Epidemiology of Bancroftian Filariasis in Nagate and Abumize Villages, Nagasaki Prefecture, Especially in Relation to Vector Mosquitoes.

3. Ecology and natural infections of mosquitoes.*

Yoshito WADA

Department of Medical Zoology, Nagasaki University School of Medicine
(Director : Prof. N. OMORI)

Department of Medical Zoology, Research Institute of Endemics, Nagasaki University
(Director : Prof. N. OMORI)

Received for publication February 22, 1966

ABSTRACT : Mosquito collections were made in the dwelling houses, cowsheds, and by human-baited-traps, in Nagate and Abumize Villages, Nagasaki Prefecture in 1961 and 1962. The former village was 14.0% and the latter was 8.3% in microfilarial incidence. The host preference, and hourly and seasonal prevalences were examined especially with three predominant species, *Culex pipiens pallens*, *Aedes togoi*, and *Armigeres subalbatus*. The natural infection rates of mosquitoes with *Wuchereria bancrofti* were compared with the former two mosquito species, the most important filaria-vectors there.

Introduction

This is the third report on the epidemiology of bancroftian filariasis in Nagate and Abumize Villages, Nagasaki Prefecture. In the first report, changes in the endemicity of filariasis in several communities in the prefecture were discussed by means of the triangular graph method. In the second report, the endemicity of filariasis of the two villages was discussed. In the present paper, the ecology and natural infections of mosquitoes in the villages will be mentioned, with the emphasis on the role of *Aedes togoi* in the transmission of bancroftian filariasis.

The writer wishes to express his sincere appreciation to Professor N. Omori of the Department of Medical Zoology, Nagasaki University School of Medicine who has given constant encouragement and has revised this manuscript. Thanks are also due to the members of the Department, particularly Mr. T. Oda, for their kind help in the field work.

*Contribution from the Research Institute of Endemics, Nagasaki University No. 485 and Contribution No. 148 from the Department of Medical Zoology, Nagasaki University School of Medicine.

Place and Method

Nagate Village has 126 houses, 577 in population and is 14.0% in microfilarial incidence. Abumize Village has 20 houses, 84 in population and is 8.3% in the incidence. These two farm villages are at the eastern coast of Fukue Island, Nagasaki Prefecture. The distance between the two villages is about 4km. Between the two lies a farm village of about 10% in microfilarial incidence.

In Nagate Village there is no paddy field; few rock pools in the seashore; few night-soil reservoirs large enough to favor the breeding of *Armigeres subalbatus*; but a great number of cess-pools, ditches and foul water collections, favorable breeding places of *Culex pipiens pallens*.

In Abumize Village there is also no paddy field; but a tremendous number of rock pools in the seashore favoring the breeding of *Aedes togoi*; and large night-soil reservoirs into which even foul water from bathtub is poured, making favorable breeding places of *Ar. subalbatus*. The soil in this village is sandy and the foul water from the kitchen sinks in some cases into the ground, collecting only in some others especially during rainy weather. The breeding of *C. p. pallens* in the village is not so active and is fluctuated with the weather.

In Nagate Village, residual spraying of houses was made on June 6, 1962 and weekly larvicide application for the breeding places of *C. p. pallens* was started from July 19 of the same year, while in Abumize no such insecticides were used. In these villages in 1961 and 1962, collections of mosquitoes were continued in dwelling houses, at cowsheds, and by human-baited-traps, and their host preference, hourly and seasonal prevalences, and natural infection with the larvae of *Wuchereria bancrofti* were examined.

Ecology of Mosquitoes

The number of mosquitoes collected in dwelling houses at Nagate and Abumize Villages in 1961 and 1962 is given in Table 1. Among 1017 and 1420 mosquitoes collected respectively at Nagate and Abumize villages, 93.1% and 50.2% were *C. p. pallens*; 2.6% and 36.8% were *Ae. togoi*; and 3.2% and 6.9% were *Ar. subalbatus*; moquitoes of the other species were very few. The number of mosquitoes collected by human-baited-traps in the same villages and years is shown in Table 2. The species structure was naturally nearly similar. These two tables show that at Nagate Village *C. p. pallens* is more predominant because of being more numerous in favorable breeding places than at Abumize Village; *Ar. subalbatus* is fewer in the former village because of being fewer in the number of large night-soil reservoirs than in the latter; *Ae. togoi* is much fewer in the former because of being very fewer in rock pools on the seashore than in the latter.

The result of mosquito collections at cowsheds in the two villages in 1961 and 1962 is shown in Table 3. The relative abundances of *C. p. pallens*, *Ar.* subalbatus, and *Ae. togoi* respectively at Nagate and Abumize Villages were 57.5 and 9.2; 21.3 and 39.5; and 15.5 and 37.3%. The higher percentage of the first species in the former village than in the latter is due not necessarily to the greater number of mosquitoes collected but to the smaller number of those of the other two species. The reverse relation is seen in the latter village.

Seasonal prevalences of mosquitoes of three dominant species, *C. p. pallens*, *Ae. togoi*, and *Ar. subalbatus*, are illustrated in Fig. 1, based on the data of collections at dwelling houses. Generally, *C. p. pallens* increases in number

Table 1. Number and percentage (in parentheses) of mosquitoes collected at dwelling houses at Nagate and Abumize Villages in 1961 and 1962.

Village	Nagate			Abumize		
Year	1961	1962	1961+1962	1961	1962	1961+1962
Month	V-XII	III-X		V-XII	III-X	
No. of houses	96	195	291	109	118	227
An. sinensis		3	3(0.3)	3	13	16(1.1)
Ar. subalbatus	7	26	33(3.2)	50	48	98(6.9)
Ae. albopictus	2		2(0.2)			
Ae. vexans				2	16	18(1.3)
Ae. togoi	21	5	26(2.6)	246	277	523(36.8)
C. bitaeniorhynchus	1		1(0.1)			
C. p. pallens	555	392	947(93.1)	445	268	713(50.2)
C. tritaeniorhynchus		5	5(0.5)	6	46	52(3.7)
Total	586	431	1,017(100.0)	752	668	1,420(100.0)

Table 2. Number and percentage (in parentheses) of mosquitoes collected by human-baited-traps at Nagate and Abumize Villages in 1961 and 1962.

Village	Nagate	Abumize		
Year	1961	1961	1962	1961+1692
Month	V-XI	V-XII	V-X	
No. of collections	13	15	6	21
An. sinensis	4(0.4)	3	1	4(0.3)
Ar. subalbatus	18(1.8)	112	96	208(17.7)
Ae. albopictus	5(0.5)	1		1(0.1)
Ae. vexans	1(0.1)	2		2(0.2)
Ae. japonicus		1		1(0.1)
Ae. togoi	30(3.0)	202	237	439(37.3)
C. whitmorei		1		1(0.1)
C. p. pallens	926(92.7)	400	115	515(43.8)
C. tritaeniorhynchus	12(1.2)	3	3	6(0.5)
C. vorax	3(0.3)			
Total	999(100.0)	725	452	1,177(100.0)

from the beginning of June, becomes the most numerous in July, and decreases very much after October. But, the feature of the prevalence is modified in Abumize Village where the breeding places of the mosquito are liable to dry up unless the rainy weather continues for a long time, because of the sandy soil in the village. *Ae. togoi* is very common in Abumize Village where its favorable breeding places, i. e. the rock pools in the seashore are numerous. The mosquito is very abundant already in May, decreases in number at summer time, and becomes numerous again in autumn. The reduction in summer is caused chiefly by drying up of breeding places by high temperature. *Ar. subalbatus* seems to be a species which is rather abundant in autumn, as seen in Abumize, though in Nagate where breeding places of this species are few, only a small number of mosquitoes were collected, and therefore the seasonal prevalence

Table 3. Number and percentage (in parentheses) of mosquitoes collected at cowsheds at Nagate and Abumize Villages in 1961 and 1962.

Village	Nagate			Abumize		
Year	1961	1962	1961+1962	1961	1962	1961+1962
Month	V-XII	III-X		V-XII	III-X	
No. of cowsheds	48	45	93	48	50	98
An. sinensis	4	1	5(2.9)	13	11	24(2.8)
Ar. subalbatus	37		37(21.3)	259	83	342(39.5)
Ae. albopictus	4		4(2.3)			
Ae. vexans				4		4(0.5)
Ae. togoi	24	3	27(15.5)	186	219	405(46.8)
C. p. pallens	88	12	100(57.5)	61	19	80(9.2)
C. tritaeniorhynchus	1		1(0.6)	8	2	10(1.2)
C. vishnui				1		1(0.1)
Total	158	16	174(100.0)	532	334	866(100.0)

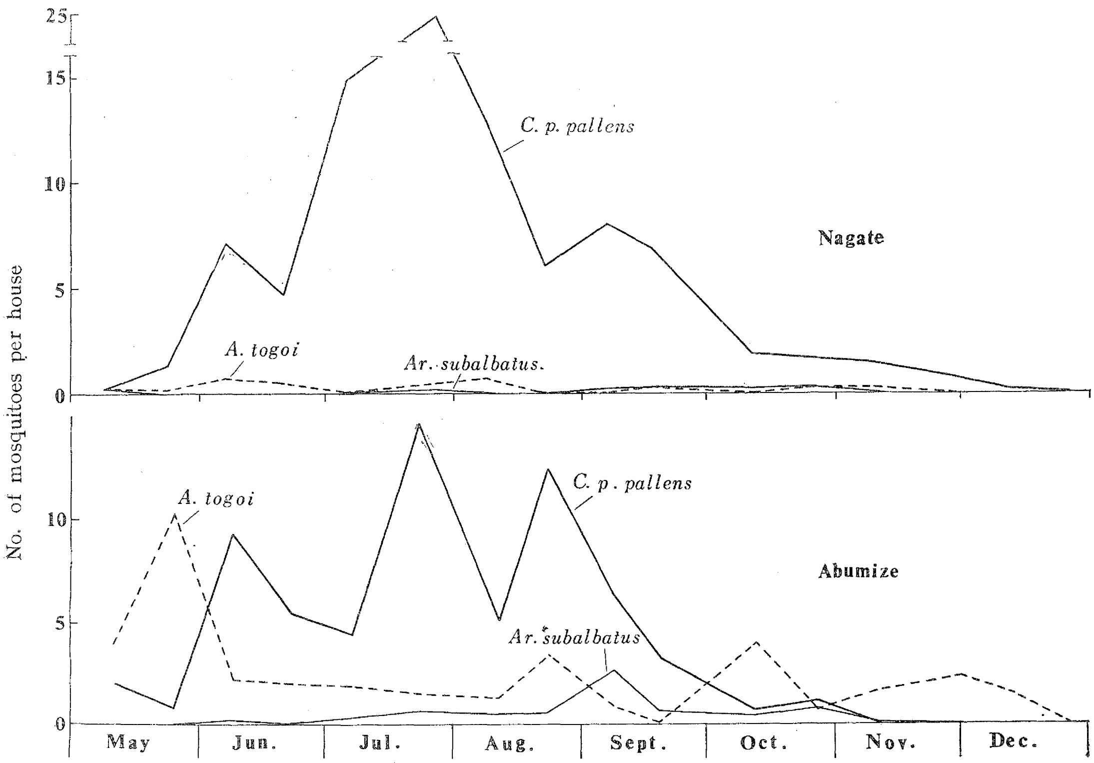

Fig. 1. Seasonal prevalence of *C. p. pallens*, *Ae. togoi*, and *Ar. subalbatus* collected in dwelling houses with microfilarial carriers at Nagate and Abumize Villages in 1961.

is not clearly shown. The seasonal prevalences of mosquitoes were also observed in 1962. At Nagate Village mosquito control works were operated in and after the beginning of June as will be given in detail in the next report.

At Abumize Village where control works were not yet started, the trends of the seasonal prevalences of the dominant species were roughly similar to those in 1961 excepting that *Ae. togoi* was fairly active in breeding in the summer probably owing to the more frequent rainfalls and rather lower temperatures in 1962.

Nocturnal activity of mosquitoes was investigated by using human-baited-traps at 34 nights during May to December in 1961 and 1962. Fig. 2

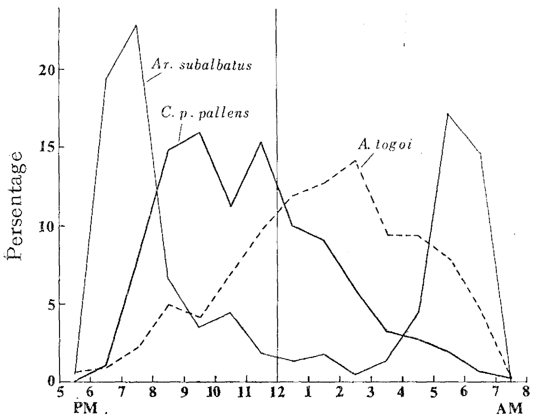

Fig. 2. Nocturnal activities of *C. p. pallens, Ae. togoi*, and *Ar. subalbatus* collected by human-baited-traps. Hourly percentage is obtained for each species to the total catch of the same species at Nagate and Abumize Villages in 1961 and 1962.

shows hourly percentage distribution of mosquitoes of each predominant species collected in the two villages during two years. ***C. p. pallens*** is the most active after 8 pm to midnight, gradually decreasing in activity towards dawn. The activity hours nearly cover those of microfilariae showing that *C. p. pallens* is very suitable mosquito to take up microfilariae in their nocturnal periodicity. *Ae. togoi* begins to increase from dusk, reaching maximum at 2 to 3 am, decreasing slowly towards dawn. However, the active hours of this mosquito are nearly as suitable as *C. p. pallens* for the taking up of microfilariae as far as the nocturnal activity is concerned. *Ar. subalbatus* is clearly crepuscular in activity, suggesting that it is unsuitable to pick up microfilariae.

Host preferences of the three dominant mosquito species are compared in Fig. 3 showing

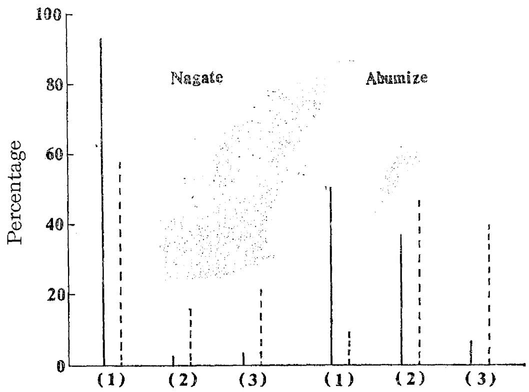

Fig. 3. Host preference of dominant mosquito species represented by the percentage of different species to the total catch in 1961 and 1962, respectively at Nagate and Abumize Villages and in dwelling houses and cowsheds. Solid line: dwelling house, broken line: cowshed. (1): *C. p. pallens*, (2): *Ae. togoi*, (3): *Ar. subalbatus*.

the relative abundances of the different species against the total catch collected in the two years respectively at Nagate and Abumize and in dwelling houses and cowsheds. Fig. 3 shows that ***C. p. pallens*** is clearly higher in relative abundance in mosquitoes collected in dwelling houses in both villages than in cowsheds, showing strong androphilism, and inversely ***Ar. subalbatus*** shows strong zoophilism in feeding habit, while ***Ae. togoi*** shows not necessarily strong zoophilism. The above suggests that *C. p. pallens* is the most important in the transmission of filariasis and ***Ae. togoi*** is rather inferior to the above species, while ***Ar. subalbatus*** is the least in the importance, as far as the host seleteing habit is concerned.

Natural infection of mosquitoes with *Wuchereria bancrofti*

Table 4 gives the total result of dissection for filaria larvae in each species of mosquitoes collected at dwelling houses having microfilarial carriers and at cowsheds. Natural infections of filaria larvae were found only in *C. p. pallens* and *Ae. togoi* collected at dwelling houses, while no infection was found in those at cowsheds. The number and percentage of *C. p. pallens* and *Ae. togoi* infected with the first, second, and third (infective) stage larvae are given in Table 5. Most infected mosquitoes of both species have the first stage larvae. The number of mosquitoes with the second stage larvae is very few, much fewer is those with the infective larvae. The fewness of mosquitoes with the second and third stage larvae may indicate rather short life-span of both species in these villages.

Table 4. Total results of natural infections with *Wuchereria bancrofti* in mosquitoes collected at dwelling houses having microfilarial carriers and at cowsheds at Nagate and Abumize Villages in 1961 and 1962.

Species	Dwelling houses			Cow-sheds		
	No. collected	No. infected	% infection	No. collected	No. infected	% infection
An. sinensis	19	0	0	11	0	0
Ar. subalbatus	131	0	0	83	0	0
Ae. albopictus	2	0	0	0	0	—
Ae. vexans	18	0	0	0	0	—
Ae. togoi	549	35	6.4	182	0	0
C. bitaeniorhynchus	1	0	0	0	0	—
C. p. pallens	1,660	160	9.6	28	0	0
C. tritaeniorhynchus	57	0	0	2	0	0
Total	2,437	195	8.0	306	0	0

Table 5. Natural infections with each stage larvae of *Wuchereric bancrofti* in *C. p. pallens* and *Ae. togoi* collected at dwelling houses with microfilarial carriers at Nagate and Abumize Villages in 1961 and 1962.

Species	Village	No. of mosquitoes dissected	No. (%) of mosquitoes infected	Mosquitoes infected					
				with 1st stage larvae		with 2nd stage larvae		with 3rd stage larvae	
				No.	%	No.	%	No.	%
C. p. pallens	Nagate	947	96(10.1)	91	9.6	6	0.6	0	0
	Abumize	713	64(9.0)	63	8.8	3	0.4	1	0.1
Ae. togoi	Nagate	26	1(3.8)	1	3.8	0	0	0	0
	Abumize	523	34(6.5)	32	6.1	2	0.4	1	0.2

Total infection rates of *C. p. pallens* and *Ae. togoi* are 10.1 and 3.8% at Nagate and 9.0 and 6.5% at Abumize respectively. To examine more clearly the difference in infection rate between the two species, the rates in mosquitoes collected at each of the same houses were compared in Fig. 4. The figure appears to indicate that the rate is higher in *C. p. pallens*. The reason may be due to the difference in the taking up of microfilariae at the time of feeding, for no difference in the hourly distribution of nocturnal feeding activity is observed between the two. To ascertain this, the number of the first, second and infective stage larvae found in mosquitoes of the two species are compared in Table 6. The table shows that the number of filaria larvae in a mosquito is clearly smaller in *Ae. togoi*. This seems, in its turn, to cause the smaller infection rate in this mosquito than in *C. p. pallens*.

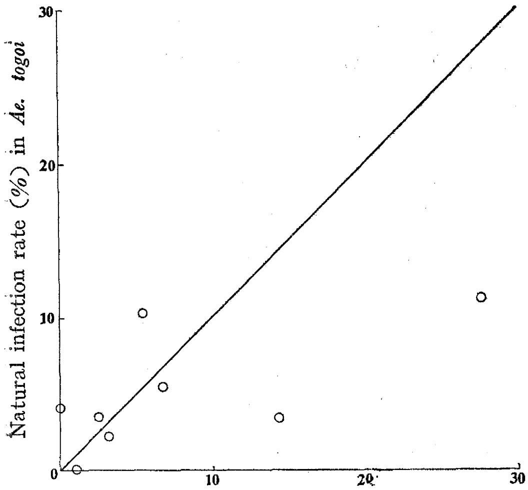

Fig. 4. Comparison of natural infection rate of *C. p. pallens* and *Ae. togoi* in each dwelling house having microfilarial carriers at Abumize Village in 1961 and 1962.

Table 6. Number of *Wuchereria bancrofti* larvae in infected *C. p. pallens* and *Ae. togoi* at Nagate and Abumize Villages.

Species	Village	Mean (and maximum) No. of larvae per mosquito			
		1st stage	2nd stage	3rd stage	Total
C. p. pallens	Nagate	4.9(100)	0.2(10)	0	5.1(100)
	Abumize	6.2(52)	0.7(26)	0.01(1)	6.9(52)
Ae. togoi	Nagate	1.0(1)	0	0	1.0(1)
	Abumize	3.9(27)	0.1(1)	0.1(5)	4.1(27)

Comparison of the role in the transmission of filariasis in Japan between *C. p. pallens* and *Ae. togoi*

Ae. togoi was proved by Nakamura (1964) of our Department experimentally to be as susceptible to *Wuchereria bancrofti* as *C. p. pallens*, but the role in nature has not been investigated fully. It is one of the objects of this study to make clear this problem. Here, a comparison of the role in the transmission of filariasis between the two mosquito species will be made briefly in the below, from the data described above.

Ae. togoi is found abundantly only in villages with rocky sea-shore, while *C. p. pallens* is the commonest mosquitoes in filariasis endemic villages in Japan. This difference in distribution shows that *Ae. togoi* is of limited importance. Moreover, *Ae. togoi* shows less strong androphilism than *C. p. pallens*, and the infection rate of *Ae. togoi* is rather lower than in *C. p. pallens*. These facts indicate minor importance of *Ae. togoi* in transmitting filariasis in Japan.

Summary

Ecology and natural filaria-infections of mosquitoes were investigated at Nagate and Abumize Villages, Fukue Island, Nagasaki Prefecture in 1961 and 1962. *Culex pipiens pallens*, *Aedes togoi*, and *Armigeres subalbatus* are dominant species at both villages. Hourly catches of mosquitoes by human-baited-traps show that *C. p. pallens* and *Ae. togoi* are nocturnal in feeding habit and peak activity is found two or three hours before midnight in the former species and after midnight in the latter; *Ar. subalbatus* is active around sunset or sunrise. From the comparison of mosquito collections at dwelling houses and at cowsheds, it is seen that *C. p. pallens* is strongly androphilic and *Ae. togoi* is rather zoophilic, while *Ar. subalbatus* is strongly zoophilic, Natural infections were found only in *C. p. pallens* and *Ae. togoi* collected at dwelling houses having microfilarial carriers. The rate of natural infection is higher and the number of filaria larvae found in mosquitoes is larger in *C. p. pallens* than in *Ae. togoi*. *Ae. togoi* is limited in distribution to the villages with many rock pools on rocky seacoast in comparison with very wide distribution of *C. p. pallens*. Being inferior to *C. p. pallens* in susceptibility to the parasite, *Ae. togoi* is of minor importance in the transmission of bancroftian filariasis even in the village where its breeding is very active.

References

1) Era, E. : Experimental studies on the periodicity of microfilariae. Endem. Dis. Bull. Nagasaki, 1(3) : 252-277, 1959. (In Japanese with English summary).

2) Nakamura, Y. : Experimental studies on the role of *Aedes togoi* in the transmission of bancroftian filariasis. (2) On the development of filariae in *Aedes togoi* and effect of their parasitism on the mosquito. Endem. Dis. Bull. Nagasaki, 6(2) : 113-124, 1964. (In Japanese with English summary).

3) Omori, N. : A review of the role of mosquitoes in the transmission of Malayan and Bancroftian filariasis in Japan. Bull. Wld Hlth Org., 27 : 585-594, 1962.

4) Omori, N. & Fujii, S. : On the feeding habits of *Aedes togoi* and some other species of mosquitoes. Yokohama Med. Bull., 4(1) : 23-31 1953.

5) Wada, Y. : Epidemiology of bancroftian filariasis in Nagate and Abumize Villages, Nagasaki Prefecture, especially in relation to vector mosquitoes. 1. Considerations on the changes in the endemicity of the filariasis. Endem. Dis. Bull. Nagasaki, 5(3) : 129-135, 1963a.

6) Wada, Y. : Epidemiology of bancroftian filariasis in Nagate and Abumize Villages, Nagasaki Prefecture, especially in relation to vector mosquitoes. 2. Endemicity of the filariasis. Endem. Dis. Bull. Nagasaki, 5(3) : 136-151, 1963b.

長崎県長手，鐙瀬両部落におけるバンクロフト糸状虫症の疫学的研究，特に伝搬蚊との関係について．
3．蚊の生態と自然感染．和田義人，長崎大学医学部医動物学教室（主任：大森南三郎教授）．長崎大学風土病研究所衛生動物部（主任：大森南三郎教授）．

総　　　括

長崎県福江島の長手，鐙瀬両部落において，1961年と1962年に，蚊の生態とフィラリアの自然感染についての調査を行なった．両部落における優占種はアカイエカ，トウゴウヤブカ及びオオクロヤブカである．人をおとりとした二重蚊帳による１時間毎の終夜採集の結果から，アカイエカの活動のピークは真夜中の２，３時間前に，トウゴウヤブカでは真夜中の２，３時間後にあって，何れの種も夜間活動性であり，オオクロヤブカは日出，日入の前後に活発であることがわかった．人家及び牛舎での蚊の採集成績を吟味した結果，アカイエカは強い人血嗜好性，トウゴウヤブカはどちらかと云えば大動物嗜好性，オオクロヤブカは強い大動物嗜好性を示すことがわかった．フィラリア患者のいる人家で採集されたアカイエカとトウゴウヤブカにおいて自然感染が見られたが，前者では感染率はより高く，蚊体内のフィラリア幼虫数もより多い．トウゴウヤブカの分布は，海岸に多数のロックプールがあって好適な発生源となっている部落に局限されて居り，アカイエカは日本中極めて普通に見られるが，この事実を除外して考えても，上記のデータからトウゴウヤブカのフィラリア伝搬上の重要性は小さいと結論できる．

1966年２月22日受付