

Ticks Collected from Wild and Domestic Animals and Natural Habitats in the Republic of Korea

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Abstract: Ticks were collected from 35 animals from 5 provinces and 3 metropolitan cities during 2012. Ticks also were collected by tick drag from 4 sites in Gyeonggi-do (2) and Jeollabuk-do (2) Provinces. A total of 612 ticks belonging to 6 species and 3 genera were collected from mammals and a bird (n=573) and by tick drag (n=39). *Haemaphysalis longicornis* (n=434) was the most commonly collected tick, followed by *H. flava* (158), *Ixodes nipponensis* (11), *Amblyomma testudinarium* (7), *H. japonica* (1), and *H. formosensis* (1). *H. longicornis* and *H. flava* were collected from all animal hosts examined. For animal hosts (n>1), the highest Tick Index (TI) was observed for domestic dogs (29.6), followed by Siberian roe deer (17.4), water deer (14.4), and raccoon dogs (1.3). A total of 402 *H. longicornis* (adults 86, 21.4%; nymphs 160, 39.8%; larvae 156, 38.9%) were collected from wild and domestic animals. A total of 158 *H. flava* (n=158) were collected from wild and domestic animals and 1 ring-necked pheasant, with a higher proportion of adults (103, 65.2%), while nymphs and larvae only accounted for 12.7% (20) and 22.2% (35), respectively. Only 7 *A. testudinarium* were collected from the wild boar (6 adults) and Eurasian badger (1 nymph), while only 5 *I. nipponensis* were collected from the water deer (4 adults) and a raccoon dog (1 adult). One adult female *H. formosensis* was first collected from vegetation by tick drag from Mara Island, Seogwipo-si, Jeju-do Province.

Key words: *Haemaphysalis longicornis*, *Haemaphysalis flava*, *Haemaphysalis formosensis*, animal, abundance, tick index

INTRODUCTION

Wild and domestic mammals and birds are hosts for known and unknown zoonotic pathogens, including tick-borne encephalitis (TBE) virus, *Ehrlichia*, *Rickettsia*, *Anaplasma*, *Bartonella*, and *Borrelia* spp. [1,2]. Recently, a patient was diagnosed with severe fever with thrombocytopenia syndrome (SFTS), a virus first reported in China in 2009 and Japan in 2011 and transmitted by *Haemaphysalis longicornis* [3-6]. In the Republic of Korea (ROK), from May to November 2013, a total of 35 patients have been confirmed with SFTS, of which there were 16 deaths (45.7%) since the first patient was confirmed in Gangwon-do on 21st May 2013.

Approximately 70% of the Korean landscape is mountainous. As a result of a national tree planting policy instituted in the 1960s, young to mature planted groves and volunteer trees now cover mountains and hillsides. These forests provide harborage for wild and feral mammals (i.e., water deer, *Hydropotes inermis*; Siberian roe deer, *Capreolus pygargus*; wild boar, *Sus scrofa*; raccoon dog, *Nyctereutes procyonoides*; leopard cat, *Prionailurus bengalensis*; Eurasian badger, *Meles leucurus*; weasel, *Mustela sibirica*; rodent; soricomorph; feral cat, *Felis catus*; and feral dog, *Canis lupus*) and forest dwelling birds like ring-necked pheasants (*Phasianus colchicus*) that are host to a number of ectoparasites and pathogens they harbor [2]. Agriculture, construction, military operations and training, and increased recreational activities corresponding to peak activity of ticks increase exposure to zoonotic pathogens. Therefore, comprehensive tick-borne disease surveillance programs that include host-vector-pathogen relationships provide a better understanding of the diversity of hosts and host-ectoparasite-zoonotic pathogen relationships that impact on the health of domestic ani-

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mals, birds, and humans.

The purpose of this tick surveillance program was to identify hosts, associated ticks, and zoonotic pathogens (reported separately), and tick indices (TIs) for ticks collected from wild and domestic mammals, birds, and vegetation in the ROK.

MATERIALS AND METHODS

Ticks were collected from wild and domestic mammals, a ring-necked pheasant, and vegetation (tick drag) in the ROK as a part of the National Institute of Biological Resources (NIBR) project (Fig. 1). Mammals and a bird were examined for ectoparasites and ticks removed and provided to Seoul National University (SNU) through the SNU sampling network (e.g., wildlife rescue centers, veterinary hospitals, zoos, and legal hunters) during 2012 (Table 1). Mammals and a bird were identified to species using morphological methods and given a unique collection number. Ticks removed were placed in 15

or 50 ml conical tubes containing 100% ethyl alcohol (EtOH), and labeled with a unique collection number. Ticks also were collected and transported to SNU from vegetation (e.g., mainly grass and shrub vegetation at deer and cattle farms, province and local parks, and resident areas) by SNU researchers during 2012. Ticks collected by drag were similarly placed in conical tubes with 100% EtOH and labeled with a unique collection number. Ticks were identified to species, developmental stage, and sex (adults) under a dissecting microscope using conventional taxonomic keys [7-9]. Mammals and a bird that were rescued, killed on highways, or legally hunted were examined under separate institutional approved animal use protocols. TIs were calculated as: the numbers of ticks collected from hosts/total number of hosts, by species.

RESULTS

A total of 573 ticks belonging to 3 genera (*Haemaphysalis*, *Ixodes*, and *Amblyomma*) and 6 species were collected from 27 wild (4 families, 5 species) and 7 domestic (1 family, 1 species) mammals and from 1 ring-necked pheasant (Table 1). A total of 9 Siberian roe deer were examined for ticks, followed by water deer (8), raccoon dogs (8), and domestic dogs (7), wild boar (1), Eurasian badger (1), and ring-necked pheasant (1).

Among the ticks collected, *H. longicornis* (402) was the most frequently collected species from mammalian/avian hosts, followed by *H. flava* (158), *A. testudinarium* (7), *H. nipponensis* (5), and *H. japonica* (1) (Table 1). In addition, a total of 39 ticks belonging to 3 species (*H. longicornis*, *H. formosensis*, and *I. nipponensis*) were collected from vegetation by tick drag. *H. flava* had the broadest host range ($n=7$), followed by *H. longicornis* ($n=5$), *A. testudinarium* ($n=2$), *I. nipponensis* ($n=2$), and *H. japonica* ($n=1$) (Table 2). *A. testudinarium* was collected only from the wild boar (6 ticks) and Eurasian badger (1), while *I. nipponensis* was collected from water deer (4) and raccoon dog (1) and by tick drag (6). *H. longicornis* and/or *H. flava* were collected from all animal hosts, while *H. japonica* (1 tick) was collected only from domestic dogs (Table 2).

Excluding the wild boar, Eurasian badger, and ring-necked pheasant, which were collected only once, the highest TI was observed for domestic dogs (29.6) (Table 2). For wild mammals, the highest TI was observed for Siberian roe deer (17.4), followed by water deer (14.4) and raccoon dogs (1.3). *H. longicornis* nymphs (160, 39.8%) and larvae (156, 38.8%) were collected more frequently than adults (86, 21.4%) (Table 3).

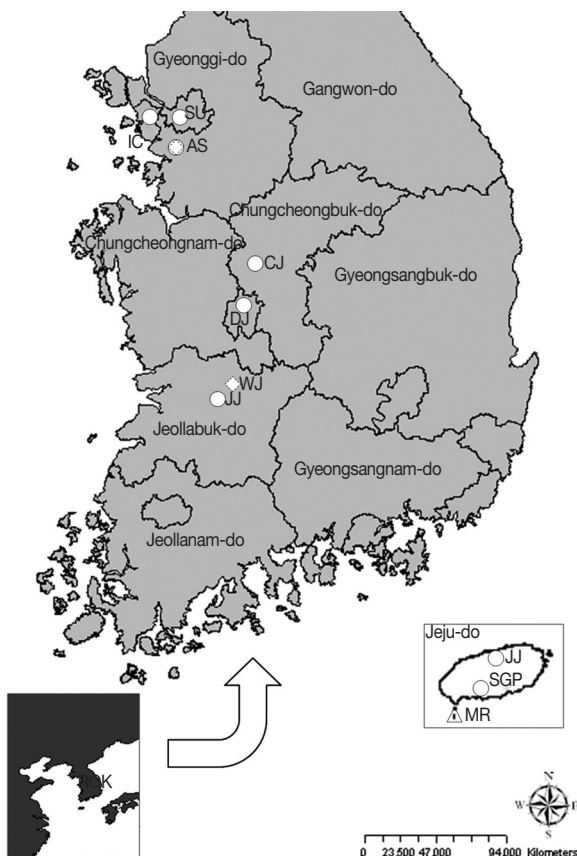


Fig. 1. Map of the surveyed areas. IC, Incheon; SU, Seoul; AS, Ansan; CJ, Cheongju; DJ, Daejeon; WJ, Wanju; JJ, Jeonju (Jeollabuk-do); JJ, Jeju (Jeju-do); SGP, Seogwipo; MR, Mara-do.

Table 1. Host animal, tick drag, species of ticks collected, and locality

Collection method	Species	Number examined	Locality	HL	HF	HFO	HJ	IN	AT	Total
Animal										
Wild boar (n=1)	<i>Sus crofa</i>	1	Jeollabuk-do		22				6	28
Water deer (n=8)	<i>Hydropotes inermis</i>	5	Jeollabuk-do	1	2			3		6
		2	Gyeonggi-do	105	1					106
		1	Chungcheongbuk-do		2			1		3
Siberian roe deer (n=9)	<i>Capreolus pygargus</i>	9	Jeju-do	155	2					157
Eurasian badger (n=1)	<i>Meles leucurus</i>	1	Jeollabuk-do	2	52				1	55
Raccoon dog (n=8)	<i>Nyctereutes procyonoides</i>	1	Chungcheongbuk-do		1			1		2
		7	Jeollabuk-do	6	2					8
Domestic dog (n=7)	<i>Canis lupus</i>	1	Seoul-si	84						84
		1	Incheon-si	48	1		1			
		2	Gyeonggi-do		6					56
		1	Daejeon-si	1	44					45
		2	Jeollabuk-do		22					22
Ring-necked pheasant (n=1)	<i>Phasianus colchicus</i>	1	Jeollabuk-do		1					1
Subtotal		35		402	158	0	1	5	7	573
Tick drag										
Vegetation (n=4)		2	Gyeonggi-do	31				6		37
		1	Jeollabuk-do	1						1
		1	Jeollanam-do			1				1
Subtotal		4		32	0	1	0	6	0	39
Total		39		434	158	1	1	11	7	612

HL, *Haemaphysalis longicornis*; HF, *Haemaphysalis flava*; HFO, *Haemaphysalis formosensis*; HJ, *Haemaphysalis japonica*; IN, *Ixodes nipponensis*; AT, *Amblyomma testudinarium*.

Table 2. Host, species of ticks, stage of tick development, and sex (adults), 2012

Family	Host common name	Number examined	Species	Larvae (%)	Nymphs (%)	Adults (male) (%)	Adults (female) (%)	Adults (total) (%)	Total	TI ^a
Suidae	Wild boar	1	<i>H. flava</i>			22 (100.0)		22 (100.0)	22	28.0
			<i>A. testudinarium</i>			6 (100.0)		6 (100.0)	6	
Cervidae	Water deer	8	<i>H. longicornis</i>	101 (95.3)	4 (3.8)		1 (0.9)	1 (0.9)	106	14.4
			<i>H. flava</i>		1 (20.0)		4 (80.0)	4 (80.0)	5	
			<i>I. nipponensis</i>			1 (25.0)	3 (75.0)	4 (100.0)	4	
	Siberian roe deer	9	<i>H. longicornis</i>	1 (0.6)	71 (45.8)	25 (16.1)	58 (37.4)	83 (53.5)	155	17.4
			<i>H. flava</i>	1 (50.0)			1 (50.0)	1 (50.0)	2	
Mustelidae	Eurasian badger	1	<i>H. longicornis</i>	2 (100.0)					2	55.0
			<i>H. flava</i>	1 (1.9)	18 (34.6)	26 (50.0)	7 (13.5)	33 (63.5)	52	
			<i>A. testudinarium</i>		1 (100.0)				1	
Canidae	Raccoon dog	8	<i>H. longicornis</i>	2 (33.3)	2 (33.3)		2 (33.3)	2 (33.3)	6	1.3
			<i>H. flava</i>			1 (33.3)	2 (66.7)	3 (100.0)	3	
			<i>I. nipponensis</i>			1 (100.0)		1 (100.0)	1	
	Domestic dog	7	<i>H. longicornis</i>	50 (100.0)	83 (62.4)				133	29.6
			<i>H. flava</i>	33 (45.2)		10 (13.7)	30 (41.1)	40 (54.8)	73	
			<i>H. japonica</i>			1 (100.0)	1 (100.0)	1		
Phasianidae	Ring-necked pheasant	1	<i>H. flava</i>		1 (100.0)				1	1.0
Total		35		191 (33.3)	181 (31.6)	93 (16.2)	108 (18.8)	201 (35.1)	573	4.2

^aTI (tick index) = total no. of ticks collected/total no. of animals examined.

In contrast, *H. flava* adults (103, 65.2%) were more commonly collected than nymphs (20, 12.7%) and larvae (35, 22.2%).

DISCUSSION

In our study, *H. flava* had the broadest host range, followed

Table 3. No. (%) of ticks by species, stage of development, and sex (adults) collected from mammals and birds, 2012

Tick species	Larvae (%)	Nymphs (%)	Adults (male) (%)	Adults (female) (%)	Adults (all) (%)	Total (%)
<i>Haemaphysalis longicornis</i>	156 (38.8)	160 (39.8)	25 (6.2)	61 (15.2)	86 (21.4)	402 (70.2)
<i>Haemaphysalis flava</i>	35 (22.2)	20 (12.7)	59 (37.3)	44 (27.8)	103 (65.2)	158 (27.6)
<i>Haemaphysalis japonica</i>			1 (100.0)		1 (100.0)	1 (0.2)
<i>Ixodes nipponensis</i>			2 (40.0)	3 (60.0)	5 (100.0)	5 (0.9)
<i>Amblyomma testudinarium</i>		1 (14.3)	6 (87.5)		6 (85.7)	7 (1.2)
Total	191 (33.3)	181 (31.6)	93 (16.2)	108 (18.8)	201 (35.1)	573 (100.0)

by *H. longicornis*, *A. testudinarium*, *I. nipponensis*, and *H. japonica*. By contrast, in a previous survey of wild mammal hosts, 70 *I. nipponensis* were collected from water deer, Siberian roe deer, and 3 other mammalian species, whereas only 1 *H. japonica* was collected from a water deer, and no *A. testudinarium* was collected from any of the mammals examined [10].

The highest TI was observed for domestic dogs, some of which seemed to be exposed to tick habitats of tall grasses and forested areas. For wild mammals, the highest TI was observed for Siberian roe deer, followed by water deer and raccoon dogs. In a separate study, the raccoon dog demonstrated a very high TI (38.0), while similar TIs were observed for water deer (16.4) and Siberian roe deer (9.0) [10]. Variability in observed TIs is likely due to differences in sample sizes, areas surveyed, and dates of collection.

Similar to other studies, *H. longicornis* was the predominant tick collected from wild and domestic animals in the ROK [10, 11]. *I. nipponensis* was infrequently collected in this study; however, it is the primary tick collected from small mammals [10, 12] and has been implicated in the transmission and maintenance of tick-borne pathogens to humans in the ROK [10, 12-16].

One adult female *H. formosensis* was first collected from vegetation by tick drag on Mara Island, Seogwipo-si, Jeju-do, a migratory bird stopover island during their spring and fall migration to breeding and feeding grounds, respectively. *H. formosensis* nymphs were reported from neighboring countries and also was collected from migratory birds during 2010-2012 [17]. Further investigation need to be conducted to determine if *H. formosensis* has become established on the island and, if so, how well it adapted there or other places.

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CONFLICT OF INTEREST

We have no conflict of interest related to this work.

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