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First zootiological survey of hard ticks (Acari: Ixodidae) infesting dogs in northern Taiwan

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Abstract
Hard ticks infesting canine hosts were determined for the first time in northern Taiwan. Between May 2010 and April 2011, a total of 9467 ticks were collected from 2025 dogs. They were identified based on pictorial keys of their morphological characteristics. These ticks belong to three genus and six species: *Rhipicephalus sanguineus, R. haemaphysaloides, Haemaphysalis hystricis, H. lagrangei, H. formosensis* and *Ixodes ovatus*. *Rhipicephalus sanguineus* was the most dominant species (92.5%), followed by *H. hystricis* (4.6%), *R. haemaphysaloides* (2.3%), *I. ovatus* (0.54%), *H. lagrangei* (0.04%) and *H. formosensis* (0.01%). The overall density was 4.7 ticks per dog (ranging from 1.8 to 20.8) and the highest seasonal prevalence was observed in September with an average density of 8.2 ticks per dog. Our results not only provide the first survey of hard ticks infesting dogs in northern Taiwan, but also highlight the possible impact of these tick species on human health.

Keywords Ixodidae · Tick · Canine · Taiwan

Introduction

Ticks are obligate blood-sucking arthropods that ectoparasitize on every class of vertebrates in almost every region of the world. There are three generally recognized families of ticks which comprise the Ixodidae named as "hard ticks" (694 species), the Argasidae named as "soft ticks" (177 species), and the Nuttalliellidae represented by a single species confined in southern Africa (Oliver 1989; Sonenshine 1991). Except the eggs, ticks have three life stages including the larva, nymph, and adult (male and female), and each stage requires blood meal for further development. Although ticks have been recognized

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as animal/human ectoparasites for thousands of years (Balashov 1972), the global impacts of ticks has been recognized by their ability to transmit a variety of tick-borne pathogens to their hosts and by direct injury to livestock because of their feeding behaviour (Jongejan and Uilenberg 2004). Their detrimental impacts on humans and animals lead to a major concern in public health.

In Taiwan, the emergence of human babesiosis (Shih et al. 1997; Shih and Wang 1998), Lyme borreliosis (Shih and Chao 1998; Chao et al. 2011, 2013) and canine babesiosis (Lee et al. 2010) raises attention on the medical and veterinary importance of ticks. Indeed, the hard ticks of *Ixodes granulatus* and *I. ovatus* were identified as the incriminated vector ticks for various genospecies of *Borrelia* spirochetes (Chao et al. 2009, 2010, 2012, 2014). The brown dog tick, *Rhipicephalus sanguineus*, has been recognized as the principle vector responsible for the enzootic transmission of *Babesia vogeli* and *B. gibsoni* in Taiwan (Chao et al. 2016b, 2017). In addition, the agent of spotted fever rickettsia had also been detected in *I. granulatus* tick in Taiwan (Tsai et al. 2008).

Because of climatic and geographical factors, the tick species infesting canine hosts may not be the same around the world (Lindgren et al. 2000; Gray 2008). Although the brown dog tick, *R. sanguineus*, is the most widespread tick species around the world and is recognized as the dominant ectoparasite on dogs (Dantas-Torres 2010), many other species of hard ticks have been observed on dogs in different geographic areas/Countries. *Dermacentor variabilis* (American dog tick) is recognized as the major ectoparasite of canine hosts reported in West USA, Canada, and Mexico (Mcnemee et al. 2003). *Ixodes ricinus* and *I. hexagonus* are reported as the main ectoparasites of dogs in Great Britain and Ireland (Ogden et al. 2000), and *D. reticulatus* is common in Western and Central Europe from France to Hungary as the potential vector for *Babesia canis* (Nosek 1972; Kabowiak 2014; Jongejan et al. 2015; Olivieri et al. 2016). It is also the main tick species attaching to dogs in Hungary (Foldvari and Farkas 2005). *Rhipicephalus sanguineus* is reported as the dominant tick species in dogs in Africa, Latin America, Mediterranean countries, and the majority of Asian countries (Walker et al. 2000; Shimada et al. 2003a; Estrada-Pena et al. 2004; Ugbomoiko et al. 2008; Tinoco-Gracia et al. 2009; Changbunjong et al. 2009; Chao et al. 2010). Indeed, *R. sanguineus* has been recognized as the principle ectoparasite of dogs in Bangladesh, Thailand, Japan, and China (Teng and Jiang 1991; Shimada et al. 2003a; Islam et al. 2006; Changbunjong et al. 2009). Other tick species were also reported on dogs depending geographies. However, the hard tick species infesting dogs in Taiwan needs to be further defined.

Materials and methods

Collection of ticks from dogs

From May 2010 to April 2011 ticks infesting dogs were collected from various localities (25.02N, 121.51E; 25.02N, 121.57E; 25.08N, 121.56E; 25.09N, 121.53E; 25.09N, 121.58E; 25.09′N, 121.51E; 25.10N, 121.58E; 25.11N, 121.55E; 25.07N, 121.54E; 25.07N, 121.56E; 25.05N, 121.50E; 25.05N, 121.51E; 25.02N, 121.50E; 25.01N, 121.49E; 25.03N, 121.48E; 25.03N, 121.57E; 25.03N, 121.53E; 25.14N, 121.51E; 25.13N, 121.50E; 25.03N, 121.62E; 25.08N, 121.60E; 25.07N, 121.56E; 24.98N, 121.57E) of Taipei City in northern Taiwan (Fig. 1). All specimens of ticks were carefully removed from dogs

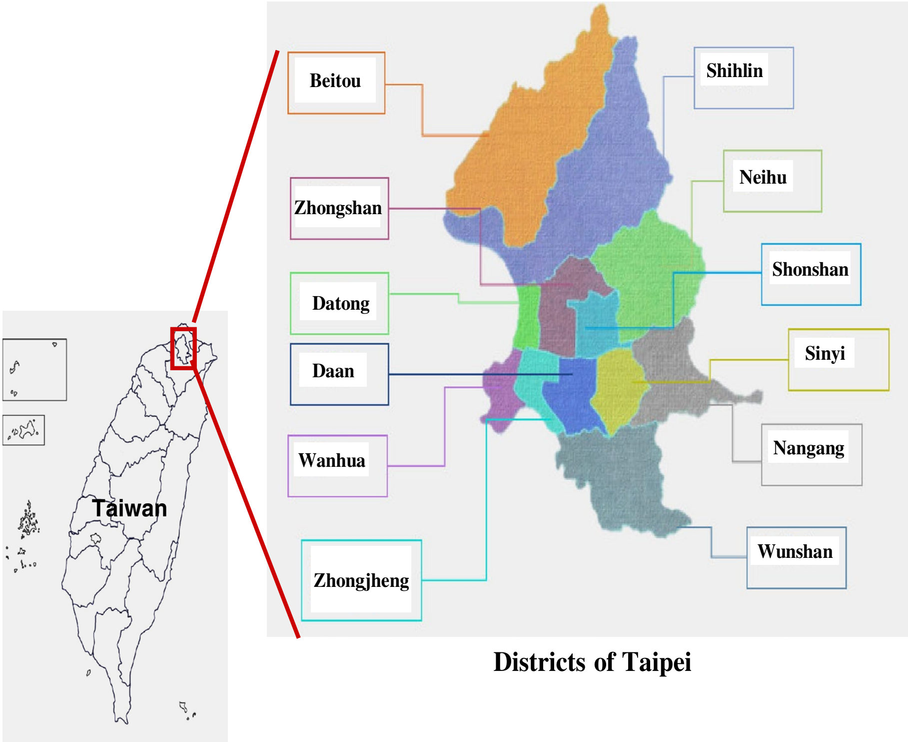

Fig. 1 Map of Taiwan showing the tick collection from various districts of Taipei City in northern Taiwan

(Fig. 2) and subsequently stored in 75% ethanol solution in separate vials until further identification.

Species identification

Based on the pictorial keys of morphological characteristics, all these tick specimens were identified to the species level, as described previously (Shih and Chao 2011; Chao and Shih 2016). Ultrastructural observations by stereo-microscope were also used to delineate the morphological features of all stages of hard ticks infested on dogs in northern Taiwan. Briefly, tick specimens were cleaned by sonication in 75% ethanol solution for 5–10 min and then washed twice in sterile distilled water. Afterwards, each stage of tick specimen was placed on a glass slide and photographed using a stereo-microscope (SMZ 1500, Nikon, Tokyo, Japan) equipped with a fiber lamp. The external features of these ticks were recorded for species identification.

Fig. 2 Inspection and collection of hard ticks infesting dogs. Pictures show attached (**a**) and engorged adults (**b**) in the ear, partial-engorged adult (**c**) attached on the elbow, and nymphs (**d**) attached between the fingers

Results

Species and life stages

A total of 9467 ticks including 4204 females, 3405 males, 1635 nymphs and 223 larvae were collected from 2025 dogs (Table 1). All ticks were identified to the species level: *R. sanguineus* (8759), *R. haemaphysaloides* (218), *H. hystricis* (434), *H. lagrangei* (4), *H. formosensis* (1), and *I. ovatus* (51). *Rhipicephalus sanguineus* (92.5%) was the most dominant species followed by *H. hystricis* (4.6%), *R. haemaphysaloides* (2.3%), *I. ovatus* (0.54%), *H. lagrangei* (0.04%) and *H. formosensis* (0.01%) (Table 1).

Table 1 Species and life-cycle stage of hard ticks collected from dogs in northern Taiwan

Tick species	Number of ticks collected				Total (%)
	Larval	Nymph	Adult		
			Male	Female	
Rhipicephalus sanguineus	166	1578	3130	3885	8759 (92.52)
R. haemaphysaloides	0	4	141	73	218 (2.31)
Haemaphysalis hystricis	55	50	117	212	434 (4.58)
H. lagrangei	0	3	0	1	4 (0.04)
H. formosensis	0	0	0	1	1 (0.01)
Ixodes ovatus	0	1	8	42	51 (0.54)
Total (%)	221 (2.3)	1636 (17.3)	3396 (35.9)	4214 (44.5)	9467 (100)

Monthly prevalence and infestation

The highest seasonal prevalence of hard ticks was collected in September (1541 specimens) followed by October (1406), August (1120), June (1034), July (1027), November (878), May (744), December (603), April (319), March (274), February (265), and January (256), as indicated in Table 2. In general, the distribution of adult and nymphal ticks can be observed from every month of the year. However, larval stage were only observed from May to November. In addition, the highest monthly prevalence for the three major tick species of *R. sanguineus, R. haemaphysaloides* and *H. hystrics* was recorded on September, March and August, respectively (Fig. 3). The average infestation is observed on dogs with a density of 4.68 ticks per dog and the highest seasonal infestation was observed in September with a density of 8.24 ticks per dog (Table 3).

Discussion

This study is the first large scale survey of hard ticks ectoparasitizing canine hosts in Taiwan. Species identification of these collected ticks reveals six species. The brown dog tick (*R. sanguineus*) was the most abundant (92.5%) species found on dogs and all life-stages of *R. sanguineus* ticks were recovered from canine hosts. *Rhipicephalus sanguineus* is recognized as a three-host tick (Dantas-Torres 2010). Indeed, the *R. sanguineus* tick is highly prevalent either in urban or suburban areas of northern Taiwan, and the availability of canine hosts is highly favorable for the life cycle of *R. sanguineus*.

The hard ticks of *H. hystricis* and *R. haemaphysaloides* were determined as the second and third dominant species infesting canine hosts in northern Taiwan. In previous studies, the *H. hystricis* was found to be distributed in the southeast Asian Countries of India, Vietnam, China and Japan. The immature (larva and nymph) and mature (adult) ticks of *H. hystrics* infest rodents and large mammals including dogs, respectively (Hoogstraal et al. 1965). *Rhipicephalus haemaphysaloides* was recognized to be distributed in Pakistan, Nepal, India, Indonesia, China and Taiwan (Walker et al. 2000; Yin and Luo 2007). In this study, all developmental stages of *H. hystricis* ticks were collected from dogs, but only adult and nymphal stages of *R. haemaphysaloides* were observed on dogs (Table 2). All these ticks were found to be most abundant in the suburban and rural areas of northern

Table 2 Monthly distribution of species and numbers of hard ticks collected from dogs in northern Taiwan

Tick species[a]	Stage/sex	Collection month												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rs	Larval	0	0	0	0	5	3	48	3	36	68	3	0	166
	Nymph	12	15	20	22	82	171	130	127	264	329	206	200	1578
	Male	82	88	71	91	256	356	368	362	553	473	316	114	3130
	Female	151	133	92	145	320	408	410	520	592	519	326	269	3885
	Subtotal	245	236	183	258	663	938	956	1012	1445	1389	851	583	8759
Rh	Nymph	0	0	0	0	0	4	0	0	0	0	0	0	4
	Male	0	10	48	1	13	15	8	2	43	0	1	0	141
	Female	0	7	24	1	10	11	10	1	8	0	1	0	73
	Subtotal	0	17	72	2	23	30	18	3	51	0	2	0	218
Hh	Larval	0	0	0	0	0	19	23	12	0	0	1	0	55
	Nymph	0	0	5	15	2	8	6	3	6	0	4	1	50
	Male	1	0	4	13	15	10	10	32	23	3	6	0	117
	Female	3	6	4	23	41	28	13	58	11	12	10	3	212
	Subtotal	4	6	13	51	58	65	52	105	40	15	21	4	434
Hl	Nymph	0	0	0	2	0	0	0	0	1	0	0	0	3
	Female	0	0	0	0	0	0	0	0	1	0	0	0	1
	Subtotal	0	0	0	2	0	0	0	0	2	0	0	0	4
Hf	Female	0	1	0	0	0	0	0	0	0	0	0	0	1
	Subtotal	0	1	0	0	0	0	0	0	0	0	0	0	1
Io	Nymph	0	0	0	0	0	0	0	0	0	0	0	1	1
	Male	0	1	0	0	0	0	0	0	2	0	1	4	8
	Female	7	4	6	6	0	1	1	0	1	2	3	11	42
	Subtotal	7	5	6	6	0	1	1	0	3	2	4	16	51

Table 2 (continued)

Tick species[a]	Stage/sex	Collection month												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Total	Larval	0	0	0	0	5	22	71	15	36	68	4	0	221
	Nymph	12	15	25	39	84	183	136	130	271	329	210	202	1636
	Male	83	99	123	105	284	381	386	396	621	476	324	118	3396
	Female	161	151	126	175	371	448	434	579	613	533	340	283	4214
	Total	256	265	274	319	744	1034	1027	1120	1541	1406	878	603	9467

[a]Tick species: *Rhipicephalus sanguineus* (*Rs*), *R. haemaphysaloides* (*Rh*), *Haemaphysalis hystricis* (*Hh*), *H. lagrangei* (*Hl*), *H. formosensis* (*Hf*), and *Ixodes ovatus* (*Io*)

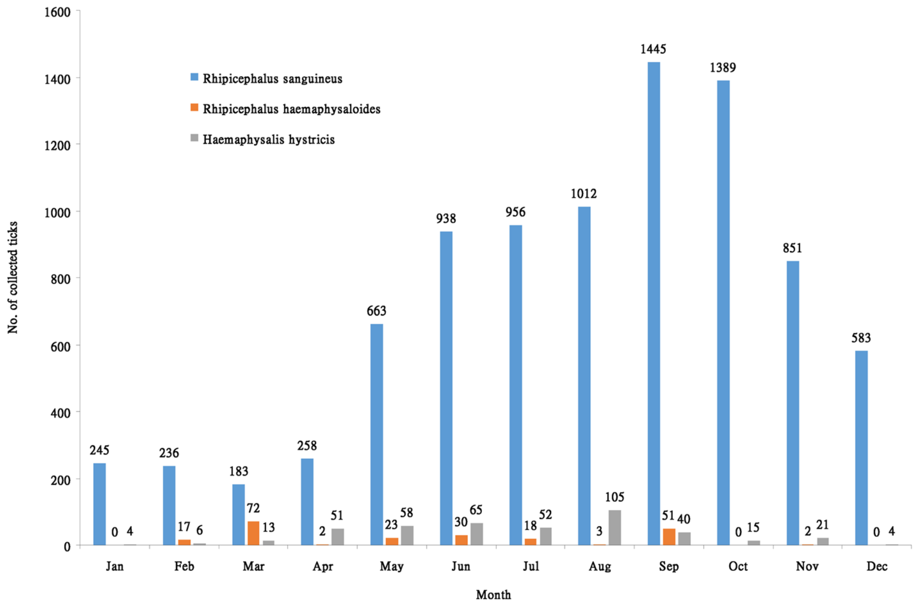

Fig. 3 Monthly prevalence of the three major tick species infesting dogs in northern Taiwan

Table 3 Monthly infestation and density of hard ticks on dogs in northern Taiwan

Month	Tick infestation and density on canine host		
	Number of ticks collected	Number of dogs examined	Average density of ticks per dog
January	256	81	3.16
February	265	97	2.73
March	274	75	3.65
April	319	128	2.49
May	744	201	3.70
June	1034	249	4.15
July	1027	223	4.60
August	1120	219	5.11
September	1541	187	8.24
October	1406	231	6.09
November	878	169	5.20
December	603	165	3.65
Total	9467	2025	4.68

Taiwan. In addition, *Ehrlichia* and *Anaplasma* have been detected in *H. hystricis* and *R. haemaphysaloides* ticks (Parola et al. 2003; Kuo et al. 2018). Thus, their vectorial capacity for tick-borne pathogens requires further investigations.

Although the hard ticks of *I. ovatus, H. formosensis*, and *H. lagrangei* had been reported in Asia (Hoogstraal et al. 1973a, b; Teng and Jiang 1991; Robbins 2005), these tick species are rarely collected from dogs in Taiwan. In Japan, the *I. ovatus* was more frequently found on cats kept near woodland area (Shimada et al. 2003). In our previous study, we also collected *I. ovatus* ticks from stray cats in the suburban region of northern Taiwan and the causative agent of Lyme disease spirochete (*Borrelia garinii*) was isolated from this tick specimen (Chao et al. 2014). In this survey, only adult and nympal ticks of *I. ovatus* were collected from dogs and most ticks were collected during the winter season (Table 2). This seasonal prevalence of *I. ovatus* ticks observed on dog may imply the possibility of other mammals or rodents serving as the hosts for the larval tick in the natural cycle of *I. ovatus* tick and need to be further identified in Taiwan.

In conclusion, this large scale survey reveals six species of hard ticks ectoparasitizing canine hosts in northern Taiwan. Because dogs are recognized as the company animal and are closely associated with humans, further investigations on the prevalence of tick-borne pathogens in these tick species may help to evaluate the impact on human health in Taiwan.

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References

Balashov YS (1972) Bloodsucking ticks (Ixodoidea)-vectors of diseases of man and animals. Misc Publ Entomol Soc Am 8:268–305

Changbunjong T, Buddhirongawatr R, Suwanpakdee S et al (2009) A survey of ectoparasitic arthropods on domestic animals in tak province, Thailand. Southeast Asian J Trop Med Public Health 40(3):435–442

Chao LL, Shih CM (2016) Molecular analysis of *Rhipicephalus sanguineus* (Acari: Ixodidae), an incriminated vector tick for *Babesia vogeli* in Taiwan. Exp Appl Acarol 70:469–481

Chao LL, Wu WJ, Shih CM (2009) Molecular analysis of *Ixodes granulatus*, a possible vector tick for *Borrelia burgdorferi* sensu lato in Taiwan. Exp Appl Acarol 48:329–344

Chao LL, Wu WJ, Shih CM (2010) Molecular detection of *Borrelia valaisiana*-related spirochetes from *Ixodes granulatus* ticks in Taiwan. Exp Appl Acarol 52:393–407

Chao LL, Chen YJ, Shih CM (2011) First isolation and molecular identification of *Borrelia burgdorferi* sensu stricto and *B. afzelii* from skin biopsies of patients in Taiwan. Int J Infect Dis 15:e182–e187

Chao LL, Liu LL, Shih CM (2012) Prevalence and molecular identification of *Borrelia* spirochetes in *Ixodes granulatus* ticks collected from *Rattus losea* on Kinmen Island of Taiwan. Parasit Vectors 5:167

Chao LL, Lu CF, Shih CM (2013) Molecular detection and genetic identification of *Borrelia garinii* and *Borrelia afzelii* from patients presenting with a rare skin manifestation of prurigo pigmentosa in Taiwan. Int J Infect Dis 17(12):e1141–e1147

Chao LL, Liu LL, Ho TY, Shih CM (2014) First detection and molecular identification of *Borrelia garinii* spirochetes from *Ixodes ovatus* tick ectoparasitized on stray cat in Taiwan. Plos One 9(10):e110599

Chao LL, Yeh ST, Hsieh CK, Shih CM (2016b) First detection and molecular identification of *Babesia vogeli* from *Rhipicephalus sanguineus* (Acari: Ixodidae) in Taiwan. Exp Appl Acarol 68:539–551

Chao LL, Liao HT, Ho TY, Shih CM (2017) First detection and molecular identification of *Babesia gibsoni* from *Rhipicephalus sanguineus* ticks. Acta Trop 166:356–362

Dantas-Torres F (2010) Biology and ecology of the brown dog tick, *Rhipicephalus sanguineus*. Parasit Vectors 3:26

Estrada-Pena A, Bouattour A, Camicas JL, Walker AR (2004) Ticks of domestic animals in the Mediterranean region: a guide to identification of species. In: International Consortium on Ticks and Tick-borne Diseases-2, Atalanta

Foldari G, Farkas R (2005) Ixodid tick species attaching to dogs in Hungary. Vet Parasitol 129:125–131

Gray JS (2008) *Ixodes ricinus* seasonal activity: implications of global warming indicated by revisiting tick and weather data. Int J Med Microbiol 298(suppl 1):19–24

Hoogstraal H, Trapido H, Kohls GM (1965) Studies on Southeast Asian *Haemaphysalis* ticks (Ixodoidea: Ixodidae). The identity, distribution, and hosts of *H.* (*Kaiseriana*) *hystricis* Supino. J Parasitol 51:467–480

Hoogstraal H, Clifford CM, Saito Y, Keirans JE (1973a) *Ixodes* (*Partipalpiger*) *ovatus* Neumann, subgen. Nov.: identity, hosts,ecology, and distribution (Ixodoidea: Ixodidae). J Med Entomol 10:157–164

Hoogstraal H, Kammah KM, Santana FJ, Van Peenen PF (1973b) Studies on southeast Asian *Haemaphysalis* ticks (Ixodoidea: Ixodidae). *H*. (*Kaiseriana*) *lagrangei* Larrousse: identity, distribution, and hosts. J Parasitol 59:1118–1129

Islam MK, Alim MA, Tsuji N, Mondal MM (2006) An investigation into the distribution, host-preference and population density of ixodid ticks affecting domestic animals in Bangladesh. Trop Anim Health Prod 38:485–490

Jongejan F, Uilenberg G (2004) The global importance of ticks. Parasitology 129:S3–S14

Jongejan F, Ringenier M, Putting M, Berger L, Burgers S, Kortekaas R et al (2015) Novel foci of *Dermacentor reticulatus* ticks infected with *Babesia canis* and *B. caballi* in the Netherlands and in Belgium. Parasit Vectors 8:232

Kabowiak G (2014) The occurrence of the *Dermacentor reticulatus* tick-its expansion to new areas and possible causes. Ann Parasitol 60:37–47

Kuo CC, Huang JL, Chien CH, Shih HC, Wang HC (2018) First molecular detection of *Anaplasma phagocytophilum* in the hard tick *Rhipiceplalus haemaphysaloides* in Taiwan. Exp App Acarol 75:437–443

Lee CC, Hsieh YC, Huang CC, Tsang CL, Chung YT (2010) Sequence and phylogenetic analysis of the thrombospondin-related adhesive protein (TRAP) gene of *Babesia gibsoni* isolates from dogs in Taiwan. J Vet Med Sci 72:1329–1335

Lindgren E, Talleklint L, Polfeldt T (2000) Impact of climatic change on the northern latitude limit and population density of the disease transmitting European tick *Ixodes ricinus*. Environ Health Perspect 108(2):119–123

Mcnemee RB, Sames WJ, Maloney FA (2003) Occurrence of *Dermacentor variabilis* (Acari: Ixodidae) around a porcupine (Rodentia: Erthethizontidae) carcass at Camp Ripley, Minnesota. J Med Entomol 40:108–111

Nosek J (1972) The ecology and public health importance of *Dermacentor marginatus* and *Dermacentor reticulatus* ticks in Central Europe. Folia Parasitol 19:93–102

Ogden NH, Cripps P, Davison CC et al (2000) The ixodid tick species attaching to domestic dogs and cats in Graet Britian and Ireland. Med Vet Entomol 14:332–338

Oliver JH Jr (1989) Biology and systematics of ticks (Acari: Ixodidae). Annual Rev Ecol System 20:397–430

Olivieri E, Zanzani SA, Latrofa MS, Lia RP, Dantas-Torres F, Otranto D, Manfredi MT (2016) The southernmost foci of *Dermacentor reticulatus* in Italy and associated *Babesia canis* infection in dogs. Parasit Vectors 9:213

Parola P, Cornet JP, Sanogo YS et al (2003) Detection of Ehrlichia spp., Anaplsma spp., Rickettsia spp., and other Eubacteria in ticks from the Thai-Myanmar border and Vietnam. J Clin Microbiol 41(4):1600–1608

Robbins RG (2005) The ticks (Acari: Ixodida: Argasidae, Ixodidae) of Taiwan: a synonymic checklist. Proc Entomol Soc wash 107(2):245–253

Shih CM, Chao LL (1998) Lyme disease in Taiwan: primary isolation of *Borrelia burgdorferi*-like spirochetes from rodents in Taiwan area. Am J Trop Med Hyg 59:687–692

Shih CM, Chao LL (2011) A catalog of Ixodidae ticks of Taiwan. Department of Parasitology and Tropical Medicine, National Defense Medical Center, Taipei

Shih CM, Wang CC (1998) Ability of azithromycin in combination with quinine for the elimination of babesial infection in human. Am J Trop Med Hyg 59:509–512

Shih CM, Liu LP, Chung WC et al (1997) Human babesiosis in Taiwan: asymptomatic infection with a *Babesia microti*-like organism in a Taiwanese woman. J Clin Microbiol 35:450–454

Shimada Y, Beppu T, Inokuma H, Okuda M, Onishi T (2003a) Ixodid tick species recovered from domestic dogs in Japan. Med Vet Entomol 17:38–45

Shimada Y, Inokuma H, Beppu T, Okuda M, Onishi T (2003b) Survey of ixodid tick species on domestic cats in Japan. Vet Parasitol 111:231–239

Sonenshine DE (1991) Biology of ticks. Oxford University Press, New York

Teng KF, Jiang ZJ (1991) Economic insect fauna of China Fasc 39 Acari: Ixodidae. Science Press, Beijing **(in Chinese)**

Tinoco-Gracia L, Quiroz-Romero H, Quintero-Martinez MT et al (2009) Prevalence of *Rhipicephalus sanguineus* ticks on dogs in a region on the Mexico-USA border. Vet rec 164:59–61

Tsai KH, Wang HC, Chen CH, Huang JH, Lu HY, Su CL, Shu PY (2008) Isolation and identification of a novel spotted fever group rickettsia, strain IG-1, from *Ixodes granulatus* ticks collected on Orchid Island (Lanyu), Taiwan. Am J Trop Med Hyg 79:256–261

Ugbomoiko US, Ariza L, Huekelbach J (2008) Parasites of importance for human health in Nigerian dogs: high prevalence and limited knowledge of pet owners. BMC Vet Res 4:49

Walker JB, Keirans JE, Horak IG (2000) The genus *Rhipicephalus* (Acari: Ixodidae): a guide to the brown ticks of the world. Cambridge University Press, Cambridge

Yin H, Luo J (2007) Ticks of small ruminants in China. Parasitol Res 101:187–189