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Seasonal prevalence and species composition of mosquitoes and chigger mites collected from Daegu, Gunwi and Sangju in South Korea, 2014

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Abstract

Background: As the habitat changes in Korea due to climate change, the emergence of disease-mediated vectors is increasing rapidly. Thus for the surveillance of mosquito- and chigger mite-borne disease, their seasonal prevalence and species composition were investigated at seven locations in Daegu, Gunwi and Sangju.

Methods: Mosquitoes were collected twice every month from five collection sites using a black light and BG sentinel traps in Daegu and Gunwi from April through November. Chigger mites were investigated twice per month from wild rodents caught with Sherman live traps in Gunwi and Sangju from April through May and September through November.

Results: A total of 2,361 female mosquitoes were collected. Cowshed (626 individuals, Trap index (TI) 44.7) and Kyungpook National University campus (846 individuals, TI 60.4) in Daegu had the highest number of mosquitoes in the black light and BG sentinel trap, respectively. The mosquitoes were collected more by BG sentinel trap than the black light trap. Nine mosquito species were trapped, and the *Culex pipiens* complex was the most commonly mosquito (1,397 individuals, 59.2%), followed by *Anopheles sinensis* (554 individuals, 23.5%). *Anopheles sinensis* (531 individuals, 51.9%) and *Culex pipiens* complex (1,142 individuals, 85.4%) were the most mosquitoes from black light and BG sentinel trap, respectively. In terms of seasonal prevalence, the highest abundance was in July, with 824 individuals collected. In chigger mites, eighty-one wild rodents of five species that are hosts of chigger mites were collected; among them, 53 and 25 individuals of *Apodemus agrarius* and *Crocidura suaveolens*, respectively were trapped. *Leptotrombidium pallidum* was a dominant species, with 2,467 individuals collected (67.8%).

Conclusions: The mosquito was the dominant species in *Culex pipiens* complex and the highest in July and August. *Apodemus agrarius* was most abundant in wild rats and *Leptotrombidium pallidum* was dominant in the collected chigger mites.

Keywords: *Anopheles sinensis*, *Apodemus agrarius*, *Culex pipiens* complex, *Leptotrombidium pallidum*, Seasonal prevalence, Surveillance

Background

Recent global climate changes affect the habitat characteristics of various species and the density of vectors of pathogens that transmit diseases to humans is rapidly increasing in various regions (Epstein et al., 1998, Martens, Jetten, & Focks, 1997, Yi et al., 2014). These changes may expand the occurrence of vector-borne diseases, thereby increasing domestic indigenous diseases; the influx of foreign vectors has also increased the risk of foreign infectious diseases (Lee & Kim, 2006).

In South Korea, 54 mosquito species have been recorded (Paek et al., 2010), of which *Culex tritaeniorhynchus* and *Anopheles Hyrcanus* Group have caused many illnesses, because they carry Japanese encephalitis virus and *Plasmodium vivax* Malaria, respectively (Korea centers for disease control and prevention, 2014). Although it has not been introduced in South Korea, possibilities of the inflow of the West Nile fever, which causes more than

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300 casualties per year in the USA (Komar, 2000), and dengue fever are gradually increasing (there was a case of dengue fever wherein the patient was infected in a foreign country and then returned to Korea).

Mosquito species vary in their seasonal prevalence, spawning sites, mating habits, biting habits, rest habits, and migration distance. Further, mosquito-borne diseases could differ among species, and hence it is critical to understand mosquito occurrence, dominant species, and seasonal prevalence for their management (Jeong & Lee, 2003).

Studies on the seasonal prevalence of mosquitoes in Korea have begun with the re-emergence of *Plasmodium vivax* which reported to have already disappeared near the Gyeonggi province in 1993 (Kim, Chong, Collier, Lee, & Klein, 2007a, Kim, Chong, Collier, & Klein, 2009a, Kim, Chong, Nunn, McNemee, & Klein, 2009b, Kim et al. 2010, Kim et al. 2006, Kim et al. 2004, Kim, Friendly, et al. 2003a, Kim et al. 1997, Kim et al. 1999, Kim et al. 2001, Kim, Lee, et al. 2003b, Kim et al. 2000, Kim, Turell, et al. 2007b, Kim, Chong, Collier, & Klein, 2009a, Lee & Kim 2001, Lee et al. 2009, Shim et al. 2010).

Chigger mites are the most detrimental mites to humans because they cause scrub typhus. So far, 61 different species of chigger mites have been documented in South Korea (Lee 2006). Among these chigger mites, the causative organism of scrub typhus (*Orientia tsutsugamushi*) was found in *Leptotrombidium pallidum* and *Leptotrombidium scutellare*, which are parasitic to a wide variety of rodents, indicating that these mites are major disease vectors in South Korea (Jackson et al. 1957, Ree et al. 1991a, Ree et al. 1992). Scrub typhus was first described in South Korea in 1951 by the UN forces participating in the Korean War. After this, it was not reported for over 30 years until multiple cases were reported in 1986 (Chang 1994). Over the last ten years, approximately 5,000–10,000 patients were diagnosed with this disease every year (Korea centers for disease control and prevention 2014), with most cases occurring in farming areas in the fall, so farm workers should take precautions at this time.

Owing to the continuous occurrence of Japanese encephalitis, malaria, and scrub typhus from mosquitoes and chigger mites in Daegu and Gunwi and Sangju of Gyeongbuk province, these insects should be regularly monitored. Therefore, in the present study, we investigated the seasonal prevalence and species composition of mosquitoes and chigger mites in the area in order to survey the mosquito- and chigger mite-borne disease propagation and monitor the influx and spread of these vectors.

Methods

Studying area

Six collection locations were selected for the investigation of mosquitoes in Daegu and Gunwi (Fig. 1), and two collection locations were assigned in Gunwi and Sangju for the chigger mites (Fig. 1).

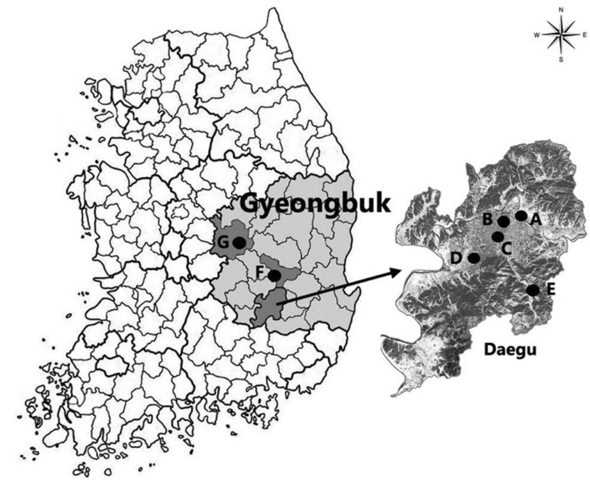

Fig. 1 Collection sites of mosquitoes and chigger mites in Daegu **a**–**e** and Gyeongbuk province **f**–**g**, South Korea. **a** Daegu International Airport, DIA (Surveillance of influx of foreign vectors), **b** Kyungpook National University campus, KNU (Urban residential areas), **c** Kyungpook National University Hospital, KNUH (Urban commercial areas), **d** Wolbae Park (Urban park areas), **e** Cowshed (Mosquito dense area with previous disease occurrence), **f** Gunwi (Migratory bird sanctuary. Surveillance of potential pathogen influx via birds), **g** Sangju (Migratory bird sanctuary. Surveillance of potential pathogen influx via birds)

Study periods

Mosquitoes were collected twice a month from April through November 2014. Chigger mites were collected twice a month from April through May and September through November 2014 based on the characteristics of the activity of wild rodents and chigger mites.

Collection and identification

Mosquitoes collected in traps (black light and BG sentinel trap) were picked up each morning and immediately placed in a freezer. They were later identified using a Leica EZ4D stereo microscope according to the taxonomic key of Hong (1982) and Ree (2003). Chigger mites were collected from wild rodents, which were caught in fifty Sherman live traps in each site, euthanized using dry ice, and then hung above a container filled with water (1 cm in depth) for two days. Chigger mites that fell on the water were collected, and 2–4 mites were placed on a slide glass; a drop of the PVA mounting medium (#6371A, BioQuip Products Inc., Rancho. Dominguez, California) was placed on the mites and then the slide glass was covered with a cover glass. Prepared chigger mite samples were then identified using a Swift M1000D microscope according to the taxonomic key of Ree (1990).

Results

Mosquitoes

A total of 2,361 female mosquitoes were collected. In the black light trap, cowshed in Daegu had the highest

Table 1 Total number of female mosquitoes collected by black light and BG sentinel traps and TI in Daegu and Gunwi from April to November, 2014

Areas		Mosquitoes (F)	Trap	Trap nights	Trap Index (TI)
Daegu	Cowshed	626	BL	14	44.7
	DIA	118	BL	10	11.8
	KNUH	115	BL	15	7.7
	Wolbae Park	46	BL	8	5.8
Gunwi		119	BL	15	7.9
Subtotal		1,024		62	16.5
Daegu	DIA	360	BG	14	25.7
	KNU	846	BG	14	60.4
Gunwi		131	BG	10	13.1
Subtotal		1,337		38	35.2
Total		2,361		100	23.6

F Female, *BL* black light trap, *BG* BG sentinel trap

number of them (626 individuals, Trap index (TI) 44.7) and 846 individuals (TI 60.4) in KNU were collected the most of them by the BG sentinel trap. As compared with black light and BG sentinel traps, the mosquitoes were trapped more in BG sentinel trap than the black light trap (Table 1).

Nine mosquito species were collected, with the *Culex pipiens* complex as the dominant species (1,397 individuals, 59.2%), followed by *Anopheles sinensis* (554 individuals, 23.5%). The *Culex pipiens* complex was the dominant species in all of the collection sites in Daegu, whereas *Anopheles sinensis* was more prevalent in cowsheds. In Gunwi, a representative habitat for migratory birds, *Armigeres subalbatus* was the most dominant in both types of traps (Table 2).

The most collected mosquitoes by black light trap and BG sentinel trap is *Anopheles sinensis* (531 individuals, 51.9%) and *Culex pipiens* complex (1,142 individuals, 85.4%), respectively.

In terms of seasonal prevalence, 824 individuals (black light trap: 366, BG sentinel trap: 458) were collected in July, which was the highest among the study periods. The *Culex pipiens* complex rapidly increased from June, and was the most prevalent in July (black light trap: 121, BG sentinel trap: 402). *Anopheles sinensis* mostly appeared between June and August, and was most prevalent in July (black light trap: 196, BG sentinel trap: 17). Similarly, *Armigeres subalbatus* mostly appeared between July and October and was the most abundant in August (black light trap: 30, BG sentinel trap: 15). Other species were relatively less abundant (Table 3).

Chigger mites

Wild rodents, which host chigger mites, were collected first; detailed host information is listed in Table 4. Four different species and 38 individuals were collected in Gunwi. Of them, *Apodemus agrarius* was the most abundant species (33 individuals). In Sangju, 43 individuals of three species were collected in our traps. Of them, 22 and 20 individuals of *Crocidura suaveolens* and *Apodemus agrarius*, respectively, were collected. In total, 2,841 parasites were found on wild rodents from Gunwi. Of these, chigger mites were the most prevalent, with 2,592 individuals (91.2%). Similarly, a total of 1,099 individuals were collected from rats from Sangju, and chigger mites were the dominant species as well (1,049 individuals; 95.5%) (Table 5). The chigger-mite infection rate was 81.8% and 80% for *Apodemus agrarius* trapped in Gunwi and Sangju, respectively. There were 2,336 (Chigger index, CI 70.8), and 1,040 (CI 52.0) individual chigger mites, respectively, indicating that it is the most important host for chigger mites. In contrast, *Crocidura suaveolens* from Gunwi and Sangju had 33.3% and 18.2% infection rates, respectively, with low numbers of chigger mites [2 individuals (CI 0.7), and 9 individuals (CI 2.4), respectively]. One individual each was collected from

Table 2 Female mosquitoes collected with black light and BG sentinel traps in Daegu and Gunwi

Mosquitoes	Black light trap						BG sentinel trap				
	Daegu				Gunwi	Subtotal (%)	Daegu		Gunwi	Subtotal (%)	Total (%)
	Cowshed	DIA	Wolbae Park	KNUH			KNU	DIA			
Aedes albopictus	2			5	7	14(1.4)	16	18	17	51(3.8)	65 (2.8)
Aedes vexans	103	11	3			117(11.4)	2		2	4(0.3)	121 (5.1)
Anopheles sinensis	506	8	1	8	8	531(51.9)	15	6	2	23(1.7)	554 (23.5)
Armigeres subalbatus	1				76	77(7.5)		2	100	102(7.6)	179 (7.6)
Culex pipiens complex	13	98	40	96	8	255(24.9)	800	334	8	1,142(85.4)	1,397 (59.2)
Culex orientalis	1	1	2	4	18	26(2.5)	10			10(0.7)	36 (1.5)
Culex vagans				2		2(0.2)	3			3(0.2)	5 (0.2)
Ochlerotatus koreicus					1	1(0.1)			2	2(0.1)	3 (0.1)
Oc. hatorii					1	1(0.1)				0(0.0)	1 (<0.1)
Total	626	118	46	115	119	1,024(100)	846	360	131	1,337	2,361 (100)

Table 3 Total number of female mosquitoes, by species, collected monthly by black light and BG sentinel traps in Daegu and Gunwi

Mosquitoes	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
	BL	BG	BL	BG	BL	BG	BL	BG	BL	BG	BL	BG	BL	BG	BL	BG
Aedes albopictus				4		2	5	4	4	31	5	10				
Aedes vexans			19		73	4	3		22							
Anopheles sinensis				1	110	1	196	17	158	2	60		7	1		1
Armigeres subalbatus				10		9	20	24	30	15	14	24	13	19		1
Culex pipiens complex	8	6	4	11	46	109	121	402	42	144	21	200	11	195	2	75
Culex orientalis	1						21	11	2	1						
Culex vagans		3			2											
Ochlerotatus koreicus			1	2												
Ochlerotatus hatorii			1													
Total (trap)	9	9	25	28	231	125	366	458	258	193	100	234	31	215	2	77
Total	18		53		356		824		451		334		246		79	

Micromys minutus and *Microtus fortis*, hence the infection rate was 100% for both, although the actual chigger mite numbers were small. Lastly, *Mus musculus* was not infected by chigger mites at all (Table 6).

Five genera and 11 species of chigger mites were identified in the study. All five genera and 11 species of chigger mites were found in samples from Gunwi, wherease only two genera and seven species were collected from collection sites in Sangju. *Leptotrombidium pallidum* was the most dominant in both areas (2,467 individuals, 67.8%) followed by *Leptotrombidium orientale* (326 individuals, 9%), *Eushoengastia koreaensis* (305 individuals, 8.4%), and *Leptotrombidium palpale* (249 individuals, 6.8%) (Table 7).

Table 4 Individual numbers and morphological properties of wild rodents, a host of chigger mites collected in Gunwi and Sangju

Wild rodents	Morphological properties	Gunwi	Sangju
Apodemus agrarius	Number of individuals	33	20
	Weight	24.61 ± 12.73	24.37 ± 11
	Total length	17.62 ± 3.4	17.38 ± 2.56
	Tail length	7.83 ± 1.69	7.85 ± 1.2
Crocidura suaveolens	Number of individuals	3	22
	Weight	9.33 ± 6.03	7.12 ± 4.35
	Total length	11.8 ± 2.01	11.15 ± 1.69
	Tail length	4.13 ± 0.42	4.25 ± 1.68
Microtus fortis	Number of individuals	1	-
	Weight	39	-
	Total length	15.3	-
	Tail length	4	-
Micromys minutus	Number of individuals	1	-
	Weight	7	-
	Total length	10.5	-
	Tail length	5.5	-
Mus musculus	Number of individuals	-	1
	Weight	-	3
	Total length	-	11
	Tail length	-	5

Discussion

Vivax malaria transmitted by anopheline mosquitoes; it was eradicated from South Korea in the late 1970s. In 1993, one malaria patient was reported around the DMZ area (Shim et al. 1997) and the outbreak peaked in 2000 with 4,142 malaria patients. With the implementation of intensive management, the number of cases was reduced to <1,000 by 2011. In 2013, it was reduced to 445 patients according to the Korea centers for disease control and prevention (2014).

So far, most malaria cases in South Korea are from Gyeonggi and Gangwon provinces. *Anopheles sinensis* is known to be a major vector. In previous studies, *Anopheles sinensis* was more prevalent in Gyeongbuk province than in Daegu, but it was slightly more common in Daegu in our study (Table 8). This might be because *Anopheles sinensis* was the dominant species in the cowsheds, raising the mean even though it was rare in the other collection location in Daegu. Compared to Munsan, which has a high malaria infection rate, the abundance of *Anopheles sinensis* in Daegu is still considered low (Table 8). Over the last five years (i.e., 2010–2014), there were 55 and 58 patients with malaria infection from Daegu and Gyeongbuk province, respectively, indicating that the *Anopheles sinensis* ratios of these two areas might be similar or slightly higher in Gyeongbuk province (Disease web statistics system 2014).

Japanese encephalitis (JE) is mainly carried via *Culex tritaeniorhynchus*. In South Korea, *Culex tritaeniorhynchus* appears in early May, peaks in mid-August, and lasts until late October. Major sources of infection of Japanese encephalitis are birds and pigs. Given that pigs

Table 5 Numbers of parasites of wild rodents trapped in Gunwi and Sangju

Sites	Tick	Mesostigmatid mites	Chigger mites	Fleas	Sucking lice	Others	Total
Gunwi	25 (0.9%)	122 (4.3%)	2,592 (91.2%)	16 (0.6%)	46 (1.6%)	40 (1.4%)	2,841 (100%)
Sangju	18 (1.6%)	14 (1.3%)	1,049 (95.5%)	6 (0.5%)	9 (0.8%)	3 (0.3%)	1,099 (100%)

are amplification hosts for the Japanese encephalitis virus (Mullen and Durden 2002), the infection rates of downtown areas, where no pigsties are located, are often very low. The fatality rate of Japanese encephalitis is 20–50%, which is relatively high; further, more than half of the survivors have complications such as motor disorders and mental retardation (Lee 2001). Of 5,616 patients in South Korea in 1949, approximately half of them died (2,794 casualties, 49%). Since then, approximately 1,000–3,000 patients were reported per year until 1968, after which the number gradually declined. Over the last 10 years, only 0–26 patients have been reported per year (Lee 2001, Korea centers for disease control and prevention 2014).

The occurrence rate of *Culex tritaeniorhynchus* has been low in Daegu. In agreement with this, we did not find *Culex tritaeniorhynchus* at all. Since it is found in and around areas where water is consistently maintained (e.g., paddy fields), their occurrence rate might be relatively low in downtown areas. We further found that *Culex tritaeniorhynchus* was rare in Gyeongbuk province; this might be because most data collection sites were in forest areas or areas nearby forests, although Gunwi and Waegwan were suburban. In a recent five-year period, nine and six Japanese encephalitis patients were reported in Daegu and Gyeongbuk province, respectively, showing that infection from *Culex tritaeniorhynchus* did actually occur and that it was somewhat more prevalent in Daegu. Daegu accounted for approximately 30% of all cases in the country in 2013 (Disease web statistics system 2014), and hence further intensive investigation and surveillance for *Culex tritaeniorhynchus* might be needed in more diverse sites in Daegu.

It has been reported that the *Culex pipiens* complex is most active in downtown areas; in Daegu, it was more abundant than both *Anopheles sinensis* and *Culex tritaeniorhynchus*. In the present study, it was 18.4 (TI), which is considered very high. In contrast, this mosquito species was very uncommon in Gyeongbuk province, confirming that the *Culex pipiens* complex is more prevalent in cities (Table 8). Although it has not been confirmed in Korea, the *Culex pipiens* complex has been known to spread West Nile fever in the USA (Kim et al. 2010).

Over the last 10 years, approximately 4,000–8,000 scrub typhus patients have been reported per year in South Korea. In 2013, more than 10,000 scrub typhus patients were reported, confirming that it is highly infectious (Korea centers for disease control and prevention 2014). In Daegu and Gyeongbuk provinces, there were 100–600 patients every year (Disease web statistics system 2014). This disease is often reported between September and November (Chang 1994), and can infect a person who is bitten by a chigger mite with *Orientia tsutsugamushi* in its system. Since it requires animal tissue fluids to grow to adulthood, chigger mites are mostly parasitic on wild rodents. *Apodemus agrarius* is the most prevalent species in South Korea (Song et al. 1996, Ree et al. 1991b), which is in agreement with the present study results. Specifically, *Apodemus agrarius* was the dominant species in Gunwi, while *Apodemus agrarius* and *Crocidura suaveolens* were similarly common in Sangju. These wild rodents have various parasites. Among them, chigger mites account for 91.2% and 95.5% of individuals in Gunwi and Sangju, respectively, confirming their dominance. Therefore, it is thought that

Table 6 The number of chigger mites collected from wild rodents in Gunwi and Sangju

Sites	Rodents	No. of collected rodents	No. of rodents with chigger mites	Infestation rate (%)	No. of collected chigger mites	Chigger index
Gunwi	*Apodemus agrarius*	33	27	81.8	2336	70.8
	Crocidura suaveolens	3	1	33.3	2	0.7
	Micromys minutus	1	1	100	9	9.0
	Microtus fortis	1	1	100	245	245.0
Sangju	*Apodemus agrarius*	20	16	80.0	1,040	52.0
	Crocidura suaveolens	22	4	18.2	9	2.4
	Mus musculus	1	0	0	0	0

Table 7 Species and number of individuals of chigger mites trapped in Gunwi and Sangju

Chigger mites	Gunwi	Sangju	Total (%)
Leptotrombidium orientale	299	27	326 (9.0)
Leptotrombidium pallidum	1,522	945	2,467 (67.8)
Leptotrombidium palpale	208	41	249 (6.8)
Leptotrombidium scutellare	14	4	18 (0.5)
Leptotrombidium subintermedium	3	4	7 (0.2)
Leptotrombidium zetum	17	7	24 (0.7)
Leptotrombidium tectum	3	0	3 (0.1)
Cheladonta ikaoensis	14	0	14 (0.4)
Neotrombicula gardellai	205	0	205 (5.6)
Neotrombicula japonica	23	0	23 (0.6)
Eushoengastia koreaensis	284	21	305 (8.4)
Total	2,592	1,049	3,641 (100.0)

scrub typhus is one of the most common diseases spread via chigger mites of wild rodents.

Apodemus agrarius had 81.8% and 80% chigger-mite infection rates in Gunwi and Sangju, respectively, which are similar to the results of previous studies by Ree et al. (1991c) and Song et al. (1996). *Crocidura suaveolens* had a similar infection rate as well. On the other hand, the chigger index was 70.8 and 52.0 in Gunwi and Sangju, respectively; these results were also similar to the numbers of chigger mites reported in the studies of Ree et al. (1991c) and Song et al. (1996) of 43.6 and 80.4, respectively. In these previous studies, in agreement with our results, *Crocidura suaveolens* had a low chigger index. However, *Micromys minutus* and *Microtus fortis* had 100% infection rates with a 245.0 chigger index. This might be because only one individual each of *Micromys minutus* and *Microtus fortis* was collected; therefore, further studies might be warranted to confirm their high infection rates.

Table 8 Trap indices of mosquitoes trapped in Daegu, Gyeongbuk, and Munsan areas in 2005–2007 and 2014

Area	Species	2007[a]	2006[b]	2005[c]	2014[d]
Daegu	*Anopheles sinensis*	0.2	0.2	0.1	7.3
	Culex tritaeniorhynchus	0.5	0.5	0.2	0
	Culex pipiens complex	1.6	0.4	0.4	18.4
Gyeongbuk[e]	*Anopheles sinensis*	17.5	0.5	2.3	0.4
	Culex tritaeniorhynchus	1.2	0.1	0.4	0
	Culex pipiens complex	0.5	<0.1	0.2	0.6
Munsan	*Anopheles sinensis*	17.0	21.9	50.9	-

[a]Kim et al. 2010, [b]Kim et al. 2009b, [c]Kim et al. 2009a, [d]This study, [e]Gyeongbuk (2005–2007: Waegwan, 2014: Gunwi)

Chigger mites carrying scrub typhus in South Korea include *Leptotrombidium pallidum* and *Leptotrombidium scutellare* (Lee et al. 1993a, Ree et al. 1991c). These two species have different distribution characteristics. In the studies of Shim et al. (1989), Ree et al. (1991c), Lee, et al. (1993a, 1993b), and Song et al. (1996), *Leptotrombidium pallidum* was the dominant species in wild rodents. In contrast, Lee et al. (1993a), Ree et al. (1992), and Ree et al. (1995) reported that *Leptotrombidium scutellare* was a dominant species. Song et al. (1996) addressed this discrepancy by showing that *Leptotrombidium pallidum* has a higher population density in the north while *Leptotrombidium scutellare* is more common in the south. In central regions, these two species coexist, although *Leptotrombidium scutellare* is less common (Lee, Ree, et al. 1993a, Ree et al. 1995). In the present study, we demonstrated that *Leptotrombidium pallidum* is the dominant species (67.8%), followed by *Leptotrombidium orientale* (9.0%) and *Eushoengastia koreaensis* (8.4%). Notably, *Leptotrombidium scutellare* was very rare (0.5%). Assuming that Gunwi and Sangju are central regions of South Korea, these results are similar to previous results. Therefore, the primary species causing scrub typhus in Gyeongbuk province might be *Leptotrombidium pallidum.*

Conclusion

Mosquitoes and chigger mites were collected from April to November 2014 in order to monitor and predict these species as the incidence of mosquito- and chigger mite-transmitted diseases have persisted in Daegu and Gyeongbuk areas. The predominant species collected were *Culex pipiens* in urban areas, *Anopheles sinensis* in cowsheds, and *Armigeres subalbatus* in habitats for migratory birds. The populations of these species typically surge from June, reach the highest levels between July and August, and drop sharply from November. Although patients had contracted Japanese encephalitis or malaria consistently in Daegu and Gyeongbuk areas, *Culex tritaeniorhynchus*, the primary vector of Japanese encephalitis mosquito vectors, was not trapped at all and *Anopheles sinensis* was found particularly in higher numbers at cowsheds. More intense investigation and monitoring are warranted at a variety of sites. To collect chigger mites, 38 and 43 wild rodents were trapped at Gunwi and Sangju, respectively, in Gyeongbuk. *Apodemus agrarius* was the most commonly trapped rodent. The predominant community parasitic on a rodent collected was 2592 (91.2%) chigger mites in Gunwi and 1049 (95.5%) mites in Sangju. A total of 5 genera and 11 species were identified. Of these, the predominant mite species were 2467 (67.8%) *Leptotrombidium pallidum*, followed by 326 (9%) *Leptotrombidium orientale*, 305 (8.4%) *Eushoengastia koreaensis* and 249 (6.8%) *Leptotrombidium palpale*. Therefore, *Leptotrombidium pallidum* parasitic on *Apodemus agrarius* appears to be the causative agent of tsustugamushi disease in Gyeongbuk.

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