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COMPARISON OF POPULATION OF VECTOR MOSQUITOES OF *DIROFILARIA IMMITIS* AND THEIR NATURAL INFECTION RATES IN SOUTHERN AND NORTHERN PARTS OF NAGASAKI CITY, JAPAN

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Abstract: Female mosquitoes including *Culex pipiens pallens*, the main vector of *Dirofilaria immitis*, and some secondary vectors, were collected at 4 to 10 sites in Nagasaki City from 1983 to 1989 using light traps, and the number of the mosquitoes and the natural infection rate with *D. immitis* were compared between the southern and the northern parts of the city. In 1983, *Cx. p. pallens* was extremely prevalent in the southern part but not in the northern part. After 1986, the prevalence of *Cx. p. pallens* became very low in both the parts. The rapid decrease of prevalence of this species may be attributable to the decrease in breeding sites by improvement of roads and open roadside ditches in parallel with spread of sewage systems. On the basis of the number of infected mosquitoes in Nagasaki City, it was suggested that, *Cx. tritaeniorhynchus* and *Ae. albopictus* are important vectors in addition to *Cx. p. pallens*, but *Ae. togoi* does not play a significant role in the transmission of *D. immitis*.

INTRODUCTION

We previously reported that the percentage of house dogs having the larvae of *Dirofilaria immitis* increased from 1968 to 1983 in the eastern, the western and the southern parts of Nagasaki City, but this percentage decreased during the same period in the northern part of the city (Oda *et al.*, 1993). We also assumed that the decrease of the infection rate of house dogs in the northern part be due to the spread of public sewage systems contributing to the reduction of breeding sites of the main vector mosquito, *Culex pipiens pallens*. To test the validity of this assumption, we compared the number and the natural infection rate of *Cx. p. pallens*, caught by using light traps, between the southern and the northern parts of this city during the period from 1983 to 1989, and analyzed the data in relation to the development of public sewage systems. Furthermore, we attempted to clarify the role of some secondary vector mosquitoes in the transmission by comparing the population densities and the natural infection rates.

PLACES AND METHODS

Between 1983 and 1989, we collected mosquitoes including *Cx. p. pallens*, which is the main vector mos quito, and three secondary vectors (*Cx. tritaeniorhynchus, Ae. albopictus* and *Ae. togoi*), using light traps (20 watt black light), in the southern part of Nagasaki City where the microfilaria positive rate was high and in the northern part where the positive rate was low. In 1983, we placed a trap in each of two southern districts

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Table 1 Period and place of mosquito collection in Nagasaki City

Date and (times) of collection	Southern part			Northern part		
	Trap. No.	District No. and name	Place of collection	Trap. No.	District No. and name	Place of collection
1983 Jul. 28-Oct. 21 (13)	S 1	28 Fukahori	Building	N 1	39 Nishiurakami	Building
	S 2	27 Doinokubi	Building	N 2	34 Sakamoto	Building
1986 Aug. 18-Sep. 27 (24)	S 3	25 Tomachi	Building	N 3	35 Takao	Building
	S 4	25 Tomachi	Building	N 4	35 Takao	Building
1987 Jul. 1-Sep. 1 (24)	S 5	25 Tomachi	House	N 5	36 Yamazato	House
1988 Jun. 10-Aug. 11 (27)	S 6	25 Tomachi	House	N 6	34 Sakamoto	House
	S 7	25 Tomachi	House	N 7	34 Sakamoto	House
1989 Jun. 5-Aug. 10 (20)	S 8	25 Tomachi	House	N 8	34 Sakamoto	House
	S 9	25 Tomachi	House	N 9	34 Sakamoto	House

S and N show southern and northern parts, respectively.

(Doinokubi and Fukahori) and two northern districts (Nishiurakami and Sakamoto). These four light traps were, as a rule, lit for operation twice weekly. In 1986, we placed 2 traps in a southern district (Tomachi) and 2 in a northern district (Takao), and collected mosquitoes three or four times weekly. In 1987 through 1989, we placed a trap in 5 houses which had microfilaria -positive dogs in each of the southern and the northern parts of the city. These light traps were lit three or four times weekly. Table 1 shows the survey sites and periods. Fig. 1 shows the locations where light traps were placed. The names and lot numbers for Nagasaki City districts were derived from the residence list of the parts used by Suenaga *et al.* (1971). The mosquitoes collected were identified and kept at −12°C. Under a stereomicroscope, female mosquitoes were dissected in physiological saline and examined for larvae of *D. immitis*. The developmental stages of larvae were decided using the classification of Suenaga (1972).

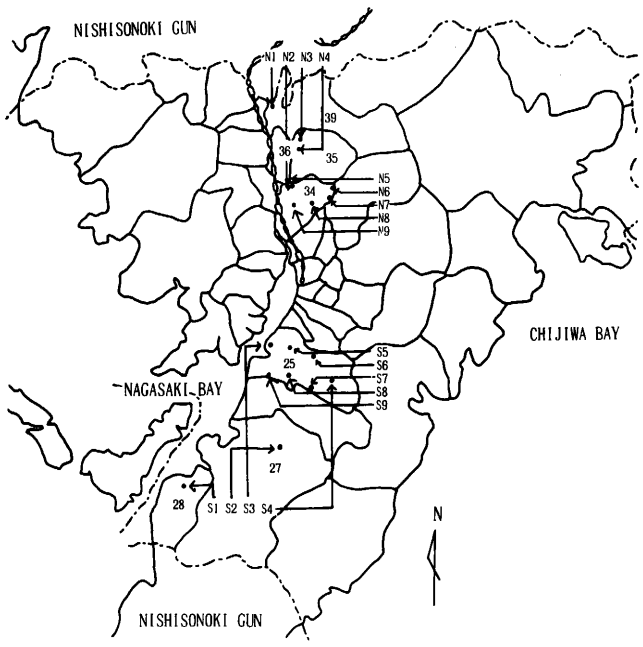

Figure 1 A map* showing district No. and place of light traps for collection of vector mosquitoes in sourthern and northern parts of Nagasaki City (see Table 1 for district No. and trap No.).

*Cited from Suenaga *et al.*, 1971.

RESULTS

I. Population and natural infection rate of the main vector mosquito, *Cx. p. pallens*, in the southern and the northern parts

1. Number of *Cx. p. pallens*

Table 2 shows the monthly numbers of female *Cx. p. pallens* in the southern and the northern parts in 1983. In two southern districts with considerably high microfilaria positive rate in dogs where Trap S1 and S2 were operated, larger numbers of mosquitoes were caught in July through October, compared with two northern districts with low positive rate where Trap N1 and N2 were operated. A comparison of the mean numbers revealed that the number of *Cx. p. pallens* caught in the southern part was about three times larger than that in the northern part.

Table 3 shows the data obtained in 1986 in Tomachi (a southern district with high microfilaria positive rate) and in Takao (a northern district with a little high

Table 2 Number of *Culex pipiens pallens* females collected by a light trap in southern and northern parts in Nagasaki City, 1983

Month and (times) of collection	No. of females collected in the indicated trap* in southern part						No. of females collected in the indicated trap* in northern part					
	S 1*		S 2*		Total		N 1*		N 2*		Total	
	No.	(Mean)	No.	(Mean)	No.	(Mean**)	No.	(Mean)	No.	(Mean)	No.	(Mean**)
Jul. (2)	7	(3.5)	5	(2.5)	12	(3.0)	2	(1.0)	5	(2.5)	7	(1.75)
Aug. (5)	41	(8.2)	34	(6.8)	75	(7.5)	4	(0.8)	12	(2.4)	16	(1.6)
Sep. (4)	8	(2.0)	4	(1.0)	12	(1.5)	2	(0.5)	7	(1.75)	9	(1.13)
Oct. (2)	11	(5.5)	2	(1.0)	13	(3.25)	2	(1.0)	3	(1.5)	5	(1.25)
Total (13)	67	(5.15)	45	(3.46)	112	(4.31)	10	(0.77)	27	(2.08)	37	(1.43)

* Trap No. is shown in Table 1.
**Mean number of females indicates mean per trap per night.

Table 3 Number of *Culex pipiens pallens* females collected by a light trap in southern and northern parts in Nagasaki City, 1986

Month and (times) of collection	No. of females collected in the indicated trap* in southern part						No. of females collected in the indicated trap* in northern part					
	S 3*		S 4*		Total		N 3*		N 4*		Total	
	No.	(Mean)	No.	(Mean)	No.	(Mean**)	No.	(Mean)	No.	(Mean)	No.	(Mean**)
Aug. (2)	1	(0.5)	0	(0.0)	1	(0.25)	0	(0.0)	0	(0.0)	0	(0.0)
Sep. (4)	2	(0.5)	0	(0.0)	2	(0.25)	1	(0.25)	1	(0.25)	2	(0.25)
Total (6)	3	(0.5)	0	(0.0)	3	(0.25)	1	(0.17)	1	(0.17)	2	(0.17)

* Trap No. is shown in Table 1.
**Mean number of females indicates mean per trap per night.

microfilaria positive rate). In contrast to the data in 1983, only a few *Cx. p. pallens* were caught in the both districts in 1986 (Table 3). Then we placed a light trap in 5 households keeping dogs positive for microfilariae in each of three districts (Tomachi in the southern part, and Sakamoto and Yamazato in the northern part), and examined the number of *Cx. p. pallens* caught during the three-year period from 1987 to 1989. As shown in Table

Table 4 Number of *Culex pipiens pallens* females collected by a light trap in southern and northern parts in Nagasaki City, 1987-1989

Year and (time) of collection	No. of females collected in the indicated trap* in southern part											
	S 5*		S 6*		S 7*		S 8*		S 9*		Total	
	No.	(Mean)	No.	(Mean)	No.	(Mean)	No.	(Mean)	No.	(Mean)	No.	(Mean**)
1987 (24)	0	(0.0)	5	(0.21)	0	(0.0)	2	(0.08)	4	(0.17)	11	(0.09)
1988 (27)	3	(0.11)	3	(0.11)	1	(0.04)	0	(0.0)	0	(0.0)	7	(0.05)
1989 (20)	1	(0.05)	1	(0.05)	2	(0.1)	1	(0.05)	2	(0.1)	7	(0.07)
Year and (time) of collection	No. of females collected in the indicated trap* in northern part											
	N 5*		N 6*		N 7*		N 8*		N 9*		Total	
	No.	(Mean)	No.	(Mean)	No.	(Mean)	No.	(Mean)	No.	(Mean)	No.	(Mean**)
1987 (24)	0	(0.0)	6	(0.25)	12	(0.5)	7	(0.29)	1	(0.04)	26	(0.22)
1988 (27)	0	(0.0)	2	(0.07)	5	(0.19)	3	(0.11)	0	(0.0)	10	(0.07)
1989 (20)	0	(0.0)	2	(0.1)	3	(0.15)	1	(0.05)	4	(0.2)	10	(0.10)

* Trap No. is shown in Table 1.
**Mean number of females indicates mean per trap per night.

Table 5-1 Annùal changes in rate of population using a sewage system in southern and northern parts in Nagasaki City, 1983-1986

Part	District	Year											
		1983			1984			1985			1986		
	No. Name	Total population (A)	Population using SS* (B)	RPSS** (B/A×100)	Total population (A)	Population using SS* (B)	RPSS** (B/A×100)	Total population (A)	Population using SS* (B)	RPSS** (B/A×100)	Total population (A)	Population using SS* (B)	RPSS** (B/A×100)
Southern	20 Sako	6,934	4,802	69.3	6,781	5,035	74.3	6,877	5,705	83.0	6,912	5,900	85.4
	21 Nita	5,144	1,410	27.4	5,022	1,671	33.3	5,052	2,552	50.5	5,138	3,218	62.6
	22 Kitaohura	12,548	1,379	11.0	12,410	1,503	12.1	12,185	1,751	14.4	11,927	2,059	17.3
	23 Minamiohura	6,999	0	0.0	6,848	0	0.0	6,698	0	0.0	6,598	0	0.0
	24 Naminohira	3,531	0	0.0	3,415	0	0.0	3,318	0	0.0	3,122	0	0.0
	25 Tomachi	15,496	0	0.0	15,408	0	0.0	15,459	4,719	30.5	15,490	5,190	33.5
	26 Kogakura	5,715	0	0.0	5,609	0	0.0	6,167	4,805	77.9	6,869	5,335	77.7
	27 Doinokubi	15,034	0	0.0	15,289	0	0.0	15,382	0	0.0	15,329	0	0.0
	28 Fukahori	11,275	0	0.0	11,452	0	0.0	11,241	0	0.0	10,920	0	0.0
	29 Minami	993	0	0.0	988	0	0.0	986	0	0.0	990	0	0.0
	30 Mogi	7,504	1,490	19.9	7,515	1,410	18.8	7,615	1,402	18.4	7,787	1,330	17.1
	31 Hayasaka	5,846	0	0.0	5,832	0	0.0	5,908	0	0.0	5,821	199	3.4
	32 Hiyoshi	1,615	0	0.0	1,612	0	0.0	1,575	0	0.0	1,565	0	0.0
	Total	98,634	9,081	9.2	98,181	9,619	9.8	98,463	20,934	21.3	98,468	23,231	23.6
Northern	33 Zenza	6,449	4,869	75.5	6,413	4,932	76.9	6,236	5,035	80.7	6,194	5,242	84.6
	34 Sakamoto	10,874	6,621	60.9	10,848	6,616	61.0	10,724	6,767	63.1	10,737	7,271	67.7
	35 Takao	18,620	0	0.0	18,984	0	0.0	18,860	0	0.0	18,694	0	0.0
	36 Yamazato	11,754	1,820	15.5	11,438	1,752	15.3	11,531	1,799	15.6	11,650	1,748	15.0
	37 Nishishiroyama	13,352	0	0.0	13,665	0	0.0	13,982	0	0.0	14,126	0	0.0
	38 Shiroyama	6,153	0	0.0	6,132	0	0.0	6,001	0	0.0	6,030	0	0.0
	39 Nishiurakami	23,790	3,063	12.9	19,744	995	5.0	19,649	964	4.9	19,590	1,064	5.4
	40 Nameshi	39,120	38,622	98.7	39,336	38,584	98.1	39,663	40,474	102.0	39,758	40,974	103.1
	41 Nishikita	12,179	404	3.3	12,108	564	4.7	12,222	551	4.5	12,386	551	4.4
	42 Nishimachi	17,228	0	0.0	16,973	0	0.0	16,841	0	0.0	16,878	0	0.0
	43 Kawabira	6,926	0	0.0	4,478	0	0.0	4,401	0	0.0	4,392	0	0.0
	Total	166,445	55,399	33.3	160,119	53,443	33.4	160,110	55,590	34.7	160,435	56,850	35.4

* SS: sewage system
**RPSS: the rate of population utilizing a sewage system.

4, the number of *Cx. p. pallens* caught was again very small in each district.

2. Relationship between *Cx. p. pallens* population and development of sewage system

The sharp decrease in number of *Cx. p. pallens* in the southern and the northern parts of Nagasaki City during the 1986-1989 period seems to be associated with the improvement of public sewage systems. Tables 5-1 and 5-2 show annual changes in the rate of human population utilizing sewage systems (RPSS) in the total population of the southern and the northern parts. The RPSS values were not so high in Nagasaki City as those in other cities in Japan, owing to a characteristic topography with a lot of steep slopes, which made difficult to establish the sewage system. In 1983 and 1984, only 4 of the 13 southern districts had sewage systems. After 1985, sewage systems were found in about half of all southern districts. The RPSS for the southern part was low in 1983 (9.2%) and 1984 (9.8%). It was doubled in 1985 (21.3%) and further rose to 37.0% in 1989. In the northern part, sewage systems were already present in 1983 and 1984 in 6 of the 11 districts. The RPSS was about 33.0% in 1983 and 1984, which was much higher than the rate for the southern part. It is therefore evident that sewage systems had been better developed in the northern part than in the southern part of this city around 1983.

Fig. 2 shows the relationship between the RPSS and the number of *Cx. p. pallens* caught in individual districts. The values of RPSS used in this figure were derived from Tables 5-1 and 5-2. The RPSS value in 1983 for the southern part is the average for Fukahori and Doinokubi, and the value for the northern part is the average for Nishiurakami and Sakamoto. Because Takao, Sakamoto and Yamazato were located close to each other, the RPSS values in 1984 through 1989 for these three districts in the northern part were averaged.

Table 5-2 Annual changes in rate of population using a sewage system in southern and northern parts in Nagasaki City, 1987-1989

Part	District No.	Name	Year 1987 Total population (A)	1987 Population using SS* (B)	1987 RPSS** (B/A×100)	1988 Total population (A)	1988 Population using SS* (B)	1988 RPSS** (B/A×100)	1989 Total population (A)	1989 Population using SS* (B)	1989 RPSS** (B/A×100)
Southern	20	Sako	6,744	5,959	88.4	6,554	6,217	94.9	6,352	5,940	93.5
	21	Nita	5,330	4,097	76.9	5,216	428	8.2	5,071	4,313	85.1
	22	Kitaohura	11,753	2,354	20.0	11,392	2,809	24.7	11,137	2,848	25.6
	23	Minamiohura	6,408	0	0.0	6,361	0	0.0	6,213	0	0.0
	24	Naminohira	3,110	0	0.0	3,036	0	0.0	2,979	0	0.0
	25	Tomachi	15,206	6,085	40.0	14,852	6,577	44.3	14,670	7,855	53.5
	26	Kogakura	7,508	5,918	78.8	8,203	6,349	77.4	8,471	6,825	80.6
	27	Doinokubi	16,064	550	3.4	16,480	1,277	7.8	16,902	1,737	10.3
	28	Fukahori	10,603	0	0.0	10,353	0	0.0	10,007	0	0.0
	29	Minami	978	0	0.0	957	0	0.0	950	0	0.0
	30	Mogi	7,997	1,311	16.4	8,083	1,307	16.2	8,239	998	12.1
	31	Hayasaka	5,803	567	9.8	5,831	1,014	17.4	5,679	1,844	32.5
	32	Hiyoshi	1,550	0	0.0	1,544	0	0.0	1,549	0	0.0
		Total	99,054	26,841	27.1	98,862	29,818	30.2	98,219	32,360	33.0
Northern	33	Zenza	6,045	5,206	86.1	5,984	5,176	86.5	5,757	5,029	87.4
	34	Sakamoto	10,679	7,260	68.0	10,390	7,105	68.4	10,161	6,868	67.6
	35	Takao	18,396	0	0.0	18,424	228	1.2	18,054	839	4.6
	36	Yamazato	12,005	1,760	14.7	11,715	2,727	23.3	11,428	3,283	28.7
	37	Nishishiroyama	11,594	0	0.0	11,358	0	0.0	11,020	0	0.0
	38	Shiroyama	5,869	0	0.0	5,813	0	0.0	5,775	0	0.0
	39	Nishiurakami	19,647	1,116	5.7	19,466	1,291	6.6	19,437	1,337	6.9
	40	Nameshi	40,188	41,493	103.2	30,088	40,985	102.2	39,240	39,240	100.0
	41	Nishikita	12,246	583	4.8	12,205	600	4.9	12,008	609	5.1
	42	Nishimachi	16,826	0	0.0	16,468	0	0.0	16,374	0	0.0
	43	Kawabira	4,340	0	0.0	4,249	0	0.0	4,151	0	0.0
		Total	57,835	57,418	36.4	166,160	58,112	37.2	153,405	57,205	37.3

* SS: sewage system
**RPSS: the rate of population utilizing a sewage system.

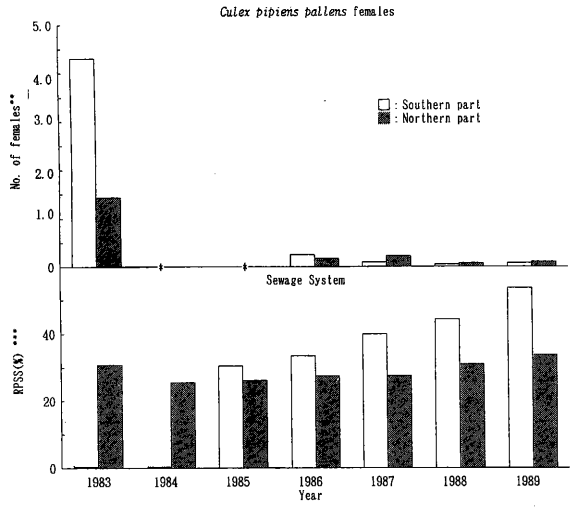

Figure 2 Annual changes in number of *Culex pipiens pallens* females and rate of population using a sewage system in southern and northern parts in Nagasaki City, 1983-1989 (see Tables 1 to 5-2).

* Collection was not made.
** Mean number of females/trap/night.
***RPSS shows the rate of population utilizing a sewage system.

The number of *Cx. p. pallens* was expressed by the mean per trap per night. As seen in Fig. 2, the southern part had a high density of *Cx. p. pallens* and inadequate public sewage systems in 1983, but the sewage systems became to be spread widely from 1986, resulting in a sharp decrease in *Cx. p. pallens*. Fig. 2 also indicates that the northern part had less *Cx. p. pallens* and more extensive public sewage systems already around 1983, compared with the southern part. Such sharp decrease of this mosquito in 1986 on seems to be due to a decrease in the breeding sites, by improvement of roads and open roadside ditches in pararell with the spread of sewage system.

3. Natural infection rates

Table 6 shows the natural infection rate in *Cx. p. pallens*. The percentage of larvae-having mosquitoes in 1983 was zero in the northern part, but it was 0.9% in the southern part. Similar results were also obtained in 1986 and 1988. These results suggest that *Cx. p. pallens* were more abundant and the natural infection rate was higher

Table 6 Number and percentage of *Culex pipiens pallens* females with *D. immitis* larvae in southern and northern parts in Nagasaki City, 1983-1989

Year	Southern part		Northern part	
	No. females dissected (A)	No. (B) and (%)* of females with larvae	No. females dissected (A)	No. (B) and (%)* of females with larvae
1983	112	1**(0.9)	37	0 (0.0)
1986	3	1**(33.3)	2	0 (0.0)
1987	11	0 (0.0)	26	2**(7.7)
1988	7	1**(14.3)	10	0 (0.0)
1989	7	0 (0.0)	10	0 (0.0)

* Natural infection rate (B/A×100)
**1st stage larvae

in the southern part than in the northern part.

II. Population and natural infection rates of three secondary vector mosquitoes in the southern and the northern parts

For the 1983-1989 period, we analyzed the number (the mean per trap per night) of *Cx. tritaeniorhynchus*, *Ae. albopictus* and *Ae. togoi* and their natural infection rate (the percentage of *D. immitis* larvae-carrying mosquitoes) in the southern and the northern parts of Nagasaki City.

Table 7 shows the annual number of *Cx. tritaeniorhynchus* for the southern and the northern parts. There was no significant difference in the annual number of this mosquito between the southern and the northern parts. The natural infection rate for this species also did not differ significantly between the two parts of the city.

The number of *Ae. albopictus* did not differ significantly in any year between the southern and the northern parts (Table 8). The natural infection rate for this species tended to be little different between the northern and the southern parts.

The number and the infection rate of *Ae. togoi* are shown in Table 9. Any *Ae. togoi* were not caught in the northern part, and the number was very small in the southern part. Only one female was found to be infected in the southern part.

Table 7 Number of *Culex tritaeniorhynchus* females collected in light traps and natural infection rate in southern and northern parts in Nagasaki City, 1983-1989

Year and (times) of collection	Southern part			Northern part		
	Total No. females (A) collected and dissected	Mean No.*	Females with larvae No. (B) (%)***	Total No. females (A) collected and dissected	Mean No.*	Females with larvae** No. (B) (%)***
1983 (13)	115	4.43	1** (0.9)	200	7.69	1** (0.5)
1986 (6)	19	1.59	0 (0.0)	26	2.17	0 (0.0)
1987 (24)	300	2.50	14** (4.7)	150	1.25	11** (7.3)
1988 (27)	593	4.39	2** (0.3)	695	5.15	6** (0.9)
1989 (20)	152	1.52	0 (0.0)	159	1.59	0 (0.0)

* Mean number of females/trap/night.
** 1st stage larvae
***Natural infection rate (B/A×100)

Table 8 Number of *Aedes albopictus* females collected in light traps and natural infection rate in southern and northern parts in Nagasaki City, 1983-1989

Year and (times) of collection	Southern part			Northern part		
	Total No. females (A) collected and dissected	Mean No.*	Females with larvae No. (B) (%)***	Total No. females (A) collected and dissected	Mean No.*	Females with larvae No. (B) (%)***
1983 (13)	9	0.35	1** (11.1)	10	0.39	0 (0.0)
1986 (6)	1	0.09	0 (0.0)	4	0.34	0 (0.0)
1987 (24)	25	0.21	1** (4.0)	51	0.43	1** (2.0)
1988 (27)	63	0.47	0 (0.0)	39	0.29	3** (7.7)
1989 (20)	27	0.27	0 (0.0)	16	0.16	5** (31.3)

* Mean number of females/trap/night.
** 1st stage larvae
***Natural infection rate (B/A×100)

Table 9 Number of *Aedes togoi* females collected in light traps and natural infection rate in southern and northern parts in Nagasaki City, 1983-1989

Year and (times) of collection	Southern part			Northern part		
	Total No. females (A) collected and dissected	Mean No.*	Females with larvae No. (B) (%)***	Total No. females (A) collected and dissected	Mean No.*	Females with larvae No. (B) (%)***
1983 (13)	4	0.16	1** (25.0)	0	—	—
1986 (6)	1	0.09	0 (0.0)	0	—	—
1987 (24)	2	0.02	0 (0.0)	0	—	—
1988 (27)	3	0.02	0 (0.0)	0	—	—
1989 (20)	2	0.02	0 (0.0)	0	—	—

* Mean number of females/trap/night.
** 1st stage larvae
***Natural infection rate (B/A×100)

Table 10 Annual changes in mean number of 3 species of vector mosquitoes and natural infection rate in Nagasaki City, 1983-1989

Year	*Cx. p. pallens*			*Cx. tritaeniorhynchus*			*Ae. albopictus*		
	Mean No.* (A)	Natural Inf.** (B)	Infected No. (A×B)	Mean No.* (A)	Natural Inf.** (B)	Infected No. (A×B)	Mean No.* (A)	Natural Inf.** (B)	Infected No. (A×B)
1983	2.87	0.45	1.2915	6.06	0.70	4.2420	0.37	5.55	2.0535
1986	0.21	16.65	3.4965	1.88	0.00	0.0000	0.22	0.00	0.0000
1987	0.16	3.85	0.6160	1.88	6.00	11.2800	0.32	3.00	0.9600
1988	0.06	7.15	0.4290	4.77	0.60	2.8620	0.38	3.85	1.4630
1989	0.09	0.00	0.0000	1.56	0.00	0.0000	0.22	15.65	3.4430

* Mean number of females/trap/night.
**Natural Inf. (Natural infection rate in %)

III. Comparison of the role in the transmission among *Cx. p. pallens, Cx. tritaeniorhynchus* and *Ae. albopictus*

From the number and the natural infection rate of female mosquitoes of three dominant species collected to date, the number of infected females was determined annually as shown in Table 10. Generally speaking, the natural infection rate of *Cx. tritaeniorhynchus* was lower and the number of the females was much greater than that of *Cx. p. pallens*, but the number of infected females was about as same as that in *Cx. p. pallens*. On the other hand, the number of *Ae. albopictus*, the natural infection rate and the number of infected females all were similar to that in *Cx. p. pallens*.

DISCUSSION

Before 1980, the number of *Cx. p. pallens* caught in Tomachi (a southern district) was considerably large (Oda *et al.*, 1993). From 1986 on, however, the number has been almost zero. This change in Tomachi may be attributable to a decrease in the sites where the mosquitoes can breed, following environmental changes, i. e., construction of large-scale apartments after about 1982, completion of southern Nagasaki sewage disposal plants in 1984, establishment of a sewage system for Tomachi in 1985 (Tables 5-1 and 5-2), and accompanying changes in roads and open roadside ditches. The number of *Cx. p. pallens* in Nagasaki City will further decrease as the current plan to expand sewage systems is put into practice.

Suenaga *et al.* (1973) suggested the principal role of *Cx. p. pallens* in the transmission of *D. immitis* in Nagasaki City, on the grounds that the number was larger and the natural infection rate was higher in *Cx. p. pallens* than in *Cx. tritaeniorhynchus* and *Ae. albopictus*. In the present study, the infection rate of *Cx. tritaeniorhynchus* was lower but the number was larger than that of *Cx. p. pallens*, resulting in similar numbers of infected mosquitoes in the both species. This may indicate that the relative importance of *Cx. tritaeniorhynchus* in the transmission has recently become a little higher in Nagasaki City as Konishi (1989) reported that this mosquito is important in transmission of *D. immitis* in Kobe. Although we can not estimate exactly the population size of *Ae. albopictus* by a light trap because they are active in daytime, our data showed that the number

of infected females of *Ae. albopictus* was not very different from that of *Cx. p. pallens*. Therefore the ability of transmission of *Ae. albopictus* seems to be quite high in the city. *Ae. togoi* was caught only in the southern part and its number was very small, but the natural infection rate was high. Keegan (1967) was the first to report *D. immitis*-carrying *Ae. togoi*. Prior to the present paper, however, no survey of *D. immitis*-carrying *Ae. togoi* in Nagasaki City has been published. Since the number of *Ae. togoi* caught was very small, this seems to have little relationship with the transmission of *D. immitis*, as suggested by Suenaga *et al.* (1973).

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REFERENCES CITED

1) Keegan, H. L., Betchley, W. W., Haberkorn, T. B., Nakasone, A. Y., Sugiyama, H., and Warme, R. T. (1967): Laboratory and field studies of some entomological aspects of canine dirofilariasis problem in Japan. Jap. J. Saint. Zool. 18, 6-18.

2) Konishi, E. (1989): *Culex tritaeniorhynchus* and *Aedes albopictus* (Diptera: Culicidae) as natural vectors of *Dirofilaria immitis* (Spirurida: Filariidae) in Miki City, Japan. J. Med. Ent. 26(4) : 294-300.

3) Oda, T., Suenaga, O., Mori, A., Fujita, K., Zaitsu, M., Kurokawa, K., Nishioka, T., Itoh, T., and M. Mine (1993): Studies on epidemiology of *Dirofilaria immitis* in house dogs in Nagasaki City, Japan, with considerations on yearly changes in microfilarial prevalence. Jpn. J. Trop. Med. Hyg., 21, 231-237.

4) Suenaga, O., Itoh, T and T. Nishioka (1971): Studies on the filarial prevalence among house dogs and the mosquito vectors in Nagasaki City, Western Japan. 1. on the natural infection rate among house dogs in Nagasaki City. Trop. Med., 12, 169-178. (in Japanese with English summary).

5) Suenaga, O. (1972): Studies on the filarial prevalence among house dogs and the mosquito vectors in Nagasaki City, Western Japan. 2. on the susceptibility of four common mosquitoes to the larvae of *Dirofilaria immitis* in Nagasaki City. Trop. Med., 14, 32-40. (in Japanese with English summary).

6) Suenaga, O., Itoh, T. and T. Nishioka (1973): Studies on the filarial prevalence among house dogs and the mosquito vectors in Western Japan. 5. on the vector mosquitoes of *Dirofilaria immitis* in Nagasaki City. Trop. Med., 15, 131-140. (in Japanese with English summary).