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▣ BRIEF COMMUNICATION

Ticks Collected from Selected Mammalian Hosts Surveyed in the Republic of Korea During 2008-2009

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Abstract: A tick survey was conducted to determine the relative abundance and distribution of ticks associated with selected mammals in the Republic of Korea (ROK) during 2008-2009. A total of 918 ticks were collected from 76 mammals (6 families, 9 species) captured at 6 provinces and 3 Metropolitan Cities in ROK. *Haemaphysalis longicornis* (54.4%) was the most frequently collected tick, followed by *Haemaphysalis flava* (28.5%), *Ixodes nipponensis* (7.6%), *Ixodes pomerantzevi* (4.8%), *Ixodes persulcatus* (4.6%), and *Haemaphysalis japonica* (0.1%). Adults (57.0%) and nymphs (28.7%) of *Ixodes* and *Haemaphysalis* spp. were collected most frequently from medium or large mammals in this survey, while few larvae (14.3%) were collected. *Hydropotes inermis* was the most frequently captured mammal (52.6%), with a 16.4 tick index and 5 of 6 species of ticks collected during this survey. *H. longicornis* (69.7%) was the predominant tick collected from *H. inermis*, followed by *H. flava* (22.2%), *I. persulcatus* (6.1%), *I. nipponensis* (1.8%), and *H. japonica* (0.2%).

Key words: *Haemaphysalis longicornis*, *Haemaphysalis flava*, *Ixodes nipponensis*, mammal, host, distribution

In the Republic of Korea (ROK), mammals and their associated ticks are hosts to a number of zoonotic pathogens, such as spotted fever group rickettsiae [1], *Ehrlichia* and *Anaplasma* spp. [2], *Bartonella* spp. [3], *Borrelia burgdorferi* [4-5], and tick-borne encephalitis virus [6-8]. Humans are incidental hosts as a result of outdoor activities, i.e., agriculture, construction, maintenance, recreation, and military training activities. New information, including retrospective febrile patient surveys, indicates that tick-borne diseases are underdiagnosed in the ROK [9-11].

Outdoor activities, including recreational hiking, agriculture, construction, and military operations, expose large sectors of human populations and their pets to all life stages of ticks, and associated pathogens of mammal [12]. Military populations are at increased risk for acquiring tick-borne infections because they often conduct training operations in unmanaged lands where small mammals (i.e., rodents, soricomorphs, rabbits, and weasels), as well as larger species (i.e., deer, wild pigs, raccoon dogs, badgers, and feral cats) and pathogen-infected ectoparasites are present.

In a large mammal tick survey, Kang (1984) reported 565 ticks to determine baseline susceptibility to selected acaricides of ticks collected from domestic livestock (cows) from 35 cities and counties and 6 provinces from 1982 to 1984. Species collected included, *Haemaphysalis longicornis* (87.4%), *Boophilus microplus* (=*Rhipicephalus microplus*) (8.8%), *Ixodes persulcatus* (3.4%), *Rhipicephalus sanguineus* (0.5%), *Argas vespertilionis* (0.2%), and 1 unidentified tick [13]. Later, Kim et al. (2008) reported 130 *H. longicornis* and 12 *Ixodes nipponensis* from 16 wild boars at Dongducheon, Gyeonggi-do (Province), for isolation and detection of tick-borne encephalitis virus [6]. Reports and studies of tick collections from wild large mammals are few, with most surveys limited to small mammals conducted as part of rodent-borne diseases surveillance programs [14-

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16]. The purpose of the present study was to determine the relative abundance, infestation rates, and geographical distributions of ticks associated with *Hydropotes inermis* (Korean water deer) and other wild mammals in the ROK.

As part of The 8th US Army, 65th Medical Brigade tick-borne disease surveillance program, the 5th Medical Detachment collaborated with 1) The Conservation Genome Resource Bank for Korean Wildlife, Seoul National University (SNU), 2) National Institute of Biological Resources (NIBR), and 3) The Migratory Birds Center located on Hong Island, National Park Research Institute (NPRI), to collect ticks from wild mammals captured for necropsy under institutional approved animal use protocols (SNU, NIBR, and the NPRI). Ticks were removed from mammals captured from 6 provinces [Gyeonggi-do (Pocheon), Gangwon-do (Chuncheon, Cheorwon, Inje), Jeollanam-do (Goheung, Gokseong, Gwangyang, Gurye, Hampyeong, Suncheon, Yeosu, Hong Island), Chungcheongbuk-do (Cheongwon), Gyeongsangbuk-do (Uljin), and Jeju-do (Jeju, Seogwipo)], and 3 Metropolitan Cities (Seoul, Daejeon, and Ulsan) in the ROK (Table 1). Ticks were carefully removed with a fine forceps from mammals, placed in 2-ml cryovials with 80% ethyl alcohol, and transported to the Entomology Section, 5th Medical Detachment, where they were identified to species and developmental stage under a dissecting microscope using standard keys and current nomenclature [17-20].

A total of 918 ixodid ticks belonging to 2 genera (*Ixodes* and *Haemaphysalis*) were collected from mammals (n = 76; 6 families, 9 species) captured for surveillance from 6 provinces and 3 Metropolitan Cities in the ROK. *H. inermis* (52.6%) was the most frequently collected mammal, followed by *Felis catus* (feral cat, 27.6%), *Capreolus pygargus* (roe deer, 5.3%), *Nyctereutes procyonoides* (raccoon dog, 3.9%) and *Tamias sibiricus* (Siberian chipmunk, 3.9%) (Table 1). Only 1-2 ticks were collected from each of the remaining 4 species. Of the 6 species of ticks collected, *H. longicornis* (54.4%) was the most frequently collected, followed by *Haemaphysalis flava* (28.5%), *I. nipponensis* (7.6%), *Ixodes pomerantzevi* (4.8%), *I. persulcatus* (4.6%), and *Haemaphysalis japonica* (0.1%). The highest tick indices for selected hosts were recorded from *N. procyonoides* (38.0), followed by *H. inermis* (16.4), *T. sibiricus* (15.0), *C. pygargus* (9.0), and *Meles leucurus* (7.0). Tick indices for the remaining mammals were < 5.0 (Table 2).

H. japonica (100.0%) was collected only from the Korean water deer, while accounting for 95.2% of *I. persulcatus*, 91.8% of *H. longicornis*, 55.7% of *H. flava*, and 17.1% of *I. nipponensis*. *H. longicornis* (69.7%) was the predominant species collected from the Korean water deer, followed by *H. flava* (22.2%), *I. persulcatus* (6.1%), *I. nipponensis* (1.8%), and *H. japonica* (0.2%) (Table 1).

Tick-borne zoonoses pose a serious health threat to US and ROK military populations throughout Korea [1-9,14-16]. Identification of arthropod ectoparasites and isolation of patho-

Table 1. Number of ticks and collection sites for each mammal species in the Republic of Korea, 2008-2009

Host species	Number surveyed	Collection sites	HL	HF	HJ	IN	IPO	IPE	Total
Tamias sibiricus	3	Gyeonggi	0	1	0	0	44	0	45
Mogera robusta	1	Gyeonggi	0	0	0	0	0	0	0
Nyctereutes procyonoides	3	Gangwon	9	105	0	0	0	0	114
Hydropotes inermis	1	Seoul	0	5	0	0	0	0	5
	9	Gangwon	92	58	0	3	0	20	173
	2	Chungcheongbuk	0	3	0	0	0	4	7
	1	Daejeon	25	4	0	0	0	0	29
	2	Gyeongsangbuk	8	1	1	0	0	0	10
	18	Ulsan	331	30	0	9	0	3	373
	7	Jeollanam	2	45	0	0	0	13	60
Capreolus pygargus	2	Ulsan	19	10	0	0	0	0	29
	2	Jeju	6	0	0	1	0	0	7
Prionalurus bengalensis	2	Jeollanam	0	0	0	6	0	0	6
Felis catus	21	Jeollanam	0	0	0	48	0	2	50
Mustela sibirica	1	Jeollanam	0	0	0	3	0	0	3
Meles leucurus	1	Jeollanam	7	0	0	0	0	0	7
Total	76		499	262	1	70	44	42	918

[a]HL, *Haemaphysalis longicornis*; HF, *Haemaphysalis flava*; HJ, *Haemaphysalis japonica*; IN, *Ixodes nipponensis*; IPO, *Ixodes pomerantzevi*; IPE, *Ixodes persulcatus*.

gens provide a descriptive analysis of the relative abundance of ticks, host associations, stages of development found on hosts, and relative distributions. Epidemiological data are critical to identify the prevalence, distribution, and disease risks of endemic and emerging zoonoses affecting animals and humans in the ROK. For US and ROK military populations, these data are central to the development of disease risk assessments and mitigation strategies (e.g., use of insecticide-impregnated uniforms) that reduce the impact of zoonotic diseases while increasing awareness among medical providers of potential arthropod-borne infections. *H. longicornis* is commonly collected on large mammals and from tall grass habitats with associated herbaceous vegetation and margins of forested hillsides and mountains (unpublished data), while *H. flava* larvae and nymphs are often associated with small mammals (e.g., rodents and soricomophs) and birds [17]. However, only 1 *H. flava* nymph was collected from 5,953 rodents and soricomorphs captured from 2004 to 2008 in Gyeonggi-do and Gangwon-do [16].

In our survey, 262 (28.5%) *H. flava* ticks were collected, with nymphs and adults found on a variety of small and large mammals (Table 3). *I. nipponensis*, larvae and nymphs, was the predominant tick (98.9%) collected from 5,953 small mammals captured (e.g., rodents and soricomorphs) in Gyeonggi-do and Gangwon-do [16]. In other reports, *I. nipponensis* was the most frequently collected tick from small mammals captured in

Table 2. Number of mammals captured and number of ticks collected, by stage of development, for each mammal species in the Republic of Korea, 2008-2009

Family	Host species	Number surveyed	Tick species	Larvae	Nymphs	Adult male	Adult female	Total	Index[a]
Sciuridae	*Tamias sibiricus*	1	*Ixodes pomerantzevi*	24	5	0	15	44	15.0
		2	*Haemaphysalis flava*	0	1	0	0	1	
Talpidae	*Mogera robusta*	1	-	0	0	0	0	0	0.0
Canidae	*Nyctereutes procyonoides*	3	*Haemaphysalis longicornis*	0	0	0	9	9	38.0
			Haemaphysalis flava	14	43	32	16	105	
Cervidae	*Hydropotes inermis*	40	*Haemaphysalis longicornis*	77	179	116	86	458	16.4
			Haemaphysalis flava	15	29	65	37	146	
			Haemaphysalis japonica	0	0	1	0	1	
			Ixodes persulcatus	1	0	15	24	40	
			Ixodes nipponensis	0	0	6	6	12	
	Capreolus pygargus	4	*Haemaphysalis longicornis*	0	7	6	12	25	9.0
			Haemaphysalis flava	0	0	6	4	10	
			Ixodes nipponensis	0	0	0	1	1	
Felidae	*Prionalurus bengalensis*	2	*Ixodes nipponensis*	0	0	2	4	6	3.0
	Felis catus	21	*Ixodes persulcatus*	0	0	0	2	2	2.4
			Ixodes nipponensis	0	0	14	34	48	
Mustelidae	*Mustela sibirica*	1	*Ixodes nipponensis*	0	0	1	2	3	3.0
	Meles leucurus	1	*Haemaphysalis longicornis*	0	0	1	6	7	7.0
Total		76		131	264	265	258	918	12.1

[a] Index = Total numbers of tick collected/total numbers of mammals collected.

Table 3. Total number, percent, and stage of development for ticks collected from mammals, Republic of Korea, 2008-2009

Tick species	Larvae	Nymph	Male	Female	Total (%)
Haemaphysalis longicornis	77 (15.4)[a]	186 (37.3)[a]	123 (47.3)[b]	113 (54.4)[c]	499
Haemaphysalis flava	29 (11.0)	73 (27.9)	103 (61.1)	57 (28.5)	262
Haemaphysalis japonica	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.1)	1
Ixodes nipponensis	0 (0.0)	0 (0.0)	23 (100.0)	47 (7.6)	70
Ixodes pomerantzevi	24 (54.5)	5 (11.4)	0 (34.1)	15 (4.8)	44
Ixodes persulcatus	1 (2.4)	0 (0.0)	15 (97.6)	26 (4.6)	42
Total	131 (14.3)	264 (28.7)	265 (57.0)	258 (100.0)	918

[a] Percent of total ticks collected from mammals by species and stage of development; [b] Percent of both male and female ticks collected from mammals; [c] Percent of ticks for all stages of development and species collected from mammals.

Gyeonggi-do, while *I. persulcatus* was more commonly collected in Gangwon-do [14]. In our survey, this species was predominantly collected from *F. catus* at Hong Island, Jeollanam-do, and accounted for 96.0% of the total collected from feral cats. Larvae and nymphs of *I. nipponensis* prefers to blood feed on small mammals, while adults are more commonly found on large mammals.

Recent studies indicate that *I. nipponensis* plays an important role in the transmission of tick-borne pathogens to humans in the ROK, as human tick bites are reported more frequently for this species among patients seen at medical clinics in the ROK [21-24]. However, the number of reports may be not only due to increased propensity to bite humans, but due to greater allergenic reactions to bites by this species than others. *Ixodes persulcatus* was collected most frequently from *H. inermis*, which was associated with dense forested habitats in the Taebaek mountain range (20/42; 47.6%) and Sobaek mountain range (13; 31.0%). *I. pomerantzevi* is an uncommonly collected tick, with all previous collection records of this species collected from small mammals (*Myodes regulus, Tscherskia triton, T. sibiricus*, and *Apodemus agrarius*) while conducting routine rodent-borne disease surveillance [18,25,26]. In this survey, *T. sibiricus* was the primary host of *I. pomerantzevi*, with 24 larvae, 5 nymphs, and 15 female adults collected from 1 *T. sibiricus* collected in northern Gyeonggi-do. Only 1 male (0.1%) *H. japonica* was collected from a Korean water deer, and it has been infrequently recorded in other collections, e.g., tick drags, rodents, and birds.

Adults (57.0%) and nymphs (28.7%) of *Ixodes* and *Haemaphysalis* spp. were mostly collected from medium/large mammals in this survey, while larval ticks only accounted for 14.3% of all ticks collected (Table 3). In contrast, larvae (82.8%) and nymphs (17.2%) were collected from small mammals, 5,397 *A. agrarius* in Gyeonggi-do and Gangwon-do during 2004-2008, while adults accounted for < 0.1% of all ticks collected [16].

The changing ecology, particularly reforestation, and associated increases in wildlife populations provide for increased proximal host contact associated with the wide distribution of blood-feeding ectoparasites in the ROK. Further studies of tick-host relationships are necessary to better understand tick species distributions and population dynamics, the distribution and prevalence of tick-borne pathogens, and their potential effects on human and animal health.

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