

# Seasonal Prevalence of Mosquitoes, Including Vectors of Brugian Filariasis, in Southern Islands of the Republic of Korea

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**Abstract:** A survey of mosquitoes, including the vector status of *Brugia malayi* filariasis and their relative larval density, was conducted from 2002 to 2005 at several southern remote islands of Jeollanam-do (province), Gyeongsangnam-do, and Jeju-do, Korea, where filariasis was previously endemic. Overall, a total of 9 species belonging to 7 genera were collected. *Ochlerotatus togoi* (formerly known as *Aedes togoi*), *Anopheles (Hyrceanus)* group, and *Culex pipiens* were the predominant species captured at all areas. *Oc. togoi* larvae were most frequently collected at salinity levels <0.5‰ during June and July, with densities decreasing sharply during the rainy season in August. The most likely explanation for the eradication of filariasis in these areas is suggested to be an aggressive treatment program executed during the 1970s and the 1990s. However, high prevalence of the vector mosquitoes may constitute a potential risk for reemerging of brugian filariasis in these areas.

**Key words:** *Ochlerotatus togoi* (= *Aedes togoi*), *Anopheles (Hyrceanus)* group, vector, brugian filariasis, southern islands

## INTRODUCTION

The identification of vector species and their relative population densities is important for a better understanding of the transmission of zoonotic and human pathogens and the epidemiology of emerging and reemerging diseases. In the Republic of Korea, lymphatic filariasis was prevalent in the inland areas of Gyeongsangbuk-do (do= province) and coastal and southern areas of Jeollanam-do and Jeju-do. However, the prevalence of filariasis has decreased sharply due to medical treatments of microfilaria-positive patients and increased use of mosquito nets [1-5]. The islands of Heuksan, Sinan-gun (county), Jeollanam-do, were identified as endemic foci of filariasis in the mid-1980s (mean microfilaria positive rate: 12.5%). However, the positive rate in endemic regions dropped to 0%, and it was finally reported that filariasis had been eradicated from Korea [6].

*Ochlerotatus togoi* (formerly known as *Aedes togoi*) is the primary vector of lymphatic filariasis along the coastal areas of Jeju-do and other southern islands, whereas *Anopheles sinensis sensu stricto*, associated with rice paddies, is found in inland areas [3,7]. In these regions, however, vector mosquitoes and their larval densities have not been fully studied. There is also little information on their distribution and relative population densities of filariasis vectors and other mosquitoes in previous endemic areas. In the present study, mosquito surveillance was conducted to identify relative distributions and population densities of filariasis vectors in previous endemic areas in Korea.

## MATERIALS AND METHODS

### Survey areas

The southern islands of Jeollanam-do (Sa-ri [ri= village] and Sim-ri, Heuksan Islands in Sinan-gun, 2002; Baekdo-ri, Bogil Island in Wando-gun, 2003; Geomun-ri, Geomun Island in Yeosu-si [si= district], 2004), Gyeongsangnam-do (Maejuk-ri, Maemul Island in Tongyoung-si, 2004), and Jeju-do (Island) (Wimi-ri, Seogui-po-si, 2005) were surveyed (Fig. 1).

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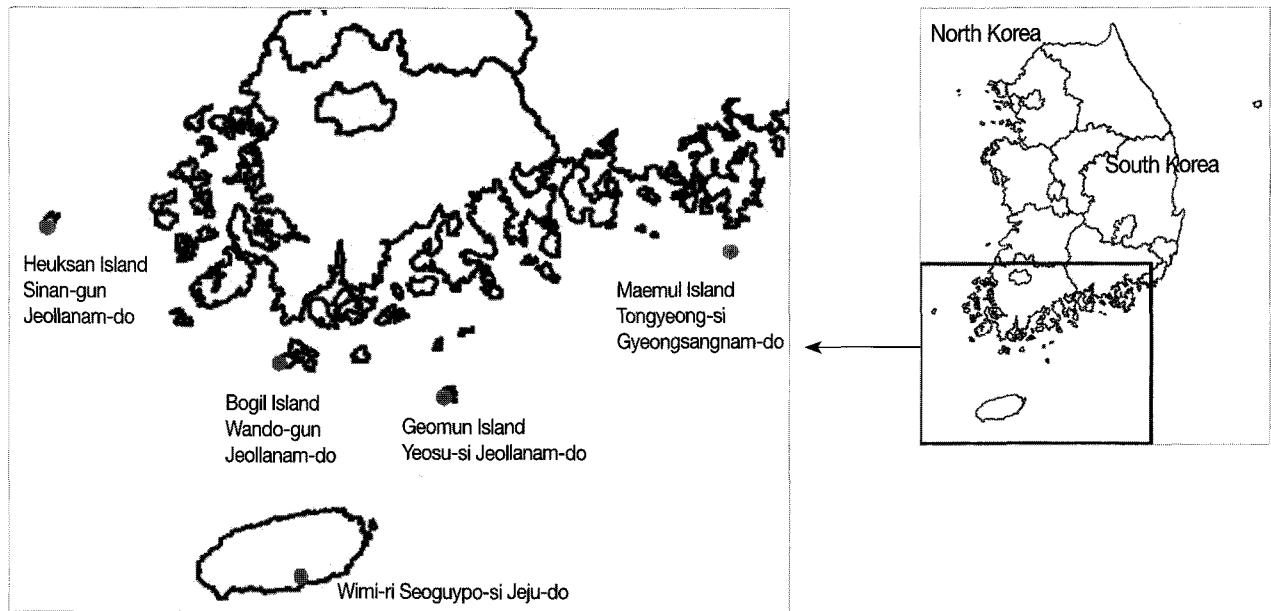


Fig. 1. Areas surveyed for adult and immature mosquitoes during 2002-2005.

**Adult mosquito surveillance**

Adult mosquitoes were collected twice weekly using the commercial Black Hole® mosquito black light trap (Model: Black Hole, Bio-trap Inc., Seoul, Korea). The traps were placed under the eaves of houses from 19:00 to 06:00 hr the following morning. All mosquitoes were identified to the genus or species level under a dissecting microscope using standard morphological keys [8,9].

**Larval surveillance**

The meshed sinking quadrat method [3,7] was used to estimate the relative larval density of *Oc. togoi*. Briefly, 5 quadrats (size: 100 cm<sup>2</sup>) were placed in each rock pool for 5 min and then removed simultaneously. Salinity was measured at the surface with a salinometer (SINAR NS-3P, Merbabu Trading Co., LTD, Tokyo, Japan). Larvae in each quadrat were counted, number recorded, and then identified under a dissecting microscope using standard morphological keys [8,9].

**RESULTS**

**Sa-ri and Sim-ri, Heuksan Island, Sinan-gun**

There were a mean of 347.0 mosquitoes collected from each trap at Sa-ri village on Heuksan Island (Table 1). Among the 4 genera and 5 species collected, *Culex pipiens* (45.8%) was the most frequently collected, followed by *Oc. togoi* (41.2%), *An. (Hyrcaus)* Group (6.3%), *Culex tritaeniorhynchus* (5.8%), and

**Table 1.** Seasonal variations of mosquitoes collected in mosquito traps in Sa-ri, Heuksan Island (latitude 34°39'N, longitude 125°25'E), Sinan-gun, Jeollanam-do in 2002

Month	<i>Ochlerotatus togoi</i>	<i>Anopheles (Hyrcaus) group</i>	<i>Culex pipiens</i>	<i>Culex tritaeniorhynchus</i>	<i>Armigeres subalbatus</i>	Mean No./trap
Jul.	45	17	20	3	0	85
Aug.	73	2	52	13	2	142
Sep.	19	2	59	4	0	84
Oct.	6	1	28	0	1	36
Total (%)	143 (41.2)	22 (6.3)	159 (45.8)	20 (5.8)	3 (0.9)	347

*Armigeres subalbatus* (0.9%). The number of *Oc. togoi* peaked in August, then decreased markedly thereafter. There were a trap mean of 359.0 mosquitoes from 5 genera and 7 species collected from Sim-ri (Table 2). The collection rates were as follows: *Cx. pipiens*, 56.3%; *Oc. togoi*, 31.2%; *Cx. tritaeniorhynchus*, 8.9%; *An. (Hyrcaus)* Group, 1.7%; *Ar. subalbatus*, 1.4%; *Culex bitaeniorhynchus*, 0.3%; and *Tripteroides bambusa*, 0.3%. The density of mosquitoes and their seasonal prevalence were similar to those of Sa-ri on Heuksan Island.

**Baekdo-ri, Bogil Island, Wando-gun**

A trap mean of 876.0 mosquitoes, comprising 4 genera and 8 species were collected from Baekdo-ri on Bogil Island (Table 3). *Oc. togoi* (41.2%), a vector of filariasis in shoreline areas, was the most frequently collected, followed by *An. (Hyrcaus)* group (26.5%), *Cx. tritaeniorhynchus* (16.6%), *Cx. pipiens* (7.8%),

**Table 2.** Seasonal prevalence of mosquitoes collected in mosquito traps in Sim-ri in Heuksan Island (latitude 34°39'N, longitude 125°25'E), Sinan-gun, Jeollanam-do in 2002

Month	<i>Ochlerotatus togoi</i>	<i>Anopheles (Hyrcaus) Group</i>	<i>Culex pipiens</i>	<i>Culex tritaeniorhynchus</i>	<i>Culex bitaeniorhynchus</i>	<i>Armigeres subalbatus</i>	<i>Tripteroides bambusa</i>	Mean No./trap
Jul.	47	4	19	3	0	0	0	73
Aug.	36	1	44	11	0	1	0	93
Sep.	21	0	88	12	0	2	1	124
Oct.	8	1	51	6	1	2	0	69
Total (%)	112 (31.2)	6 (1.7)	202 (56.3)	32 (8.9)	1 (0.3)	5 (1.4)	1 (0.3)	359

**Table 3.** Seasonal variation of adult mosquitoes collected in mosquito traps in Baekdo-ri, Bogil Island (latitude 34°08'N, longitude 126°32'E), Wando-gun, Jeollanam-do in 2003

Month	<i>Ochlerotatus togoi</i>	<i>Anopheles (Hyrcaus) Group</i>	<i>Culex pipiens</i>	<i>Culex tritaeniorhynchus</i>	<i>Armigeres subalbatus</i>	<i>Aedes albopictus</i>	<i>Ochlerotatus dorsalis</i>	<i>Culex bitaeniorhynchus</i>	Mean No./trap
May	46.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	47.0
Jun.	81.5	7.0	1.0	0.0	1.0	0.0	0.5	0.0	91.0
Jul.	108.5	53.5	19.0	6.0	7.0	0.0	0.0	0.0	194.0
Aug.	67.0	114.0	40.5	44.0	17.5	0.5	0.0	0.0	283.5
Sep.	31.0	57.5	6.5	88.5	34.5	0.5	0.5	0.5	219.5
Oct.	26.5	0.5	0.5	6.5	6.5	0.0	0.5	0.0	41.0
Total (%)	361.0 (41.2)	232.5 (26.5)	68.0 (7.8)	145.0 (16.6)	66.5 (7.6)	1.0 (0.1)	1.5 (0.2)	0.5 (0.1)	876.0

**Table 4.** Seasonal variation in mosquitoes collected by black light trap in Geomun-ri (latitude 34°17'N, longitude 127°23'E), Geomun Island, Yeosu-si, Jeollanam-do in 2004

Month	<i>Ochlerotatus togoi</i>	<i>Culex pipiens</i>	<i>Culex tritaeniorhynchus</i>	<i>Armigeres subalbatus</i>	<i>Aedes albopictus</i>	Mean No./trap
Mar.	0.0	0.0	0.0	0.0	0.0	0.0
Apr.	0.5	0.0	0.0	0.0	0.0	0.5
May	2.8	0.5	0.0	0.0	0.0	3.3
Jun.	15.6	0.1	0.0	0.3	0.0	16.0
Jul.	14.3	0.0	0.0	0.3	0.0	14.6
Aug.	4.0	0.0	0.0	0.0	0.0	4.0
Sep.	3.4	0.8	0.0	0.0	0.0	4.2
Oct.	7.4	4.0	1.1	1.0	0.1	13.6
Total (%)	48.0 (85.4)	5.4 (9.6)	1.1 (2.0)	1.6 (2.8)	0.1 (0.2)	56.2

*Ar. subalbatus* (7.6%), *Aedes dorsalis* (0.2%), *Aedes albopictus* (0.1%), and *Cx. bitaeniorhynchus* (0.1%). *O. togoi* increased sharply during the rainy season from June through July, followed by a marked decline in numbers through October. The number of *An. (Hyrcaus)* group was very low in June, which rapidly increased in July and August, and decreased in October.

#### Geomun-ri, Geomun Island, Yeosu-si

A trap mean of 56.2 mosquitoes belonging to 3 genera and

**Table 5.** Seasonal variation in mosquitoes collected by black light trap in Maejuk-ri (latitude 38°38'N, longitude 128°34'E), Maemul Island, Tongyeong-si, Gyeongsangnam-do in 2004

Month	<i>Ochlerotatus togoi</i>	<i>Culex pipiens</i>	<i>Culex tritaeniorhynchus</i>	<i>Armigeres subalbatus</i>	Mean No./trap
Mar.	1.0	0.0	0.0	0.0	1.0
Apr.	3.8	0.0	0.0	0.0	3.8
May	17.9	0.3	0.0	0.0	18.2
Jun.	25.8	0.0	0.0	0.1	25.9
Jul.	21.1	0.3	0.0	0.0	21.4
Aug.	9.3	0.0	0.0	0.0	9.3
Sep.	2.7	0.0	0.0	0.0	2.7
Oct.	15.7	0.3	0.3	0.1	16.4
Total (%)	97.3 (98.6)	0.9 (0.9)	0.3 (0.3)	0.2 (0.2)	98.7

5 species were collected (Table 4). While *Oc. togoi* comprised of 85.4% of all mosquitoes, relatively low numbers of other mosquitoes were collected.

#### Maejuk-ri, Maemul Island, Tongyeong-si

A total of 98.7 mosquitoes belong to 3 genera and 4 species were collected (Table 5). *Oc. togoi* comprised of 98.6% with the highest numbers collected from May to July (range 17.9-25.8) and October (15.7).

## Wimi-ri, Namwon-eup, Seogyupo-si

A total of 76 mosquitoes belong to 3 genera and 4 species were collected (Table 6). *Cu. pipiens* (53.9%) comprised the largest proportion of all mosquitoes, followed by *Oc. togoi* (40.1%), *Cx. tritaeniorhynchus* (5.3%), and *An. (Hyrceanus)* group (0.7%).

Relationships of population density of *Oc. togoi* larvae with salinity and temperature

The *Oc. togoi* larval population was investigated at Geomun-

**Table 6.** Seasonal variation in mosquitoes collected by black light trap in Wimi-ri (latitude 33°16'N, longitude 126°39'E), Seogyupo-si, Jeju-do in 2005

Month	<i>Ochlerotatus togoi</i>	<i>Anopheles (Hyrceanus) Group</i>	<i>Culex pipiens</i>	<i>Culex tritaeniorhynchus</i>	Mean No./trap
Apr.	2.0	0.0	4.5	0.0	6.5
May	3.0	0.0	4.5	0.0	7.5
Jun.	8.0	0.0	8.0	0.0	16.0
Jul.	4.0	0.5	8.5	1.0	14.0
Aug.	9.0	0.0	9.5	1.5	20.0
Sep.	4.5	0.0	6.0	1.5	12.0
Total (%)	30.5 (40.1)	0.5 (0.7)	41.0 (53.9)	4.0 (5.3)	76.0

**Table 7.** Larval density of *Ochlerotatus togoi* in rock pools using the meshed-sinking quadrat (100 cm<sup>2</sup>) collection method at Geomun-ri (latitude 34°17'N, longitude 127°23'E), Geomun Island, Yeosu-si, Jeollanam-do in 2004

Month	Number of rock pools examined	No. of dips	1st-2nd		3rd		4th		Pupa		Mean	Salinity (%)	Water temperature (°C)
			No.	%	No.	%	No.	%	No.	%			
Mar.	7	31	10.4	15.9	32.4	49.6	22.4	34.3	0.1	0.2	65.3	0.2	5.8
Apr.	7	30	1.4	4.3	5.8	17.9	10.7	33.0	14.5	44.8	32.4	0.1	22.5
May	7	33	11.2	42.6	3.9	14.8	4.2	16.0	7.0	26.6	26.3	0.2	24.1
Jun.	7	34	34.1	36.5	52.5	56.1	5.8	6.2	1.1	1.2	93.5	0.8	26.8
Jul.	7	35	13.2	33.8	13.4	34.3	6.3	16.1	6.2	15.9	39.1	2.6	32.8
Aug.	7	35	1.8	24.3	1.9	25.7	3.1	41.9	0.6	8.1	7.4	2.6	24.3
Sep.	7	33	6.2	27.8	9.7	43.5	4.3	19.3	2.1	9.4	22.3	0.6	24.7
Oct.	7	33	0.9	9.2	2.6	26.5	3.5	35.7	2.8	28.6	9.8	1.8	18.8

**Table 8.** Larval density of *Ochlerotatus togoi* in rock pools using the meshed-sinking quadrat (100 cm<sup>2</sup>) collection method at Maejuk-ri (latitude 34°38'N, longitude 128°34'E), Maemul Island, Tongyeong-si, Gyeongsangnam-do in 2004

Month	Number of rock pools examined	No. of dips	1st-2nd		3rd		4th		Pupae		Mean	Salinity (%)	Water temperature (°C)
			No.	%	No.	%	No.	%	No.	%			
Mar.	7	23	2.1	8.4	19.1	76.7	3.0	12.1	0.7	2.8	24.9	0.6	16.1
Apr.	7	28	2.8	9.9	5.8	20.5	12.9	45.6	6.8	24.0	28.3	0.3	18.9
May	7	34	23.1	48.1	14.1	29.4	4.9	10.2	5.9	12.3	48.0	0.1	19.5
Jun.	7	32	46.2	63.4	10.3	14.1	10.1	13.9	6.3	8.6	72.9	0.1	20.2
Jul.	7	30	40.2	58.4	15.6	22.7	11.5	16.7	1.5	2.2	68.8	0.3	29.7
Aug.	7	30	5.0	39.4	2.3	18.1	5.3	41.7	0.1	0.8	12.7	3.7	24.0
Sep.	7	33	3.5	76.1	0.6	13.0	0.3	6.5	0.2	4.4	4.6	4.1	21.2
Oct.	7	32	0.3	16.7	1.3	72.2	0.1	5.6	0.1	5.6	1.8	3.8	19.3

ri and Maejuk-ri from rock pools using a meshed sinking quadrat from March through October (Tables 7-9), and Wimi-ri on Namwon-eup in Seogyupo-si from April though July (Table 10). The number of larvae for each quadrat at Geomun-ri was 65.3 in March, peaked in June (93.5), and then gradually declined. While 3rd and 4th instars comprised the greatest proportion during the entire period at Geomun-ri, 1st and 2nd instars comprised the greatest proportion collected at Maejuk-ri (Table 10). The salinity of the rock pools varied from 0.2% to 4.1% at both sites (Tables 7, 8), while most of the larvae (68.6% and 78.1%) were collected in water with <0.5% salinity (Table 10).

At Maejuk-ri, the number of mosquitoes in each quadrat was 24.9 in March, peaked in June (72.9), and decreased gradually after August (Table 8).

At Wimi-ri, the number of *Oc. togoi* (14.7) was the highest in April. Unlike the previous 2 sites, larvae were comprised mostly of 1st and 2nd instars (70.7%). The sampling schedule was disrupted at times due to frequent periods of drought, which resulted in some of the rock pools drying.

**Table 9.** Larval density of *Ochlerotatus togoi* in rock pools using the meshed-sinking quadrat (100 cm<sup>2</sup>) collection method at Namwon-eup (latitude 33°16'N, longitude 126°39'E), Seogwipo-si, Jeju-do in 2005

Month	Number of rock pools examined	No. of dips	1st-2nd		3rd		4th		Pupae		Mean
			No.	%	No.	%	No.	%	No.	%	
Apr.	5	23	6.5	70.7	1.0	10.9	0.9	9.8	0.8	8.7	9.2
May	5	25	2.8	68.3	0.6	14.6	0.5	12.2	0.2	4.9	4.1
Jun.	3	15	14.6	99.3	0.0	0.0	0.1	0.7	0.0	0.0	14.7
Jul.	5	25	6.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0

**Table 10.** Frequency distribution of salinity of *Ochlerotatus togoi* larvae and pupae at Geomun-ri (latitude 34°17'N, longitude 127°23'E), Geomun Island, Yeosu-si, Jeollanam-do, and Maejuk-ri (latitude 34°38'N, longitude 128°34'E), Maemul Island, Tongyeong-si, Gyeong-sangnam-do in 2004

Location	Geomun-ri			Maejuk-ri			Mean	%
	Number of rock pools	Mean No. of larvae & pupae	%	Mean No. of rock pools	Mean No. of larvae & pupae	%		
Salinity (%)								
0.0-0.4	27	1,373.9	68.6	13.0	1,126.5	78.1	2,500.4	72.5
0.5-0.9	6	257.5	12.8	5.0	182.2	12.6	439.7	12.8
1.0-1.9	3	93.2	4.7	2.0	11.2	0.8	104.4	3.0
2.0-2.9	8	200.0	10.0	3.0	7.6	0.5	207.6	6.0
3.0-3.9	5	79.4	4.0	2.0	16.4	1.1	95.8	2.8
4.0-4.9	0	0.0	0.0	9.0	89.1	6.2	89.1	2.6
5.0-5.9	0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
6.0-6.9	0	0.0	0.0	2.0	10.0	0.7	10.0	0.3
Total	49	2,004.0	100.0	38.0	1,443.0	100.0	3,447.0	

## DISCUSSION

*Oc. togoi* and *Cx. pipiens* were the most frequently collected mosquitoes captured by black-light traps in southern islands of Korea during this survey. *An. (Hircanus)* group was collected at high densities only in the Baekdo-ri village, suggesting that it is a potential important vector of filariasis in this area. The mosquito population on Geomun-ri was the highest during the early rainy season and peaked a month earlier than the population on Maejuk-ri, due presumably to differences in climate (e.g., temperature and rainfall) between the 2 areas. However, both areas had a lower population after July because of frequent typhoons during the summer season (data not shown). The larval densities were the highest in June, when the average rainfall and temperature in these areas were 195–210 mm (data not shown) and 20–27°C (Tables 7, 8), respectively. The appearance of *Oc. togoi* larvae coincided with decreases in the salinity of rock pools due to frequent rains (Table 10). Thus, lower salinity during this period may be a reason for increased population densities as observed in previous reports [10,11]. Larval *Oc. togoi* densities decreased during the drier summer due to strong direct sunlight and high water temperature [12]. In a

previous study, increase in salinity played a role in reducing the susceptibility of *Oc. togoi* larvae [4,13]. The presence of <0.5% salt concentrations during the summer and the rainfall amount influenced the number of larval survival [7,14].

The number of *Oc. togoi* collected in our study was greater than a previous survey collection by Lee et al. [15] at the same location on Heuksan Island. This difference may have been due to differences in collection methods between the CDC miniature type (American Biophysics Co., East Greenwich, Rhode Island, USA) used in the Lee et al. study [15] and black-light traps used in our study. However, the proportion of *Oc. togoi* in the collected mosquitoes in this study was also lower than that reported by Kim et al. [1] and Lee [16]. These previous studies reported that collection of *Oc. togoi* and *Cx. pipiens* ranged 70–90% and 5–26%, respectively, in Jeju-do.

As both vector species are present in Korea, the most likely explanation for the eradication of filariasis is suggested to be an aggressive treatment program executed during the 1970s and 1990s [2,3,17,18], with the consequent benefit that there were fewer vector mosquitoes that have contracted the disease from human carriers. Furthermore, transmission of mosquito-borne diseases has been greatly reduced by the commercializa-

tion of mosquito repellents and insecticides, as well as the use of bed nets and screened windows, all of which decrease human-vector contact [19]. However, a steadily high prevalence of the vector mosquitoes may constitute a potential risk for re-emergence of brugian filariasis in these areas.

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