

Seasonal Abundance of *Culicoides* (Diptera: Ceratopogonidae) Collected by Mosquito Magnet® in Northern Gyeonggi-do (Province), Korea

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Abstract: Biting midges (*Culicoides*: Ceratopogonidae) were collected by Mosquito Magnet® traps at the Neutral Nations Supervisory Commission (NNSC) camp and Daeseongdong village inside the demilitarized zone (DMZ) and near the military demarcation line (MDL) separating North and South Korea and at Warrior Base (US Army training site) and Tongilchon 3 km south of the DMZ in northern Gyeonggi Province, Republic of Korea (ROK), from May–October 2010–2012, to determine their seasonal distributions. A total of 18,647 *Culicoides* females (18,399; 98.7%) and males (248; 1.3%) comprising 16 species were collected. Overall, the most commonly collected species was *Culicoides nipponensis* (42.9%), followed by *C. erairai* (29.2%), *C. punctatus* (20.3%), *C. arakawae* (3.3%), *C. pallidulus* (1.8%), and *C. circumscriptus* (1.4%), while the remaining 10 species accounted for only 1.1% of all *Culicoides* spp. collected. The seasonal distribution of *C. nipponensis* was bimodal, with high numbers collected during May–June and again during September. *C. erairai* was more frequently collected during June–July, followed by sharply decreased populations from August–October. *C. punctatus* was collected in low numbers from May–September with high numbers collected during October. *C. erairai* was predominantly collected from the NNSC camp (85.1% of all *C. erairai* collected) located adjacent to the MDL at Panmunjeom in the northernmost part of Gyeonggi-do (Province), while other sites yielded low numbers of specimens.

Key words: *Culicoides nipponensis*, *Culicoides erairai*, *Culicoides punctatus*, biting midge, Korea

INTRODUCTION

Culicoides spp. Latreille (Diptera: Ceratopogonidae) or biting midges are small (0.5–2.0 mm in length) bloodsucking insects that have a broad distribution and impact on human and veterinary health as vectors of viruses (bluetongue, African horse sickness, epizootic hemorrhagic disease of deer, Akabane, Aino, Chuzan, and bovine ephemeral fever viruses), protozoan parasites (*Haemoproteus* and *Leucocytozoon* spp.), and filarial worms (*Onchocerca* and *Dipetalonema* spp.) throughout their range [1–15].

The first nationwide biting midge surveys in the Republic of Korea (ROK) were reported in 1974 [16,17], with seasonal

abundance and host blood meal analysis of *Culicoides* spp. collected from cattle and poultry farms in Gyeonggi-do (Province) reported much later [18]. More recently, a brief summary of the history of research into the *Culicoides* fauna and seasonal prevalence of *Culicoides* spp. collected at 9 cowsheds in the southern part of the ROK were reported by Kim et al. [19] along with new records of 3 *Culicoides* spp. (*C. nasuensis* Kitao-ka, *C. pallidulus* Yu, and *C. jacobsoni* Macfie) [20], bringing the total number of *Culicoides* spp. reported in the ROK to 31.

Vector-borne disease surveillance is conducted by the 65th Medical Brigade in collaboration with the Public Health Command Region-Pacific (PHCR-PAC) to determine the species composition and seasonal and geographical distributions for mosquitoes and other biting flies, e.g., *Culicoides* spp., and pathogens they harbor using Mosquito Magnet® traps in/near the demilitarized zone (DMZ) that separates North and South Korea in northern Gyeonggi-do, ROK.

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MATERIALS AND METHODS

Mosquito Magnet® traps (ProModel, Woodstream Corp., Lititz, Pennsylvania, USA) use counter-flow technology and propane gas to produce heat and CO₂ as attractants to capture mosquitoes and other biting flies, such as *Culicoides*. Collections were made at 4 sites, including the Neutral Nations Supervisory Commission (NNSC) camp (37° 57' 16.39" N, 26° 40' 50.03" E), Daeseongdong village (37° 56' 26.92" N, 126° 40' 37.42" E) inside the 2-km wide demilitarized zone (DMZ) and adjacent to the military demarcation line (MDL) that separates North and South Korea and at Warrior Base, a US Army training site (37° 55' 17.01" N, 126° 44' 30.22" E), and a beef farm at Tongilchon (37° 54' 32.18" N, 126° 44' 01.88" E) located north of the Imjin river and approximately 3 km from the DMZ, Gyeonggi-do, ROK, from May-October 2010-2012 (Fig. 1). Traps at the NNSC camp were set <50 m from the MDL. Daeseongdong is a village of approximately 200 residents that is under the protection of South Korea and is approximately 100-200 m from the MDL. Rice farming is the principal activity, with an enclosed (not pastured) beef farm of <50 cattle. The Mosquito Magnet was placed at the northern most edge of Daeseongdong and approximately 100 m north of the beef farm. Warrior Base is a US military training site approximately

3 km south of the DMZ. Traps were set adjacent to the barracks where soldiers sleep during the evening hours. Tongilchon is a small village of approximately 200 residents with 2 enclosed (not pastured) beef farms of approximately 50 cattle each. It is located approximately 2 km west of Warrior Base and 3 km from the DMZ. The Mosquito Magnet was placed outside one of the beef farms adjacent to a rice paddy and dry land vegetable farming.

Mosquito Magnet® traps were operated continuously, with specimens collected twice weekly from May-October in 2010-2012. Specimens were transported to the 5th Medical Detachment, US Army Garrison, Yongsan, Seoul, ROK, where mosquitoes and other biting flies were separated. Specimens of *Culicoides* were transferred into 70% ethanol and identified using the keys of Arnaud [21] and the checklist of Bellis et al. [20]. Voucher specimens were submitted to the Northern Territory Quarantine Insect Collection (NTQIC) in Darwin, Northern Territory, Australia, for future reference and genetic studies.

RESULTS

A total of 18,677 *Culicoides* females (18,399; 98.7%) and males (248; 1.3%) comprising 16 species were collected from May-October over a 3-year period from 2010-2012. *Culicoides*

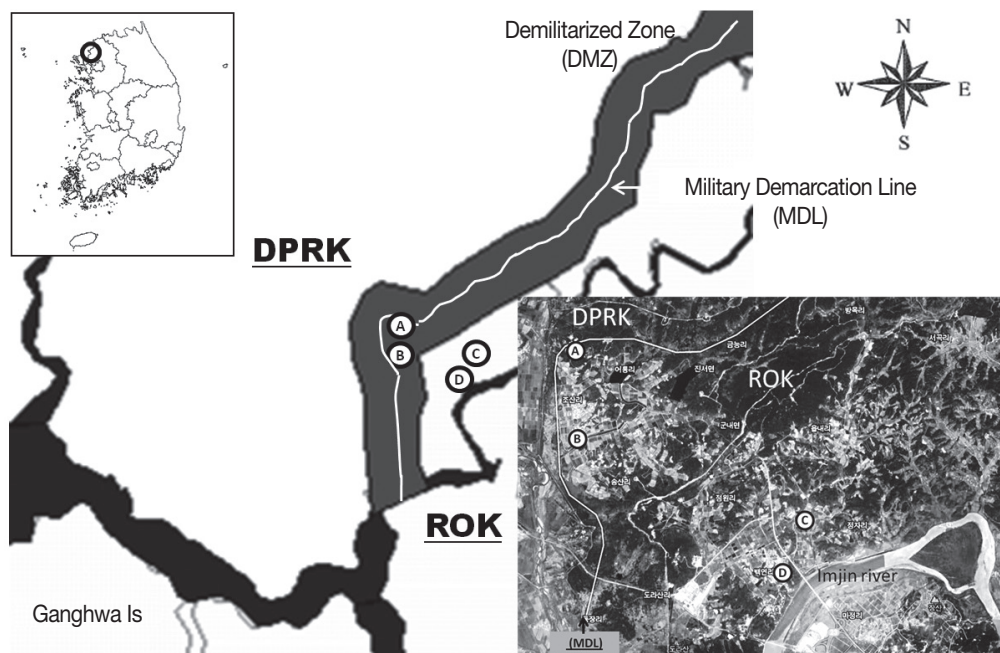


Fig. 1. Survey sites for *Culicoides* spp. collected by Mosquito Magnet® traps in northern Gyeonggi-do (Province), Republic of Korea. A: Neutral Nations Supervisory Commission camp (NNSC), B: Daeseongdong, C: Warrior Base, and D: Tongilchon.

nipponensis Tokunaga was the most commonly collected species (42.9%), followed by *Culicoides erairai* Kono and Takahasi (29.2%), *Culicoides punctatus* (Meigen) (20.3%), *Culicoides arakawae* (Arakawa) (3.3%), *C. pallidulus* (1.8%), and *Culicoides circumscriptus* Kieffer (1.4%), while the remaining 10 species accounted for only 1.1% of all *Culicoides* spp. collected

(Table 1). *C. nipponensis* was the most frequently collected species (females and males) at Daeseongdong village (67.1%), and was commonly collected from the NNSC camp (35.6%), Tongilchon (33.9%), and Warrior Base (19.5%). *C. erairai* was the most frequently collected species at NNSC camp (53.6%) and accounted for 85.1% of *C. erairai* collected at all 4 sites

Table 1. Total number of *Culicoides* females (F) and males (M) collected by Mosquito Magnet® traps in northern Gyeonggi-do (Province), 2010-2012

Species\Sites	NNSC		Daeseongdong		Warrior Base		Tongilchon		Female	Male	Total	%
	F	M	F	M	F	M	F	M				
<i>C. arakawae</i>	47	4	318	48	140	18	35	11	540	81	621	3.3
<i>C. circumscriptus</i>	62	5	141	3	48	2	3	2	254	12	266	1.4
<i>C. erairai</i>	4,631	6	318	3	78	0	411	0	5,438	9	5,447	29.2
<i>C. festivipennis</i>	9	0	1	0	1	1	1	0	12	1	13	<0.1
<i>C. homotomus</i>	0	0	2	0	0	0	6	0	8	0	8	<0.1
<i>C. japonicus</i>	2	0	7	0	1	0	0	0	10	0	10	<0.1
<i>C. kibunensis</i>	9	1	10	0	8	1	2	2	29	4	33	0.2
<i>C. koreensis</i>	0	0	16	0	2	0	0	0	18	0	18	0.1
<i>C. sphagnumensis</i>	2	0	1	0	0	0	0	0	3	0	3	<0.1
<i>C. morisitai</i>	5	0	20	3	1	0	2	0	28	3	31	0.2
<i>C. nipponensis</i>	3,060	23	3,267	69	162	0	1,420	1	7,909	93	8,002	42.9
<i>C. pallidulus</i>	22	0	204	15	60	20	5	1	291	36	327	1.8
<i>C. pictimago</i>	7	0	13	0	0	0	0	0	20	0	20	0.1
<i>C. punctatus</i>	754	5	504	2	237	2	2,278	0	3,773	9	3,782	20.3
<i>C. sinoensis</i>	0	0	0	0	1	0	1	0	2	0	2	<0.1
<i>C. tainanus</i>	3	0	6	0	49	0	6	0	64	0	64	0.3
Total	8,613	44	4,828	143	788	44	4,171	17	18,399 (98.7%)	248 (1.3%)	18,647	100.0

Table 2. Seasonal prevalence of female *Culicoides* collected by Mosquito Magnet® at four collection sites in northern Gyeonggi-do (Province), 2010-2012

<i>Culicoides</i> species	May		June		July		August		September		October		Total	%
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%		
<i>C. arakawae</i>	26	1.2	25	0.5	9	0.3	35	2.9	153	3.8	292	9.3	540	2.9
<i>C. circumscriptus</i>	46	2.2	133	2.7	35	1.2	0	0	19	<0.1	21	0.7	254	1.4
<i>C. erairai</i>	16	0.8	2,962	59.2	2,154	76.0	160	13.2	145	3.6	1	<0.1	5,438	29.6
<i>C. festivipennis</i>	7	0.3	3	<0.1	1	<0.1	0	0	1	<0.1	0	0	12	<0.1
<i>C. homotomus</i>	2	<0.1	2	<0.1	3	0.1	1	<0.1	0	0	0	0	8	<0.1
<i>C. japonicus</i>	4	0.2	0	0	0	0	0	0	0	0	6	0.2	10	<0.1
<i>C. kibunensis</i>	1	<0.1	16	0.3	3	0.1	5	0.4	3	<0.1	1	<0.1	29	0.2
<i>C. koreensis</i>	18	0.9	0	0	0	0	0	0	0	0	0	0	18	0.1
<i>C. sphagnumensis</i>	0	0	2	<0.1	0	0	0	0	1	<0.1	0	0	3	<0.1
<i>C. morisitai</i>	0	0	2	<0.1	3	0.1	8	0.7	14	0.3	1	<0.1	28	0.2
<i>C. nipponensis</i>	1,754	82.4	1,479	29.5	523	18.5	807	66.3	3,332	81.7	14	0.5	7,909	43.0
<i>C. pallidulus</i>	31	1.5	200	4.0	20	0.7	5	0.4	21	0.5	14	0.5	291	1.6
<i>C. pictimago</i>	17	0.8	3	<0.1	0	0	0	0	0	0	0	0	20	0.1
<i>C. punctatus</i>	206	9.7	177	3.5	84	3.0	178	14.6	372	9.1	2,756	88.0	3,773	20.5
<i>C. sinoensis</i>	1	<0.1	0	0	0	0	0	0	0	0	1	<0.1	2	<0.1
<i>C. tainanus</i>	1	<0.1	3	<0.1	0	0	18	1.5	19	0.5	23	0.7	64	0.4
Total	2,130	11.6	5,007	27.2	2,835	15.4	1,217	6.6	4,080	22.2	3,130	17.0	18,399	100.0

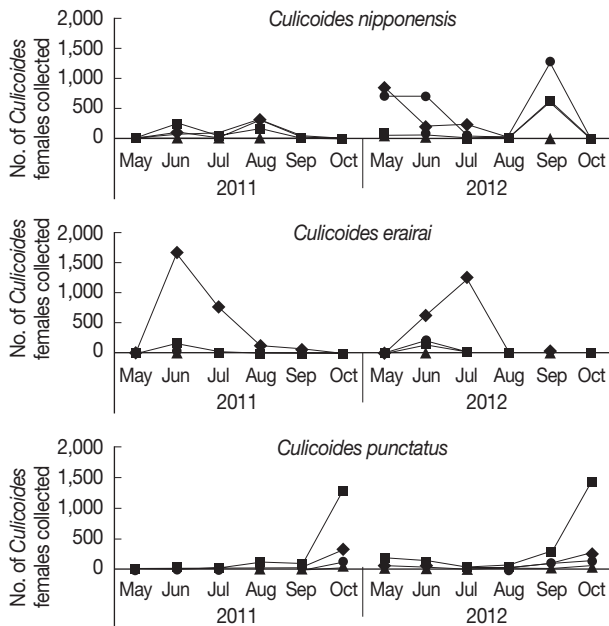


Fig. 2. Seasonal prevalence of 3 predominant species, *Culicoides nipponensis*, *C. erairai*, and *C. punctatus* females, collected from Mosquito Magnet® traps at 4 collection sites in northern Gyeonggi-do (Province), in/near the demilitarized zone, Republic of Korea, 2011-2012 (◆-Neutral Nations Supervisory Commission camp (NNSC), ●-Daeseongdong, ▲-Warrior Base, and ■-Tongilchon).

(Table 1), while *C. punctatus* was the most frequently collected species at both Tongilchon (54.4%) and Warrior Base (28.7%).

C. nipponensis females demonstrated bimodal capture rates, with large numbers collected during May (1,754, 82.4%), June (1,479, 29.5%), and then again during September (3,332, 81.7%) (Table 2). *C. erairai* was more frequently collected during June (2,962, 59.2%) and July (2,154, 76.0%) followed by a sharp decline in numbers collected from August-October. *C. punctatus* was collected infrequently from May-September (range, 84-372) with large numbers only collected during October (2,756, 88.0%).

Overall, low numbers of *C. nipponensis* were collected during 2011, while higher numbers were observed during May-June and again during September 2012 at the NNSC camp and Daeseongdong (Fig. 2). *C. erairai* was collected more frequently at the NNSC camp during the months of June-July 2011 and 2012, with few collected from August-October for either year. Low numbers of *C. punctatus* were collected from May-September, with a sharp increases in numbers observed primarily at the beef farm at Tongilchon during October for both 2011 and 2012.

DISCUSSION

This is the first report for collections of *Culicoides* using Mosquito Magnet traps that use only heat and CO₂ as attractants. The addition of other chemical attractants, e.g., octenol, has been shown to repel some species of culicine mosquitoes [22], while enhancing the collection of others, but the relative attractiveness of this attractant has not been investigated for most species of *Culicoides*. A major difference between Mosquito Magnet and light traps is that Mosquito Magnet traps operate continuously without bias toward nocturnal and diurnal active species. This difference, however, indicates that comparative analysis between data obtained from Mosquito Magnet and light traps should be viewed with caution.

Biting midges are both nuisance biters and vectors of medical and veterinary important pathogens that impact the economy of the animal industry in the ROK [14,15]. *C. nipponensis*, and *C. punctatus* were the most commonly collected species by Mosquito Magnets during this study and have been associated with the transmission of important livestock pathogens, e.g., Fukuoka, Aino, and Ibaraki viruses [5,23], or as biting pests of humans (*C. erairai*) [24,25]. Consequently, surveillance of these and other species of *Culicoides* and associated pathogens are an important part of the veterinary health service to identify relative vector populations, their distributions throughout the ROK, and the presence and prevalence of pathogens affecting livestock and poultry.

The dominance of *C. nipponensis* and *C. punctatus* in the Mosquito Magnet collections is similar to findings by Cho and Chong [17] and Kang and Yu [18] using New Jersey light traps. Similarly, Lee [26] found that *C. punctatus*, *C. arakawae*, and *C. tainanus* Kieffer were the most commonly collected species at inland sites, whereas *C. nipponensis* and *C. sinanoensis* Tokunaga were the predominant species collected from the south and eastern coastal areas in the ROK. Recently Kim et al. [19] found that *C. punctatus* and *C. arakawae* were the dominant species collected from light traps set in 9 cowsheds in the southern part of the ROK. The unprecedented predominance of *C. erairai* and relatively low numbers of *C. arakawae* in the Mosquito Magnet traps compared to these and other previous reports [17,27] may reflect the relative attraction of these species to light and the attractants associated with the Mosquito Magnet traps.

The dominance of *C. nipponensis* and *C. punctatus* at a cowshed at Tongilchon agrees with the host preference of these

species for cattle [23,26,28]. Although *C. arakawae* appears to have a preference for feeding on birds [29], it also readily feeds on cattle [18,26], which would explain its abundance around cowsheds in other reports but not the low numbers collected at the cowshed at Tongilchon in this survey.

The variable distribution of *Culicoides* spp. over a limited area (2 km radius) demonstrates the focal species abundance due to little understood environmental and host attraction factors. For example, high numbers of *C. erairai* were observed at the NNSC camp where humans are believed to be the primary host, while *C. nipponensis* was the primary species collected at Daeseongdong and Tongilchon where a variety of hosts (e.g., cattle, dogs, large water birds, and humans) serve as potential hosts. Thus, further studies comparing light and Mosquito Magnet traps and range of available hosts may reveal differential attraction for different species and assist in surveys targeting particular species. Additionally, studies on the geographical and seasonal distributions, host attraction (e.g., placement of traps near human habitation and poultry, cattle, and swine farms), temporal biting activity, pathogen infection rates, and their role as potential vectors of zoonotic pathogens that impact on human and animal health are warranted. Although limited, the data presented herein provide a better understanding of the biology, ecology, and environmental parameters that affect relative population abundance of *Culicoides* spp. that can be used to predict potential human and animal health risks and develop and implement mitigation strategies.

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CONFLICT OF INTEREST

We have no conflict of interest related with this work.

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