DISTRIBUTION AND ABUNDANCE OF STOMOXYINI FLIES (DIPTERA: MUSCIDAE) IN THAILAND

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Abstract. Stomoxyini flies (Diptera: Muscidae) include species of parasitic flies of medical and veterinary importance. The adult flies feed on the blood of mammals and may transmit several parasites and pathogens. We conducted an entomological survey of Stomoxyini flies from different sites in Thailand. Stomoxyini flies were collected at four major types of sites: zoos, livestock farms, wildlife conservation areas and a national park using vavoua traps between November 2010 and April 2011. A total of 3,314 Stomoxyini flies belonging to the genera *Stomoxys*, *Haematobosca*, *Haematostoma* and *Haematobia* were collected. Eight species were identified: *S. calcitrans* (46.6%), *S. uruma* (26.8%), *S. pulla* (4.3%), *S. indicus* (0.7%), *S. sitiens* (0.1%), *H. sanguinolenta* (11.2 %), *H. austeni* (0.5%) and *H. irritans exigua* (9.8%). The diversity of Stomoxyini flies in the livestock farms was higher than the other sites. Altitude correlated with the number of flies. This study provides information that may be useful for Stomoxyini flies control.

Keywords: Stomoxyini flies, Muscidae, *Stomoxys*, *Haematobosca*, *Haematostoma*, *Haematobia*

INTRODUCTION

Stomoxyini flies are classified into the subfamily Muscinae. This subfamily is part of the family Muscidae which is comprised of 4,500 described species divided into 180 genera (De Carvalho *et al*, 2005). Stomoxyini flies consist of 10 genera and 50 species (Crosskey, 1993). Adult Stomoxyni flies are obligate blood feeders and can easily be recognized by their conspicuous proboscis adapted for biting and sucking blood (Zumpt, 1973). Stomoxyini flies are associated with livestock, wildlife and humans (Zumpt, 1973). Of these flies, *Stomoxys calcitrans* and *Haematobia irritans* are major pests for livestock and cause a huge economic

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loss in the cattle industry (Foil and Hogsette, 1994; Taylor *et al*, 2012). *H. irritans* is known as a vector for the nematode *Stephanofilaria stilesi*, which can infect cattle (Crosskey, 1993). *S. calcitrans* is a vector for *Habronema microstoma*, which can infect horses (Moon, 2009), and has been implicated as a mechanical vector for several pathogens, such as *Trypanosoma* spp (Soulsby, 1982; Lehane, 2005) and retroviruses (equine infectious anemia virus and bovine leukosis virus) (Williams, 2009). These flies are also suspected of transmitting other infectious diseases to animals (Greenberg, 1973; Zumpt, 1973; Mellor *et al*, 1987; Turrell *et al*, 2010; Doyle *et al*, 2011). Although Stomoxyini flies are a major cause of animal health problems, some species may also attack and annoy humans when their animal hosts are absent (Zumpt, 1973).

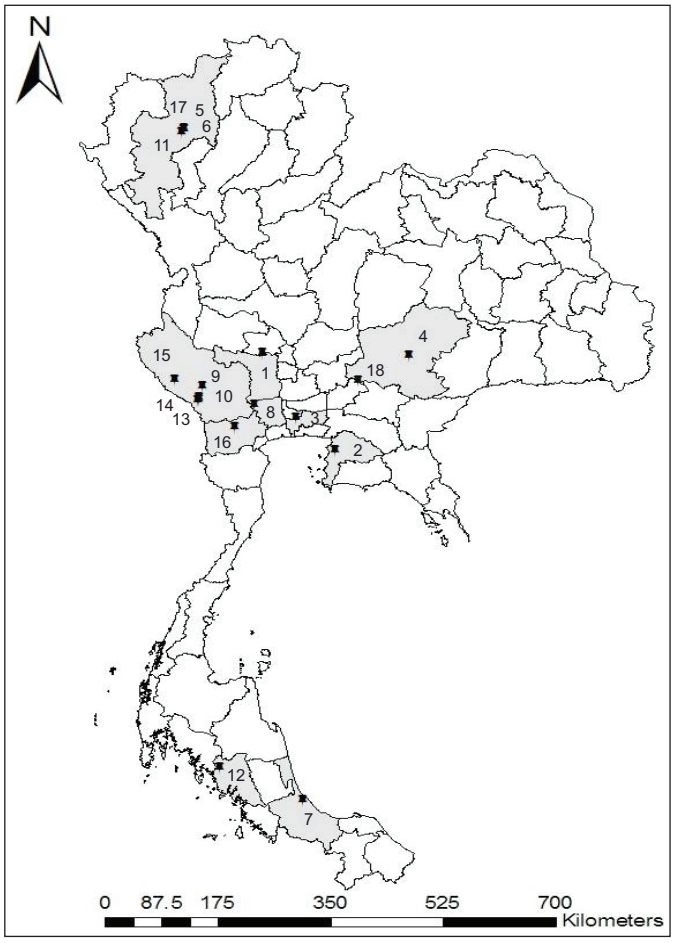

Fig 1–Map of Stomoxyini fly collection sites in Thailand: Suphan Buri (1), Chon Buri (2), Bangkok (3), Nakhon Ratchasima (4, 18), Chiang Mai (5, 6, 11, 17), Songkhla (7), Nakhon Pathom (8), Kanchanaburi (9, 10, 13, 14, 15), Trang (12), Ratchaburi (16).

The geographical distribution of Stomoxyini flies is worldwide, although some species can be found in only particular regions (Zumpt, 1973). The largest number of species has been reported from the Afrotropical region (Zumpt, 1973). Although several studies have been conducted regarding the distribution and abundance of Stomoxyini flies in Thailand (Masmeatathip *et al*, 2006; Muenworn *et al*, 2010), most of them focused only on the genera *Stomoxys*. Only one study investigated all the different genera of these flies in Thailand (Tumrusvin and Shinonaga, 1978), but the study did not compare the species at each site. The main purpose of the present study was to survey Stomoxyini flies at different collection sites in Thailand. This information may be useful for future control programs.

MATERIALS AND METHODS

Study sites

Stomoxyini flies were collected at 18 locations from all the major geographical regions of Thailand (Fig 1). The types

Table 1
Stomoxyini fly collection sites and dates in Thailand.

Categories	No.	Date	Collection sites	District/Province	Altitude	Coordinates (Lat/Long)
Zoo	1	Nov 2010	Bungchawak Zoo	Doem Bang Nang Buat, Suphan Buri	14	N14°54′42.5″, E 100°02′51.1″
	2	Dec 2010	Khao Kheow Open Zoo	Sri Racha, Chon Buri	189	N13°12′55.7″, E101°03′04.0″
	3	Jan 2011	Dusit Zoo	Bangkok	61	N13°46′21.9″, E100°30′53.7″
	4	Jan 2011	Nakhon Ratchasima Zoo	Mueang, Nakhon Ratchasima	307	N14°51′13.7″, E102°05′05.4″
	5	Feb 2011	Chiang Mai Zoo	Mueang, Chiang Mai	411	N18°48′04.6″, E098°56′44.1″
	6	Feb 2011	Chiang Mai Night Safari	Hang Dong, Chiang Mai	398	N18°44′05.4″, E098°55′09.6″
	7	Feb 2011	Songkhla Zoo	Mueang, Songkhla	112	N07°08′26.9″, E100°36′20.6″
Livestock farm	8	Nov 2010	Local dairy farm no. 1	Kamphaeng Saen, Nakhon Pathom	60	N13°59′47.0″, E099°55′19.7″
	9	Dec 2010	Livestock farm of Faculty of Veterinary Science	Sai Yok, Kanchanaburi	270	N14°08′12.9″, E099°08′59.1″
	10	Dec 2010	Local beef cattle farm no.1	Sai Yok, Kanchanaburi	101	N14°06′05.4″, E099°09′03.5″
	11	Feb 2011	Local dairy farm no. 2	San Sai, Chiang Mai	381	N18°50′02.6″, E009°05′20.4″
	12	Feb 2011	Trang Livestock Testing Research Station	Huai Yot, Trang	100	N07°41′47.9″, E099°26′56.5″
	13	Mar 2011	Local beef cattle farm no. 2	Sai Yok, Kanchanaburi	93	N14°25′53.9″, E098°48′35.0″
	14	Mar 2011	Local beef cattle farm no. 3	Sai Yok, Kanchanaburi	36	N14°05′00.6″, E099°08′11.7″
Wildlife conservation area	15	Dec 2010	Khao Namphu Wildlife Conservation Promotion and Development Station	Si Sawat, Kanchanaburi	123	N14°19′21.1″, E099°12′28.9″
	16	Dec 2010	Khao Prathap Chang Open Safari and Wildlife Breeding Research Station	Chom Bueng, Ratchaburi	71	N13°36′42.91″, E099°39′43.06″
	17	Feb 2011	Choeng Doi Su Thep Wildlife Conservation Development and Extension Station	Mueang, Chiang Mai	406	N18°46′52.2″, E098°56′43.2″
National park	18	April 2011	Khao Yai National Park	Pak Chong, Nakhon Ratchasima	774	N14°24′55.1″, E101°22′33.4″

Table 2
Information about climatic data at the collection sites.

No	Collection sites	Temperature (°C)		Humidity (%)	
		Max	Min	Max	Min
1	Bungchawak Zoo	31.2	26.4	64.1	48.4
2	Khao Kheow Open Zoo	30.8	27.6	61.0	58.9
3	Dusit Zoo	30.9	28.2	58.3	41.1
4	Nakhon Ratchasima Zoo	26.5	18.0	73.9	40.2
5	Chiang Mai Zoo	32.5	21.6	55.2	25.9
6	Chiang Mai Night Safari	32.8	23.1	43.9	22.7
7	Songkhla Zoo	31.3	26.8	72.4	58.7
8	Local dairy farm no. 1	34.4	26.7	72.4	50.8
9	Livestock farm of Faculty of Veterinary Science	29.9	25.3	56.7	40.3
10	Local beef cattle farm no. 1	30.4	26.6	50.8	45.7
11	Local dairy farm no. 2	28.1	23.2	44.4	20.2
12	Trang Livestock Testing Research Station	32.4	26.2	60.8	46.3
13	Local beef cattle farm no. 2	33.1	22.1	69.1	48.5
14	Local beef cattle farm no. 3	24.5	21.3	74.0	54.3
15	Khao Namphu Wildlife Conservation	30.2	26.4	51.7	44.2
16	Khao Prathap Chang Open Safari	31.4	25.3	64.3	48.9
17	Choeng Doi Su Thep Wildlife Conservation	32.6	21.5	54.3	29.4
18	Khao Yai National Park	32.9	23.5	85.6	47.6

of sites included zoos, livestock farms, wildlife conservation areas and a national park, which were classified by management objectives and ecosystem (Table 1, Fig 2).

Stomoxyini fly collection

Adult flies were collected at various times using ten vavoua traps (Laveissiere and Grebaut, 1990) made from blue and black cotton cloth with white polyester mosquito netting. The traps were placed at collection sites, approximately 10 meters apart, from 6:00 AM to 6:00 PM over a 2 day period (Muenworn *et al*, 2010). The temperature and relative humidity at each collection site were also recorded (Table 2). The flies were then transported to the laboratory of the Vector-Borne Diseases Research Unit (VBRU), Faculty of Veterinary Science, Mahidol University, Thailand for species identification.

Morphology identification

The specimens were identified to species level using the taxonomic keys of Tumrasvin and Shinonaga (1978) and Zumpt (1973) with a stereomicroscope.

Data analysis

Shannon-Wiener diversity index (H) was used to analyze species diversity at each of the four collection sites:

$$H = -\sum_{i=1}^{s} (P_i \ln P_i)$$

This index accounts for both abundance and richness of the species present.

Table 3
Total number of Stomoxyini flies collected at 18 collection sites in Thailand.

Collection sites	*S. calcitrans*	*S. indicus*	*S. sitiens*	*S. pulla*	*S. uruma*	*H. sanguinolenta*	*H. austeni*	*H. exigua*	Total
Bungchawak Zoo	190	0	0	0	0	0	0	0	190
Khao Kheow Open Zoo	66	0	0	0	0	0	0	196	262
Dusit Zoo	87	0	1	0	0	0	0	0	88
Nakhon Ratchasima Zoo	134	0	0	0	0	0	0	0	134
Chiang Mai Zoo	110	0	0	0	0	0	0	0	110
Chiang Mai Night Safari	2	0	0	0	0	0	0	6	8
Songkhla Zoo	85	0	0	0	0	0	0	0	85
Local dairy farm no. 1	64	0	0	0	0	0	0	55	119
Livestock farm of Faculty of Veterinary Science	16	1	0	0	0	0	0	11	28
Local beef cattle farm no. 1	12	6	0	0	0	0	0	6	24
Local dairy farm no. 2	7	0	0	0	0	0	0	0	7
Trang Livestock Testing Research Station	10	0	0	0	0	0	0	0	10
Local beef cattle farm no. 2	2	0	0	57	25	160	0	15	259
Local beef cattle farm no. 3	18	0	0	0	0	0	0	6	24
Khao Namphu Wildlife Conservation	6	0	0	1	0	0	0	7	14
Khao Prathap Chang Open Safari	3	0	0	0	0	0	0	23	26
Choeng Doi Su Thep Wildlife Conservation	19	3	0	0	0	1	0	1	24
Khao Yai National Park	715	12	0	84	863	212	16	0	1,902
Total	1,546	22	1	142	888	373	16	326	3,314
Percent	46.6	0.7	0.1	4.3	26.8	11.2	0.5	9.8	100

The proportion of species (i) relative to the total number of species (P_i) was calculated and then multiplied by the natural logarithm of this proportion (InP_i). The result was summed across species and multiplied by -1 (Smith, 2002). The correlation between the number of Stomoxyini flies and altitude was analyzed using the Pearson's correlation coefficient ($p < 0.01$). Analysis was conducted with the Statistical Package for the Social Sciences (SPSS) program, version 17 (SPSS, Chicaco, IL).

RESULTS

A total of 3,314 Stomoxyini flies were collected, comprising 4 genera: *Stomoxys*, *Haematobosca*, *Haematostoma* and *Haematobia* (Table 3, Fig 3). The most abundant genera was *Stomoxys* (78.5%) followed by *Haematobosca* (11.2%), *Haematobia* (9.8%) and *Haematostoma* (0.5%). Eight species of Stomoxyini flies were identified: *S. calcitrans* (46.6%), *S. uruma* (26.8%), *S. pulla* (4.3%), *S. indicus* (0.7%), *S. sitiens* (0.1%), *H. sanguinolenta* (11.2%), *H. austeni* (0.5%) and *H. irritans exigua* (9.8%). Fifty-seven point four percent of flies were collected from the national park, 26.5% from zoos, 14.2% from livestock farms and 1.9% from wildlife conservation areas. The diversity

Table 4
Total number and species diversity of Stomoxyini flies in four categories of collection sites.

Categories of collection sites	*S. calcitrans*	*S. indicus*	*S. sitiens*	*S. pulla*	*S. uruma*	*H. sanguinolenta*	*H. austeni*	*H. exigua*	Diversity index (H)
Zoo (7)	674	0	1	0	0	0	0	202	0.55
Livestock farm (7)	129	7	0	57	25	160	0	93	1.52
Wildlife conservation area (3)	28	3	0	1	0	1	0	31	0.99
National Park (1)	715	12	0	84	863	212	16	0	1.18
Total	1,546	22	1	142	888	373	16	326	

of Stomoxyini flies in livestock farms (H = 1.52) was much higher than the national park (H = 1.18), wildlife conservation areas (H = 0.99) or zoos (H = 0.55) (Table 4). The altitude correlated with the number of flies collected (r = 0.66).

Genus *Stomoxys*

Five species were found in the genus *Stomoxys*: *S. calcitrans*, *S. indicus*, *S. sitiens*, *S. pulla* and *S. uruma*. *S. calcitrans* was the most abundant species found at all collection sites, especially at the national park and zoos. The highest and the lowest numbers of *S. calcitrans* were collected at Khao Yai National Park and Chiang Mai Night Safari, respectively. The relative abundance of *S. calcitrans* at zoos, livestock farms, wildlife conservation areas and the national park were 76.9% (674/877), 27.4% (129/471), 43.8% (28/64) and 37.6% (715/1,902), respectively. The second most abundant species was *S. uruma*; most were found in the national park and a few were found on livestock farms. They were the predominant species found at the national park. The relative abundance of *S. uruma* at the national park and livestock farms were 45.4% (863/1,902) and 5.3% (25/471), respectively. *S. indicus* was captured at three of the four collection site categories (except zoos), with the highest numbers being found at the national park. The relative abundance of *S. indicus* at the livestock farms, wildlife conservation areas and national park were 1.5% (7/471), 4.7% (3/64), 0.6% (12/1,902), respectively. *S. pulla* was also found in three of the four categories of sites: livestock farms, wildlife conservation areas and national park with a relative abundance of 12.1% (57/471), 1.6% (1/64) and 4.4% (84/1,902), respectively. The rarest species collected was *S. sitiens*; only 1 specimen was found at the Dusit Zoo in Bangkok with a relative abundance of 0.1% (1/877).

Genus *Haematobosca*

Haematobosca sanguinolenta was found at three of the four categories of collection sites: livestock farms, wildlife conservation areas and the national park, with a relative abundance of 44.0% (160/471), 11.1% (212/1,902), and 1.6% (1/64), respectively.

Genus *Haematostoma*

Haematostoma austeni was only found

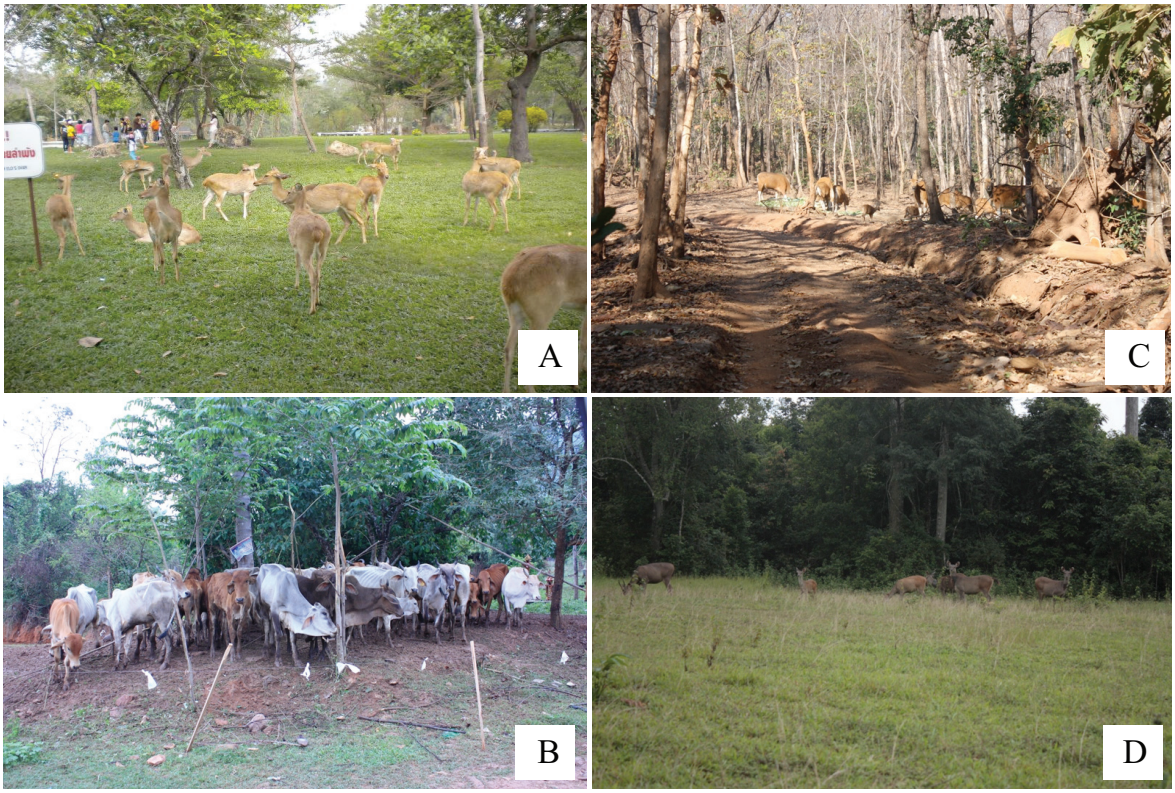

Fig 2–Representation of collection sites. A, Zoo; B, Animal farm; C, Wildlife conservation area; D, National Park.

at the national park. The relative abundance of flies in this area was 0.8% (16/1,902).

Genus *Haematobia*

Haematobia irritans exigua was the only species of this genus collected in this study. This species was found in three of the four category sites (excluding the national park). The relative abundance of these flies at the zoos, livestock farms and wildlife conservation areas were 23.0% (202/877), 19.7% (93/471) and 48.4% (31/64), respectively.

DISCUSSION

With the exception of the study by Tumrasvin and Shinonaga (1978), little information is available for most species of Stomoxyini flies in Thailand (Masmeatathip *et al*, 2006; Muenworn *et al*, 2010). Our study provides updated information about the distribution and abundance of Stomoxyini flies in Thailand. The 8 species found in our study are known to be present in the Orient (Zumpt, 1973). Tumrasvin and Shinonaga (1978) collected 9 species from 5 genera in Thailand: *Stygeromyia* (1 species), *Stomoxys* (5 species), *Haematobosca* (1 species), *Haematostoma* (1 species), and *Haematobia* (1 species). We found a remarkably large abundance of flies compared to earlier surveys (Tumrasvin and Shinonaga, 1978; Masmeatathip *et al*, 2006; Muenworn *et al*, 2010). These differences may be related to collection site and collection methods (Mihok *et al*, 1995; Muenworn *et al*, 2010).

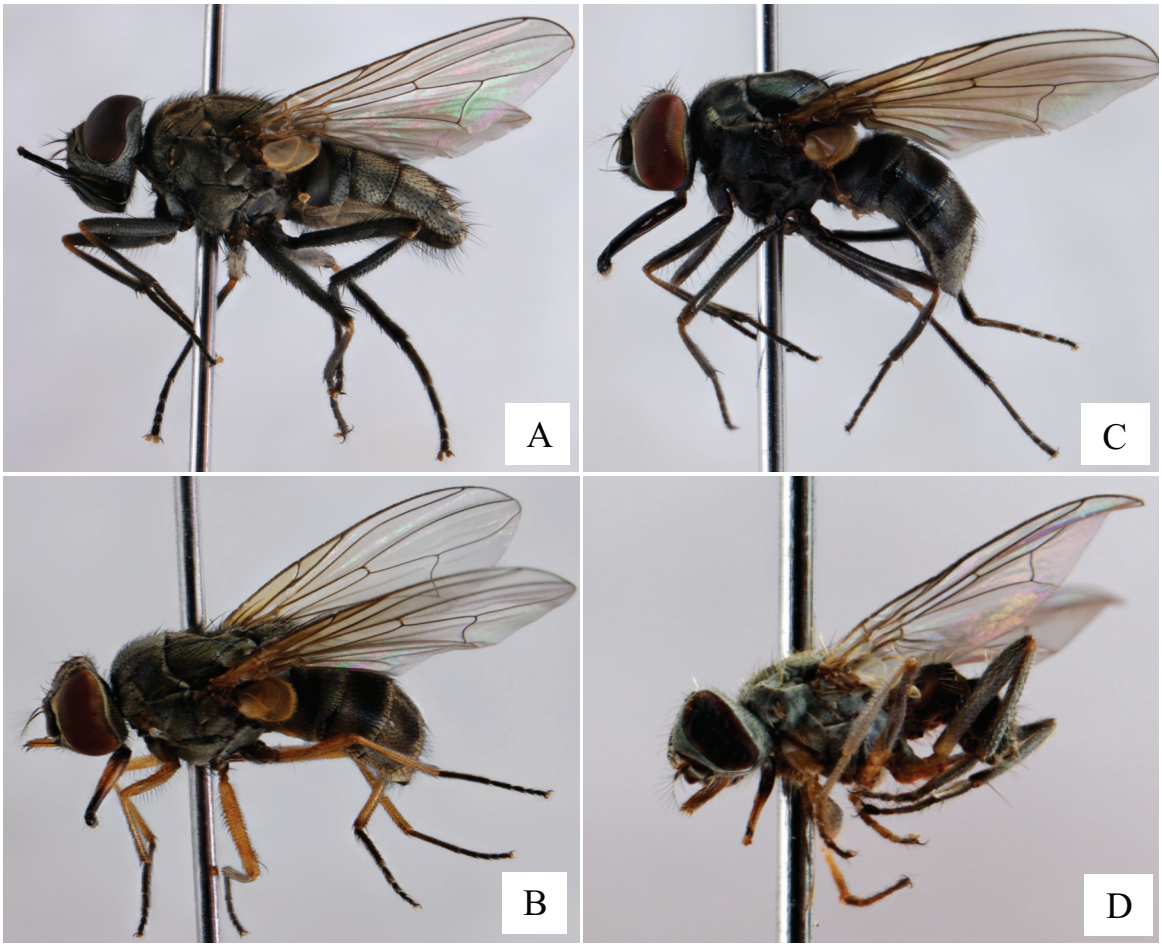

Fig 3–Morphology of Stomoxyini flies of different genera collected in this study. A, *Stomoxys* spp; B, *Haematobosca* spp; C, *Haematostoma* spp; D, *Haematobia* spp.

S. calcitrans was the predominant species, followed by *S. uruma*. *S. calcitrans* was found at all collection sites. This species has been found to be the predominant species on dairy farms in Thailand (Muenworn *et al*, 2010). *S. uruma* has not been recorded in Thailand since 1973 (Zumpt, 1973). This species has been found in Hong Kong, India, Vietnam and Taiwan (Zumpt, 1973). The lowest number of specimens was with *S. sitiens* in our study, similar to the study conducted by Muenworn *et al* (2010); they found only 5 specimens on livestock farms. In the genus *Haematostoma*, *H. austeni* has been reported as a jungle fly and has rarely been collected despite its wide distribution in the Orient, including Borneo, Malaysia, Lao PDR and Myanmar (Zumpt, 1973). This study, *H. austeni* was only present in the national park, similar to the finding of Tumrasvin and Shinonaga (1978). *Stygeromyia* was the only specimen previously described in Thailand (Tumrasvin and Shinonaga, 1978) but not found in our survey. However, the previous description

by Zumpt (1973) does not fit the specimens; therefore, this specimen may have been misidentified. The absence of some species in our study, such as *Stygeromyia* spp and *Stomoxys* spp, may be due to using only one trap type, the time or season of collection or the collection site. Muller *et al* (2011) recently collected *Stygeromyia maculosa* using CDC UV traps and animal traps after sunset in Israel. Other trapping methods may be necessary at other sites over a longer period of time to conclusively determine the abundance and distribution of Stomoxyini flies in Thailand.

Livestock farms were the sites with the greater diversity of Stomoxyni flies species compared to other sites. This may be due to the presence of animal species that are the host preferences for these flies. Zumpt (1973) demonstrated that cattle and horses were the hosts of many species of Stomoxyini flies. The highly diverse habitats found on livestock farms in this study may support many Stomoxyini species. These habitat types included human settlements, forests and wetlands and were found especially on the beef cattle farms.

The beef cattle farm used in this study is located in Kanchanaburi Province, western Thailand. On this farm, 5 species of Stomoxyini flies (*S. calcitrans*, *S. pulla*, *S. uruma*, *H. sanguinolenta* and *H. exigua*) were collected. *S. pulla*, *S. uruma* and *H. sanguinolenta* were found only on this farm. The national park used in this study, Khao Yai National Park, had a variety of species collected. This was Thailand's first national park and contains evergreen forests and grasslands. There are many wildlife species in this area, including Indian sambar deer (*Cervus unicolor*) (DNP, 2011). The sambar deer appears to be an important host for Stomoxyini flies; we observed many files (possibly Stomoxyini) aggregated on the body of one of them. Mihok and Clausen (1996) found the bushbuck (*Tragelaphus scriptus*) was the major host for *Stomoxys* spp in Nairobi National Park in Kenya. Khao Yai National Park contains a large amount of organic matter suitable for fly larvae development. At the park, 6 species of Stomoxyini flies were collected: *S. calcitrans*, *S. indicus*, *S. uruma*, *S. pulla*, *H. sanguinolenta* and *H. austeni*. *S. indicus* and *S. uruma* were newly described for the area. The large diversity and abundance of Stomoxyini flies in the national park are similar to a study conducted by Mihok *et al* (1995) at the Nairobi National Park in Kenya using vavoua traps; they found 11 species of *Stomoxys* and other genera of Stomoxyini files including *Prostomoxys*, *Haematobosca*, *Stygeromyia* and *Rhinomusca*. The number of *Stomoxys* flies collected at peak in their study was 3,000 per day. Lower species diversity of Stomoxyini flies was found in the zoo and wildlife conservation areas. The zoo has a limited area and is located in the city; this can cause low species diversity although there are a variety of animal species. The wildlife conservation area has a low number of animal species with no diverse habitats.

Stomoxyini flies can vary in abundance by season and climate; Cruz-vazquez *et al* (2004) found an increase in *S. calcitrans* numbers in Mexico with an increase in relative humidity during the spring-summer period. Our collections were conducted during the dry season with low relative humidity, but we still found large numbers of flies. In Thailand, Masmeatathip *et al* (2006) found 80% of Stomoxyine flies (*S. calcitrans*, *S. indicus* and *S. sitiens*) collected from dairy and beef cattle farms in Nakhon Pathom Province were captured during the rainy season.

We found the altitude correlated with the number of flies. These results correspond with those of Gilles *et al* (2008). They found the abundance of *S. calcitrans* and *S. niger* increased with the altitude. Although altitude is not a climatic factor by itself, it can act on the distribution of Stomoxyini flies as it affects habitats and climate variations. Tumrasvin and Shinonaga (1978) found altitude affected Stomoxyini fly distribution in Thailand.

In conclusion, this study provides information about the distribution and abundance of Stomoxyini flies at some locations in Thailand. The four site categories were different in species diversity. The number of flies found correlated with the altitude of the collection site. Further studies about the climatic factors at the collection sites can provide information about the population dynamics of these flies. Our results may be useful for fly control programs.

ACKNOWLEDGEMENTS

This work was supported by the Monitoring and Surveillance Center for Zoonotic Diseases in Wildlife and Exotic Animals (MOZWE), Faculty of Veterinary Science, Mahidol University. The authors would like to thank the Zoological Park Organization under the Royal Patronage of His Majesty the King and the Department of Natural Parks, Wildlife and Plant Conservation for permission to conduct the study in the area. Special thanks to Norberto Asensio for his critical review of this manuscript.

REFERENCES

Crosskey RW. Stable flies and horn flies (blood-sucking Muscidae). In: Lane RP, Crosskey RW, eds. Medical insects and arachnids. London: Chapman & Hall, 1993: 389-402.

Cruz-Vázquez C, Mendoza IV, Parra MR, García-Vázquez Z. Influence of temperature, humidity and rainfall on field population trend of *Stomoxys calcitrans* (Diptera: Muscidae) in a semiarid climate in Mexico. *Parasitol Latinoam* 2004; 59: 99-103.

De Carvalho CJB, Couri MS, Pont AC, Pamplona D, Lopes SM. A Catalogue of the Muscidae (Diptera) of the Neotropical region. *Zootaxa* 2005; 860: 1-282.

Department of Natural Parks, Wildlife and Plant Conservation (DNP). Khao Yai National Park. [Homepage on the Internet]. Bangkok: DNP, 2011 Nov 30. (Cited 2012 Apr 20). Available from: URL: http://www.dnp.go.th/mfcd3/kaoyai.htm

Doyle MS, Swope BN, Hogsette JA, Burkhalter KL, Savage HM, Nasci RS. Vector competence of the stable fly (Diptera: Muscidae) for West Nile virus. *J Med Entomol* 2011; 48: 656-68.

Foil LD, Hogsette JA. Biology and control of tabanids, stable flies and horn flies. *Rev sci tech Off int Epiz* 1994; 13: 1125-58.

Gilles J, David JF, Duvallet G, Tillard E. Potential impacts of climate change on stable flies, investigate along an altitudinal gradient. *Med Vet Entomol* 2008; 22: 74-81.

Greenberg B. Flies and disease. Vol II: Biology and disease transmission. Princeton (NJ): Princeton University Press, 1973.

Laveissiere C, Grebaut P. The trapping of tsetse flies (Diptera: Glossinidae) improvement of a model: the Vavoua trap. *Trop Med Parasitol* 1990; 41: 185-92.

Lehane MJ. The biology of blood sucking in insect. 2nd ed. Cambridge: Cambridge University Press, 2005.

Masmeatathip R, Gilles J, Ketavan C, Duvallet G. First survey of seasonal abundance and daily activity of *Stomoxys* spp. (Diptera: Muscidae) in Kamphaengsaen Campus, Nakornpathom Province, Thailand. *Parasite* 2006; 13: 245-50.

Mellor PS, Kitching RP, Wilkinson PJ. Mechanical transmission of Capripox virus and African swine fever virus by *Stomoxys*

calcitrans. *Res Vet Sci* 1987; 43: 109-12.

Mihok S, Clausen PH. Feeding habits of *Stomoxys* spp. stable flies in a Kenyan forest. *Med Vet Entomol* 1996; 10: 392-4.

Mihok S, Kang'ethe EK, Kamau GK. Trials of traps and attractants for *Stomoxys* spp. (Diptera: Muscidae). *J Med Entomol* 1995; 32: 283-9.

Moon RD. Muscid Flies (Muscidae). In: Mullen GR, Durden LA, eds. Medical and veterinary entomology. Burlington: Academic Press, 2009: 275-95.

Muenworn V, Duvallet G, Thainchum K, *et al*. Geographic distribution of Stomoxyine flies (Diptera: Muscidae) and diurnal activity of *Stomoxys calcitrans* in Thailand. *J Med Entomol* 2010; 47: 791-7.

Muller GC, Hogsette JA, Kravchenko VD, Revay EE, Schlein Y. New records and ecological remarks regarding the tribe Stomoxyini (Diptera: Muscidae) from Israel. *J Vector Ecol* 2011; 36: 468-70.

Smith EP. Ecological statistics. In: El-Shaarawi AH, Piegorsch WW, eds. Encyclopedia of envirometrics. Chichester: John Wiley & Sons, 2002: 589-602.

Soulsby EJL. Helminths, arthropods and protozoa of domesticated animals. 7th ed. London: Bailliere Tindall, 1982.

Taylor DB, Moon RD, Mark DR. Economic impact of stable flies (Diptera: Muscidae) on dairy and beef cattle production. *J Med Entomol* 2012; 49: 198-209.

Tumrasvin W, Shinonaga S. Studies on medically important flies in Thailand. V. On 32 species belonging to the subfamilies Muscinae and Stomoxyinae including the taxonomic keys (Diptera: Muscidae). *Bull Tokyo Med Dent Univ* 1978; 25: 201-27.

Turell MJ, Dohm DJ, Geden CJ, Hogsette JA, Linthicum KJ. Potential for stable flies and house flies (Diptera: Muscidae) to transmit Rift Valley fever virus. *J Am Mosq Control Assoc* 2010; 26: 445-8.

Williams RE. Veterinary entomology: livestock and companion animals. 1st ed. Bosca Raton: CRC Press, 2009.

Zumpt F. The *Stomoxyine* biting flies of the world. Stuttgart: Gustav Fisher Verlag, 1973.