spears, G. F. S., Penaia, L., Sone, F., Paulson, G. S. and Cummings, R. F. 1987. Distribution of vectors, transmission indices and microfilaria rates of subperiodic *Wuchereria bancrofti* in relation to village ecotypes in Samoa. *Trans. R. Soc. Trop. Med. Hyg.*, 81: 129-135.
- Samarawickrema, W. A., Sone, F. and Cummings, R. F. 1987a. Seasonal abundance, diel biting activity and parity of *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg) (Diptera: Culicidae) in Samoa. *Bull. Entomol. Soc. Am.*, 77: 191-200.
- Samarawickrema, W. A., Sone, F. and Cummings, R. F. 1987b. Natural infections of *Wuchereria bancrofti* in *Aedes (Stegomyia) polynesiensis* and *Aedes (Finlaya) samoanus* in Samoa. *Trans. R. Soc. Trop. Med. Hyg.*, 81: 124-128.
- Samarawickrema, W. A., Sone, F., Paulson, G. S., Kimura, E. and Cummings, R. F. 1992. Observations on *Culex quinquefasciatus* say in relation to transmission of filariasis due to subperiodic *Wuchereria bancrofti* in Samoa. *Ann. Trop. Med. Parasitol.*, 86: 517-522.
- Samarawickrema, W. A., Sone, F., Self, R. F., Cummings, R. F. and Paulson, G. S. 1992. Distribution of breeding and control of the filariasis vector *Aedes samoanus* in leaf axils of *Pandanus* in Samoa. *Med. Vet. Entomol.*, 17: 367-370.
- Samarawickrema, W. A., Sone, F., Self, R. F., Kimura, E., Self, L. S., Cummings, R. F., and Paulson, G. S. 1993. The relative importance and distribution of *Aedes polynesiensis* and *Ae. aegypti* larval habitats in Samoa. *Med. Vet. Entomol.*, 7: 27-36.
- Samarawickrema, W. A., Spears, G. F. S., Sone, F., Ichimori, K. and Cumming, R. F. 1983. Filariasis transmission in Samoa. II. Some factors related to the development of microfilariae in the intermediate host. *Ann. Trop. Med. Parasitol.*, 79: 101-107.
- Samarawickrema, W. A., Spears, G. F. S., Sone, F., Ichimori, K. and Cummings, R. F. 1985. Filariasis transmission in Samoa. I. Relation between density of microfilariae and larval density in laboratory-bred and wild-caught *Aedes (Stegomyia) polynesiensis* (Marks) and wild-caught *Aedes (Finlaya) samoanus* (Grünberg). *Ann. Trop. Med. Parasitol.*, 79: 89-100.

- Samoa Department of Health 1998. Databook-filariasis control project Samoa 1993-1994, 1992-1997, 1998.
- Sasa, M. 1976. Human Filariasis. 819 pp. Tokyo Press, Japan.
- Suzuki, T. and Sone, F. 1974. The bionomics of filariasis vectors in Western Samoa. *Jpn. J. Sanit. Zool.*, 25: 251-257.
- Suzuki, T. and Sone, F. 1975. Filarial infection in vector mosquitos after mass drug administration in Western Samoa. *Trop. Med.*, 16: 147-156.
- Symes, C. B. 1960. Observations on the epidemiology of filariasis in Fiji. *J. Trop. Med. Hyg.*, 63: 1-4.
- Webber, R. H. 1975. Vector control of filariasis in the Solomon Islands. *Southeast Asian J. Trop. Med., Public Health*, 6: 430-434.
- WHO 1982. Teaching guide for health personnel and school teachers in Samoa on control of subperiodic bancroftian filariasis. 21 pp. Manila, Philippines.
- WHO 1997. Lymphatic filariasis: Reasons for hope. 20 pp. WHO, Geneva.
- WHO and SPC 1999. PacELF booklet WHO/SPC. 22 pp. SPC, Noumea.