Vector Mosquitoes of Filariasis in Japan

Yoshito Wada

1 Species of vector mosquitoes

The main vector of Brugia malayi in the small endemic focus on Hachijo-koshima Island was determined to be Ochlerotatus togoi (as Aedes togoi) [1]. As to Wuchereria bancrofti, many species of mosquitoes were experimentally examined for susceptibility in the laboratory as by Mo-chizuki in 1911 and 1913 [2, 3], Yamada in 1927 [4], Fujisaki in 1958 and 1959 [5, 6], and Omori in 1962 [7]. The results indicated that among 26 mosquito species tested Culex pipiens pallens, Cx. pipiens molestus, Cx. Pipiens quinquefasciatus, Cx. vagans, Cx. whitmorei and Ochlerotatus togoi (as Aedes togoi) were highly susceptible (the microfilaria could develop to the infective stage in the body of mosquitoes in high rates), while Cx. bitaeniorhynchus, Cx. pseudovishnui (as Cx. vishnui), Cx. sinensis, Cx. tri-taeniorhynchus, Anopheles sinensis and Armigeres subalbatus had extremely low susceptibility [8].

Of the highly susceptible six mosquitoes, Cx. pipiens molestus, Cx. vagans and Cx. whitmorei were excluded from important vectors of bancroftian filariasis in Japan, because they were rather rare at least in filariasis endemic areas and no natural infections were observed [9]. Oc. togoi, which breeds almost exclusively in rock pools near the sea, was common in some coastal areas, for example, in Goto Islands of Nagasaki prefecture, and the natural infection with the parasite was not rarely observed. However, because of rather poor anthropophily in blood feeding habit [10] this mosquito was regarded only as the secondary vector even in particular coastal areas where the density was quite high. The remaining two mosquitoes, Cx. pipiens pallens and Cx. pipiens quinquefasciatus, were the most important vectors transmitting bancroftian filariasis in Japan. They are taxonomically different only in subspecific status, and the former is distributed in Kyushu Island and further north and the latter in Amami-Oshima Island and further south. The both mosquitoes with similar biological characteristics were always very common in dwelling houses in areas endemic for bancroftian filariasis and very anthropophilic in blood feeding, and the natural infections with W. bancrofti were frequently found. The main breeding places were drains receiving domestic waste water and manure pits.

2 Natural decrease of filariasis endemicity before the start of national drug treatment

Filariasis was obviously a serious health problem in many parts of Japan since old times [11]. In blood surveys of army recruits from all over Japan in 1912 reported by Army Medical Surgeon, the overall microfilaria positive rate was 1.86%, or 2,090 positive cases out of 112,353 recruits tested [12]. It is noteworthy that infected persons were found even in Aomori, the northernmost prefecture of Honshu Island, where vector mosquitoes could be active only in very short summer. The prevalence was naturally higher in more southern parts of Japan with higher vector density.

It is considered that the microfilaria positive rate decreased year by year after that time and filariasis in many of its endemic foci particularly in northern and central Japan disappeared in about a half century, though there still existed a number of small isolated foci in rural areas. This decrease in the endemicity of filariasis is apparently caused by the decrease in man/vector contacts by changes in living style including the popularization of mosquito nets and by reduction of vector density itself due to improvements of sanitary environments.

On the other hand, the prevalence of filariasis in southern Japan including Kyushu Island and the Ryukyu Archipelagoes was still one of the most serious public health problems for the inhabitants even in early 1960s. It should be noted that the prevalence was generally much higher in rural areas than in urban areas, probably because of the delay in the change of living style and of the reduction of vector density in the former areas.
3 Field experiments toward the control of vector mosquitoes

Several groups of workers took up the area control of filariasis in Japan on an experimental basis. One of the most systematic trials carried out was that by Sasa and others [13], aiming to eradicate malayan filariasis from Hachijo-Koshima Island. Extensive use was made of the anti-filarial drug (diethylcarbamazine) with simultaneous applications of anti-mosquito measures including residual spraying of dieldrin and DDT.

The Filariasis Control Committee with workers from the universities of Tokyo, Nagasaki and Kagoshima was organized in 1958 with financial aid from the Ministry of Education. The members of the Committee conducted field studies on the control of filariasis at some 10 different localities, to find out the most effective and economic measures and to establish a standard method to be applied to all endemic areas [13-15]. Anti-mosquito measures were included in the principle adopted by the Committee.

The effectiveness of insecticides available at that time was evaluated in the control of vector mosquitoes. The insecticides examined included chlorinated hydrocarbons such as DDT, lindane and dieldrin, and organophosphorus compounds such as diazinon and malathion. Indoor residual spraying with those insecticides was apparently effective in reducing the mosquito population for quite a long period. Such household insect pests as flies, fleas and cockroaches were also greatly affected by the residual spraying.

Developments of the resistance to any of the above insecticides in larvae and adults of Cx. pipiens pallens were already demonstrated in a few areas according to the previous history of the insecticide applications, but the insecticide resistance was regarded as little practical importance in the control at that time [13, 15].

4 Anti-mosquito measures in national filariasis control program

On the basis of the information and experience accumulated during the period of ten years, the government of Japan decided to support a country-wide filariasis control program starting in the fiscal year 1962 [12]. A text drafted by Dr. M. Sasa was issued by the Ministry of Health and

---

**Fig. 1** The back page of a leaflet made by Nagasaki prefecture around 1962 for distribution to inhabitants in endemic areas of bancroftian filariasis, appealing the importance of receiving blood examination for filariasis. A microfilaria (Wuchereria bancrofti) and a mosquito (Culex pipiens pallens, the principal vector) are drawn.
Welfare as the guide for standard method of filariasis control. The prefectural health departments were responsible for selecting the areas for conducting the control, while the municipalities within each prefecture actually carried out the drug administration and the mosquito control.

At the start of the program in 1962, four prefectures in southwestern Japan, namely Ehime, Kochi, Kagoshima and Nagasaki, accepted the government proposal. Additional five prefectures, Niigata, Tokyo (the Izu Islands), Oita, Miyazaki and Kumamoto joined the project in 1963 and 1964. Some prefectures terminated the project within one to several years as the number of microfilarial carriers had been reduced nearly to zero, but the project continued for approximately ten years in such very endemic prefectures as Kagoshima, Kumamoto and Nagasaki. The filariasis control program in Okinawa started in 1966 under different administrative background but with the same technical method. Several kinds of leaflets made by the Ministry of Health and Welfare and the prefectures conducting the filariasis control program were distributed to inhabitants in endemic areas to enlighten the importance of the program. Examples of such leaflets are shown in Figs. 1 and 2.

The survey and the control of vector mosquitoes for the prevention of filariasis transmission were included in the text for the filariasis control program issued by the Ministry of Health and Welfare [12]. Procedures in the endemic areas concerned were the survey and the removal of breeding places of mosquitoes with emphasis on sewage ditches near houses, and the use of insecticides and natural enemies to control mosquitoes according to the direction in the text for the program. As a use of natural enemies it was recommended to release fishes into breeding places of mosquitoes.

Prefectural governments were asked to organize necessary units of filariasis control teams, each composed roughly of one health officer, three technicians and one entomologist. By involvement of entomologists in filariasis control teams, it was assumed that survey and control of mosquitoes would be very actively carried out. Expenses of insecticides used mostly for residual spraying were considerable as seen in the example of Nagasaki prefecture in Table 1 [16].

However, well-trained entomologists were not always available in each control team. The residual spraying was actually troublesome to the inhabitants, since all furniture
had to be taken out as seen in Fig. 3 for residual insecticide to be effectively sprayed on inside walls. Although the rate of houses sprayed was fairly high, it was not recorded whether or not the insecticide was properly applied. In either case, it seems very probable that the residual spraying was effective for temporal interruption of transmission, but not for eradication from a particular area unless it was repeated at least for many years, because the adult worm continues to produce microfilariae for nearly 10 years [17]. Thus, the effects of residual spraying upon the prevalence of filariasis in human populations is much less marked than in the case of malaria [1].

| Year | No. houses sprayed with insecticide | Total expense of filariasis campaign in thousand Yen | Cost in thousand Yen of insecticide used (% to the total expenses) |
|------|-----------------------------------|-----------------------------------------------------|---------------------------------------------------------------|
| 1962 | 40,534                            | 11,564                                              | 4,568 (39.5)                                                  |
| 1963 | 35,858                            | 12,614                                              | 5,272 (41.8)                                                  |
| 1964 | 30,220                            | 11,398                                              | 4,842 (42.5)                                                  |
| 1965 | 18,852                            | 7,284                                               | 3,779 (51.9)                                                  |
| 1966 | 12,718                            | 5,744                                               | 2,755 (48.0)                                                  |
| 1967 | 11,257                            | 5,329                                               | 2,580 (48.4)                                                  |
| Total| 149,439                           | 53,933                                              | 23,796 (44.1)                                                 |

Table 1. Vector control in Nagasaki prefecture in 1962-1967 as a part of the National Filariasis Control Project

Fig. 3 Nagate village, Nagasaki prefecture, on the day of residual spraying with insecticide in 1961. Furniture was taken out from houses for insecticide to be sprayed effectively on inside walls

5 Filariasis eradication experiment by vector control alone

Since bancroftian filariasis is transmitted from man to man only by vector mosquitoes, it is supposed that without vector mosquitoes no transmission will occur and adult filariae in infected persons will die out some years after infection. Since investigations along this line were thought to be very useful for understanding the epidemiology, a filariasis eradication experiment involving only the control of the principal vector mosquito *Cx. pipiens pallens* was planned in 1962 at Nagate village, Nagasaki prefecture, Kyushu without treatment of persons by drugs [17].
The decrease in the vector density in recent years is very remarkable in Japan. In 1994, mosquitoes were collected by the human bait method in a village of Nagate, Nagasaki prefecture, where bancroftian filariasis was formerly endemic (microfilaria positive rate was 14.0% in 1961) but all inhabitants became free of microfilariae by the control of vector mosquitoes carried out from 1962 to 1971. The abundance of mosquitoes collected in 1994 [21] was compared with that in 1961 in previously published report [10]. A remarkable decrease of the principal vector mosquito, Cx. Pipiens pallens, was noted from 1961 to 1994 (Table 3). Reduction in the mean number per collection night of the principal vector from 71.2 in 1961 to 0.6 in 1994 was chiefly due to the reduction in the breeding place of this mosquito. The main breeding place in 1961 was standing water in open ditches collecting household waste water [10],

Table 2. The reduction in the microfilaria positive rate in all persons in Nagate village, Nagasaki prefecture, during a ten year period under continuous vector control starting in 1962

| Year | No. persons examined | No. positives | % positives |
|------|----------------------|--------------|------------|
| 1961 | 577                  | 81           | 14.0       |
| 1962 | 571                  | 71           | 12.4       |
| 1963 | 567                  | 62           | 10.9       |
| 1964 | 541                  | 53           | 9.8        |
| 1965 | 493                  | 39           | 7.9        |
| 1966 | 515                  | 31           | 6.0        |
| 1967 | 491                  | 20           | 4.1        |
| 1968 | 441                  | 9            | 2.0        |
| 1969 | 447                  | 5            | 1.1        |
| 1970 | 430                  | 2            | 0.5        |

6 The recent situation of filariasis transmission by vector mosquitoes

It has been a great concern for epidemiologists studying filariasis to evaluate the relative efficiency of chemotherapy, vector control and a combination of both in a campaign against lymphatic filariasis. In this context, the phenomena of 'facilitation' and 'limitation' have recently been discussed. WHO (1984) stated “It has been shown that, as the number of microfilariae ingested increases, there is a decrease in the proportion passing through the wall of the mosquito stomach and developing further [18]. This phenomenon has been termed limitation ... The reverse situation, termed facilitation, in which the proportion of microfilariae that develop increases as the numbers of ingested microfilariae increase, is exhibited by Anopheles mosquitoes”. Then, WHO (1992) stated that the situation of facilitation will give rise to transmission thresholds that could lead to the ultimate extinction of lymphatic parasites from the human population, when the microfilarial reservoir in the human population is lowered to a certain level by chemotherapy [19].

If the above is justified, then the facilitation would be a very attractive idea in planning a control of filariasis. However, careful examination of previously reported papers revealed that there was no clear evidence to support the existence of facilitation and facilitation-based unstable equilibrium, in relation to microfilaria prevalence and density in human population, below which filariasis would spontaneously disappear even when the vector was Anopheles mosquitoes [20].

Natural reductions in microfilaria prevalence and density were commonly encountered with W.bancrofti transmitted by Cx. pipiens pallens in many areas of Japan in the past before mass chemotherapy was implemented in 1962 [11]. It seems apparent that the natural reduction in microfilaria prevalence and density in Japan was due to the decrease of vector density, or more accurately of man/mosquito contacts. This strongly suggests the existence of critical man/mosquito contacts, but not of the unstable equilibrium of filaria parasites, below which filariasis tends to disappear.

The decrease in the vector density in recent years is very remarkable in Japan. In 1994, mosquitoes were collected by the human bait method in a village of Nagate, Nagasaki prefecture, where bancroftian filariasis was formerly endemic (microfilaria positive rate was 14.0% in 1961) but all inhabitants became free of microfilariae by the control of vector mosquitoes carried out from 1962 to 1971. The abundance of mosquitoes collected in 1994 [21] was compared with that in 1961 in previously published report [10]. A remarkable decrease of the principal vector mosquito, Cx. Pipiens pallens, was noted from 1961 to 1994 (Table 3). Reduction in the mean number per collection night of the principal vector from 71.2 in 1961 to 0.6 in 1994 was chiefly due to the reduction in the breeding place of this mosquito. The main breeding place in 1961 was standing water in open ditches collecting household waste water [10],

...
but nearly all ditches have been changed to underdrains, thus there are scarcely any breeding mosquitoes. In this way, there is now no risk of filariasis infection at Nagate.

The situation in other parts of Japan was apparently similar to Nagasaki, and man/mosquito contacts were considered far below the critical level for the existence of filariasis. This was closely related to the movement for controlling flies and mosquitoes through community participation under the strong support of the government of Japan. The movement was implemented in 1955 in almost all communities throughout Japan, and this contributed greatly to the improvement of general public health situations. Such booklets as in Fig. 4 were published by many communities for use in the movement for controlling flies and mosquitoes.

Acknowledgements

I wish to express my thanks to Dr. T. Kurihara of National Institute of Infectious Diseases, Tokyo, who kindly provided me with references on filariasis vectors.

This paper is revised from Asian Parasitology Vol.3 Filariasis in Asia and Western Pacific Islands, 119-126 by The Federation of Asian Parasitologists in 2004.

References

[1] Sasa M. Human filariasis, a global survey of epidemiology and control. University of Tokyo Press: Tokyo, 1976, 819pp.
[2] Mochizuki D. On the relation between mosquitoes and microfilariae of Filaria bancrofti. Fukuoka Ika Daigaku Zasshi 1911; 4: 384-444 (in Japanese).
[3] Mochizuki D. Culicidae in Fukuoka district. Fukuoka Ika Daigaku Zasshi 1913; 7: 1-65 (in Japanese).
[4] Yamada S. An experimental study on twenty-four species of Japanese mosquitoes regarding their suitability as intermediate hosts for Filaria bancrofti COBBOLT. Sci Rep Gov Inst Inf Dis 1927; 6: 559-622.
[5] Fujisaki T. Supplements to the findings on the susceptibility of Japanese mosquitoes to Wuchereria bancrofti. 1. On the susceptibility of Culex pipiens molestus. Nagasaki Igakkai Zasshi 1958; 33 (11, Suppl.): 71-77 (in Japanese).
[6] Fujisaki T. Supplements to the findings on the susceptibility of Japanese mosquitoes to Wuchereria bancrofti. 2. On the susceptibility of Anopheles hynchus and Culex pipiens. Endem Dis Bull Nagasaki 1959; 1: 278-287 (in Japanese).
[7] Omori N. A review of the role of mosquitoes in the transmission of malayan and bancroftian filariasis in Japan. Bull Wld Hlth Org 1962; 27: 585-594.
[8] Omori N. On the role of Japanese mosquitoes, especially of Culex pipiens pallens in the transmission of bancroftian filariasis. In: Progress of Medical Parasitology in Japan. Vol.3. Tokyo: Meguro Parasitological Museum, 1966; 471-507.
[9] Omori N. The role of Japanese mosquitoes in the transmission of filariasis. Proc 16th General Assembly Japan Medical Congress 1963; 2: 759-776 (in Japanese).
[10] Wada Y. Epidemiology of bancroftian filariasis in Nagate and Abumize villages, Nagasaki Prefecture, especially in relation to vector mosquitoes 3. Ecology and natural infections of mosquitoes. Endem Dis Bull Nagasaki 1966; 8: 45-53.
[11] Sasa M. Epidemiology of human filariasis in Japan. In: Progress of Medical Parasitology in Japan. Vol. 3. Tokyo:
Meguro Parasitological Museum, 1966: 385-436.

[12] Ōsaka M, Kanda T, Mitsui G, Shirasaka A, Ishii A, Chinzei H. The filariasis control programs in Japan and their evaluation by means of epidemiological analysis of the microfilaria survey data. In: Recent Advances on Filaria sis and Schistosomiasis. Tokyo Univ Press, 1970: 3-72.

[13] Ōsaka M, Hayashi S, Sato K, Ikeshoji T, Tanaka H. A review of field experiments in the control of bancroftian and malayan filariasis in Japan, 1958. Japan J Exp Med 1959; 29: 369-405.

[14] Ōmori N, Kamura T, Fujisaki T, Suenaga O, Kitamura S, Katamine D, Era E, Fukuma H. Filariasis control experiments in western Kyushu, Japan. Jap J Parasitol 1959; 8: 886-894 (in Japanese).

[15] Maeda O, Suenaga O, Taketomi M, Omori N. Field studies on the control of mosquitoes by residual sprays and larvicides 1. Control of mosquitoes in Ojika Islands during from 1958 to 1963. Endem Dis Bull Nagasaki 1964; 6: 247-261.

[16] Nagasaki Prefecture. Filariasis Campaign in Nagasaki Prefecture 1962-1967. 1968 (in Japanese).

[17] Ōmori N, Wada Y, Oda T. Eradication experiments of bancroftian filariasis in the control of vector mosquitoes in Nagate village, Nagasaki prefecture. In: Research in Filaria sis and Schistosomiasis, Vol. 2, Tokyo Univ Press and Univ Park Press, 1972: 3-72.

[18] WHO. Lymphatic filariasis. Technical Report Series 702, 1984, 112pp.

[19] WHO. Lymphatic filariasis: the disease and its control. Technical Report Series 821, 1992, 71pp.

[20] Wada Y, Kimura E, Takagi M, Tsuda Y. Facilitation in Anopheles and spontaneous disappearance of filariasis: Has the concept been verified with sufficient evidence? Trop Med Parasitol 1995; 46: 27-30.

[21] Takagi M, Tsuda Y, Wada Y; Takafuji A. Decrease of vector mosquitoes of bancroftian filariasis in a village on Fukue Island, Nagasaki, southwestern Japan. Trop Med 1995; 37: 159-163.