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▣ BRIEF COMMUNICATION

Epidemiological Investigation of Tick Species from Near Domestic Animal Farms and Cattle, Goat, and Wild Boar in Korea

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Abstract: This study aimed to investigate the tick species and give background for tick-borne investigations in Korea. Ticks were collected from the area within 2 km radius of the 4 domestic animal farms, where they were located in mountainous areas and raising animals on pasture, and from animal bodies in 2014 and 2015. In total, 7,973 nymphal and adult ticks were collected from the farms - 7,758 *Haemaphysalis longicornis*, 198 *Haemaphysalis flava*, and 17 *Ixodes nipponensis*, and 1,763 were collected from animals - 729 *H. longicornis* from cattle; 569 *H. longicornis* from goats; and 297 *H. longicornis*, 118 *H. flava*, 1 *I. nipponensis*, and 49 *Amblyomma testudinarium* from wild boars. As more species of ticks were collected from wild boars than domesticated animals and their habitats, various animal hosts should be considered while investigating tick species.

Key words: Tick, distribution, animal

Ticks are external parasites that suck blood from several animal species and also important vectors for various pathogens [1]. There are many genera of hard ticks in the world including *Ixodes, Amblyomma, Haemaphysalis, Boophilus, Rhipicephalus, Dermacentor*, and *Anocentor*. For various reasons, the distribution of ticks has been continuously investigated worldwide. The majority of ixodid ticks in China are from the genera *Haemaphysalis* (44 species) and *Ixodes* (24 species) [2]. Nationwide surveys in mainland Portugal listed 20 tick species [3] and more than 30 tick species, including soft ticks, were collected nationwide in Turkey [4]. In Iran, *Boophilus, Dermacentor, Haemaphysalis, Hyalomma, Ixodes*, and *Rhipicephalus* were isolated from approximately 1,500 sheep, 1,200 goats, and 500 cattle of 12 herds [5]. In addition, 25,566 ticks from 9 species of domesticated animals and 1,385 ticks from 20 animal species were collected in Sri Lanka [6].

In Korea, concerns related to ticks and tick-borne pathogens have been increasing and many studies on tick population and tick-borne diseases were conducted. Especially, tick surveillance studies related to host species (small mammals, migratory birds, wild boars, etc.) [7-9] or provinces [10,11], and tick-borne pathogens including *Anaplasma* spp., *Bartonella* spp., *Borrelia* spp., and a newly emerging pathogen called severe fever with thrombocytopenia syndrome virus, were conducted [8,12].

Given that the current climate is in constant change in Korea as well as in other countries, there may be changes in the habitats of existing organisms and the influx of new species [13-15]. As tick distribution can be influenced by many factors, including local host populations [16], the host population should be considered while surveying tick population. The current study aimed to investigate the distribution of ticks, by collecting them from near animal farms and animals located throughout Korea.

Ticks were collected from 9 provinces in Korea (Gangwon-do, Gyeonggi-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, Gyeongsangnam-do, and Jeju-do) from June to November in 2014 and March to November in 2015. To locate animal farms in mountain areas, we conducted an internet search and obtained information from Korean Ministry of Agriculture and Forestry, and working local veterinarians. After contacting farm

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owners, we obtained informed consents to investigate their farms and nearby areas. In total, 78 farms (29 cattle, 9 chicken, 27 goat, and 14 pig farms) that were in the mountainous areas and allowed their animals to graze were selected for investigation. The farms investigated in this study did not overlap. The areas around the farms, where ticks could live, were investigated, and the marginal areas were defined within a radius of 2 km using GPS system. Among the various farms, the defined areas of investigation were almost consistent, comprising of vegetation and some grasses less than 0.5 m in height. Ticks were collected from the fields using the flagging method (flags were made using a wooden stick attached to a 1×1 m white flannel cloth). Only nymphal and adult ticks were collected. Collected ticks were stored in a 15 ml centrifuge tube, with a grass leaf to maintain the humidity, and transported to the laboratory. The ticks were stored at 4˚C until identification.

Nymphal and adult ticks were collected from restrained (cattle and goat) or captured (wild boar) animals using fine forceps. For animal welfare and ethical issues, tick investigation was performed while animals were restrained for their health checkup. Wild boars were captured and hunted following the guidelines for the capture of hazardous wild animals published by the Korean Ministry of Environment with the help of the Korean Wildlife Management Association. In the guidelines for the capture of hazardous wild animals performed by Korean Ministry of Environment, the Korean Wildlife Management Association might carry out the guidelines to adjust the number of wild boars by hunting. Collected ticks from each animal were stored at 4˚C in a 15 ml centrifuge tube with a grass leaf and transported to the laboratory.

The species and developmental stage of all collected ticks were identified using a stereo microscope (SZH10, Olympus, Japan), following identification standards [21]. Each identified tick was stored at -20˚C in a 2 ml microcentrifuge tube for further study.

In total, 7,973 nymphal and adult ticks (2,215 in 2014; 5,758 in 2015) belonging to 2 genera and 3 species were collected from the areas around the farms. Among the tick species, 7,758 (97.3%) were *Haemaphysalis longicornis* (2,072 in 2014; 5,686 in 2015; 496 adult males [243 in 2014; 253 in 2015], 845 adult females [333 in 2014, 512 in 2015], and 6,417 nymphs [1,496 in 2014; 4,921 in 2015]). Of the remaining ticks, 198 (2.5%) were *Haemaphysalis flava* (143 in 2014; 55 in 2015; 38 adult males [33 in 2014; 5 in 2015], 25 adult females [21 in 2014; 4 in 2015], and 135 nymphs [89 in 2014; 46 in 2015]), and 17 (0.2%) were *Ixodes nipponensis* (none in 2014; 17 in 2015; 2 adult males, 7 adult females, and 8 nymphs).

For each province, 1,128 ticks from Gangwon-do (1,093 *H. longicornis* [30 adult males, 49 adult females, and 1,014 nymphs], 31 *H. flava* [1 adult male, 2 adult females, and 28 nymphs], and 4 *I. nipponensis* [2 adult females, and 2 nymphs]), 1,171 ticks from Gyeonggi-do (1,168 *H. longicornis* [36 adult males, 32 adult females, and 1,100 nymphs], and 3 *H. flava* nymphs), 268 ticks from Chungcheongbuk-do (263 *H. longicornis* [23 adult males, 51 adult females, and 189 nymphs], and 5 *H. flava* [1 adult male, and 4 nymphs]), 532 ticks from Chungcheongnam-do (511 *H. longicornis* [55 adult males, 94 adult females, and 362 nymphs], 17 *H. flava* [9 adult males, 2 adult females, and 6 nymphs], and 4 *I. nipponensis* [2 adult males, and 2 adult females]), 1,061 ticks from Gyeongsangbuk-do (1,061 *H. longicornis* [12 adult males, 56 adult females, and 993 nymphs]), 818 ticks from Gyeongsangnam-do (796 *H. longicornis* [59 adult males, 80 adult females, and 657 nymphs], 21 *H. flava* [6 adult females, and 15 nymphs], and 1 *I. nipponensis* nymph), 1,075 ticks from Jeollabuk-do (1,032 *H. longicornis* [15 adult males, 42 adult females, and 975 nymphs], 35 *H. flava* [4 adult males, 5 adult females, and 26 nymphs], and 8 *I. nipponensis* [3 adult females, and 5 nymphs]), 595 ticks from Jeollanam-do (548 *H. longicornis* [23 adult males, 35 adult females, and 490 nymphs], and 47 *H. flava* [11 adult males, 8 adult females, and 28 nymphs]), and 1,325 ticks from Jeju-do (1,286 *H. longicornis* [243 adult males, 406 adult females, and 637 nymphs], and 39 *H. flava* [12 adult males, 2 adult females, and 25 nymphs]) were collected (Fig. 1).

From the animals, 1,763 ticks were collected (1,084 in 2014; 679 in 2015) belonging to 3 genera and 4 species; 729 (209 in 2014; 520 in 2015; 41.3%) were from cattle, 569 (569 in 2014; none in 2015; 32.3%) were from goats, and 465 (306 in 2014; 159 in 2015; 26.3%) were from wild boars (Table 1). From cattle, 729 *H. longicornis* were collected (78 adult males [49 in 2014, 29 in 2015], 649 adult females [159 in 2014, 490 in 2015] and 2 nymphs [1 in 2014, 1 in 2015]). From goats, 569 *H. longicornis* were collected (369 adult males, 162 adult females, and 38 nymphs). From wild boars, 297 *H. longicornis* (44 adult males [31 in 2014; 13 in 2015], 185 adult females [114 in 2014; 71 in 2015], and 68 nymphs [all in 2014]; 63.9%), 118 *H. flava* (94 adult males [48 in 2014; 46 in 2015], and 24 adult females [9 in 2014; 15 in 2015]; 25.4%), 1 *I. nipponensis* (1 adult male in 2014; 0.2%), and 49 *Amblyomma testudinarium* (30 adult males [22 in 2014; 8 in 2015], and 19

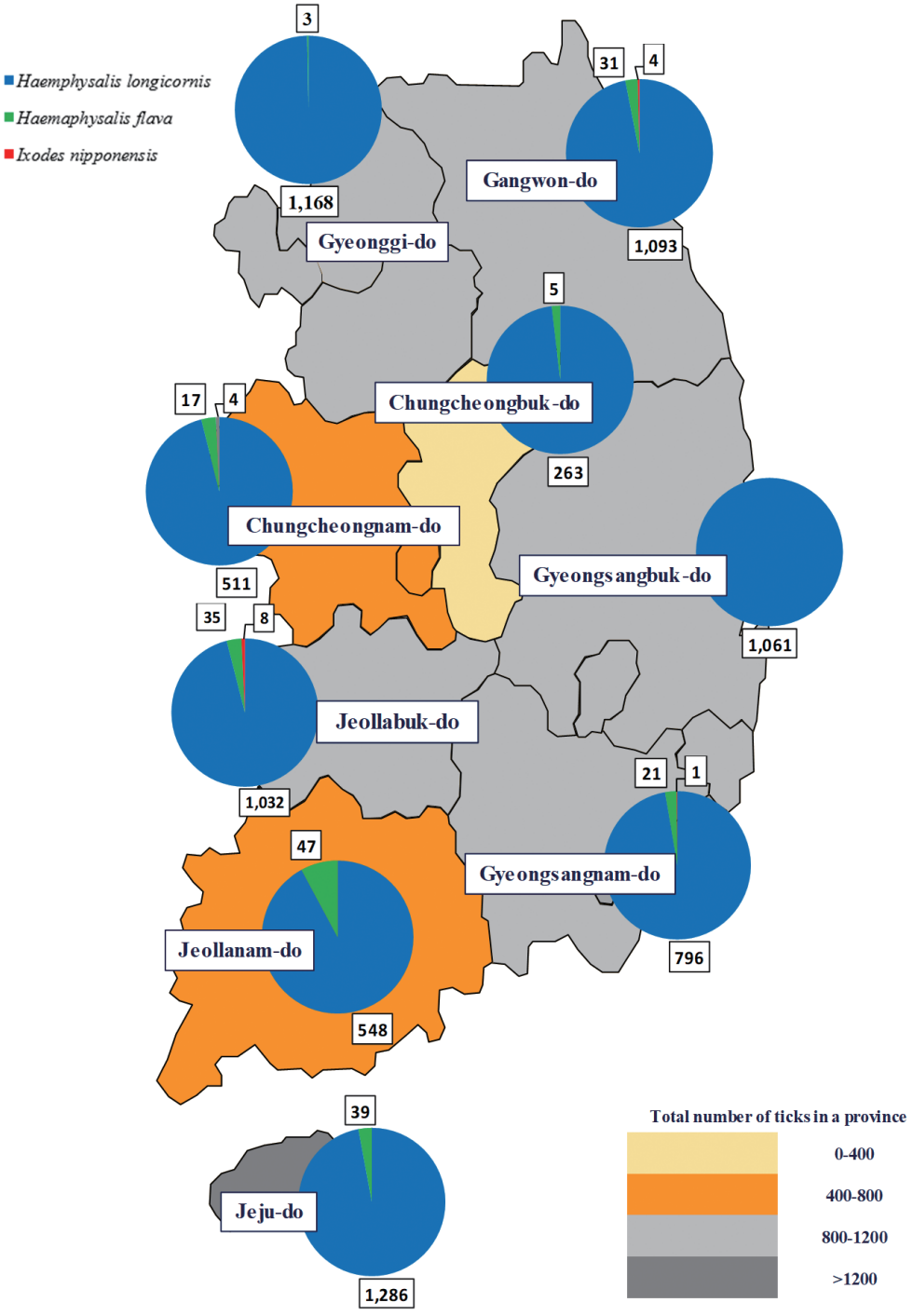

Fig. 1. A map on distribution of ticks around the farms of 4 kind animals in provinces. Circular graph depicts species and number of ticks in the province.

adult females [13 in 2014; 6 in 2015]; 10.5%) were collected.

In this study, we investigated the distribution of tick species and numbers from all provinces of Korea related to animal hosts. Given that once the larvae hatch, they do not move over a wide range, a large number of larvae can be collected in one flagging, which may skew the results of the overall distribution. Therefore, our collection was limited to the adult and nymph stages. Our results showed that near grazing animal

Table 1. Tick species collected from cattle, goats and wild boars in 2014 and 2015

Animals	Tick species	Developmental stages	Number of ticks		
			2014	2015	Total
Cattle	*Haemaphysalis longicornis*	Adult male	49	29	78
		Adult female	159	490	649
		Nymph	1	1	2
		Subtotal	209	520	729
Subtotal			209	520	729
Goat	*Haemaphysalis longicornis*	Adult male	369	0	369
		Adult female	162	0	162
		Nymph	38	0	38
		Subtotal	569	0	569
Subtotal			569	0	569
Wild boar	*Haemaphysalis longicornis*	Adult male	31	13	44
		Adult female	114	71	185
		Nymph	68	0	68
		Subtotal	213	84	297
	Haemaphysalis flava	Adult male	48	46	94
		Adult female	9	15	24
		Nymph	0	0	0
		Subtotal	57	61	118
	Ixodes nipponensis	Adult male	1	0	1
		Adult female	0	0	0
		Nymph	0	0	0
		Subtotal	1	0	1
	Amblyomma testudinarium	Adult male	22	8	30
		Adult female	13	6	19
		Nymph	0	0	0
		Subtotal	35	14	49
Subtotal			306	159	465
Grand Total			1,084	679	1,763

farms, *H. longicornis* was the most commonly found tick species, followed by *H. flava* and *I. nipponensis*. These results are similar to those of previous studies on ticks collected from the environment in Korea [17]. *Haemaphysalis* and *Ixodes* are known as typical forest ticks, which have a passive ambush strategy of host seeking [18]. As dragging and flagging method, conducted in the areas around farm in this study, is known as the efficient method for surveying questing ticks, it is natural that only abundant *Haemaphysalis* spp. and *Ixodes* spp. were collected near animal farms.

By region, the highest number of ticks was collected in Jeju-do. Different from other provinces, Jeju-do has a subtropical climate, plenty of grasslands and pasturing cow and goat farms. Therefore, their distribution was much higher in the Jeju-do province than other provinces in Korea. Moreover, 3 species were collected in Gangwon-do, Chungcheongnam-do, Gyeongsangnam-do, and Jeollabuk-do, but 2 species were collected in Gyeonggi-do, Chungcheongbuk-do, Jeollanam-do, and Jeju-do, and only 1 species was collected in Gyeongsangbuk-do. However, it is difficult to determine the underlying factor for these differences between the regions.

From animals, adult ticks were collected in larger numbers than nymphs, which is contradictory to the results of tick collected from farms. This might be because most of the nymphs are known to bite small/medium-sized animals and are also difficult to see when covered by animal hair, as they are relatively smaller than adult ticks.

From the cattle and goats, only *H. longicornis* was collected. However, from the wild boars, 4 species (*H. longicornis, H. flava, I. nipponensis, A. testudinarium*) were collected, which have been previously reported from wild boar's bodies and their habitats [7]. *A. testudinarium* was only found on wild boars in this research. This might be explained by different species of ticks having different habitat preferences depending on various factors such as host type, temperature, humidity, and soil condition [19]. Moreover, unlike grazing animals, which inevi-

tably inhabit smaller areas, wild boars have a wide range of movement and are more likely to be exposed to many kinds of ticks.

To conclude, *H. longicornis* was the most common species collected from animals and the areas around the farms in this study. *H. longicornis* is the most dominant species of hard ticks in Korea, and almost all tick-borne diseases in Korea are known to originate from *H. longicornis* [7,20,21]. Moreover, studies on tick-borne diseases from many other kinds of animals have also detected *H. longicornis* [22-24]. Apart from *H. longicornis*, other species were also collected from wild boars, and there might be more species of ticks than those detected in this study in Korea [17]. Thus, our study emphasizes that ticks may appear differently depending on the host, so ticks should be investigated considering the various animal hosts.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

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