Pestiferous nature, resting sites, aggregation, and host-seeking behavior of the eye fly *Siphunculina funicola* (Diptera: Chloropidae) in Thailand

Mir S. Mulla[1]✉ and Uruyakorn Chansang[2]

[1]*Department of Entomology, University of California, Riverside, CA 92521, U.S.A.*
[2]*National Institute of Health, Department. of Medical Sciences, Ministry of Public Health, Nonthaburi 11000, Thailand*

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ABSTRACT: Species of eye flies and eye gnats (Diptera: Chloropidae) are severe and persistent pests of man, domestic and wild animals, and potential vectors of pathogens. The species prevailing in the Oriental region belong to the genus *Siphunculina,* while those in the Neotropic and Nearctic regions belong to *Liohippelates* and *Hippelates*. These are small insects of 1-2 mm that feed on wounds, lacerations, scratches, and mucous membranes of man and higher animals. One species, *Siphunculina funicola,* commonly known as the Oriental eye fly, is considered the most anthropophilic in the genus, with potential involvement in the spread and mechanical transmission of infectious agents to humans and animals. Very little is known about the biology, prevalence, host-seeking, and aggregation behavior of this species in South and Southeast Asia. We initiated studies on biological aspects of this potential vector and human pest in central Thailand. The most significant findings of our study were the aggregation behaviors of *S. funicola*, that both sexes attack hosts, and that males outnumbered females attacking humans, dogs, and other domestic animals. They feed on wounds, scabs, lacerations, eyes, and mucous membranes. They hover around and feed on hosts during the daylight hours when host-seeking activities are more pronounced at temperatures above 25-27° C under calm conditions. We noted that large masses of males and females aggregated on a variety of hanging objects such as strings, trailings, electrical lines, decorations, ropes, twines, abandoned cob webs, clothes hangers, and other hanging substrates in open shade of structures and dwellings. This behavior of eye flies brings them closer to human and animal hosts. In these aggregations, both males and females were present, with mating pairs frequently noted. In the aggregations, about 37% of the females had fully developed eggs in the rainy season, but only <1-3.6% were gravid in the hot and dry season. The average number of eggs per female was generally 42 to 44. ***Journal of Vector Ecology* 32 (2): 292-301. 2007.**

Keyword Index: Eye flies, *Siphunculina funicola*, host seeking, aggregation behavior, fecundity, Thailand.

INTRODUCTION

Members of the family Chloropidae (Diptera) are small two-winged acalypterate flies that have diverse modes of life. Most species are parasitic on eggs and larvae of insects and spiders, but a few are phytophagous damaging cereal crops, and still others are important pests and vectors of human and animal pathogens. There are three genera in this family, some members of which are of medical and public health importance. Members of the genera *Hippelates* and *Liohippelates* have Neotropical and Nearctic distribution and are commonly known as eye gnats. They are attracted to humans and domestic animals, causing great annoyance and mechanically transmitting pathogenic organisms (Basset 1967, Bengston 1933, Dawson 1960, Dow and Hines 1957, Kumm 1935, Schneider 1927). Members of the New World group that are anthropophilic and zoophilic were placed in the genus *Hippelates* (Sabrosky 1941), but were later moved into the three genera, *Liohippedales, Hippelates,* and *Appalates* (Sabrosky 1980), the latter genus not attracted to humans or animals. Their counterparts and ecological homologues of the Neotropical species of chloropids found in the Orient, South and SE Asian regions are included in the genus *Siphunculina*. *Siphunculina funicola* (de Meijere), commonly known as the Oriental eye fly, is the subject of this paper. It is primarily a human and animal pest with wide distribution in those regions. Eye flies are a neglected group of insects with little information on their biology and ecology. These flies are extremely annoying to humans and domestic animals, feeding on mucous secretions and moist surfaces of the host body such as wounds, scratches, eyes, nose, ears, and lips. Graham-Smith (1930), Muirhead-Thomson (1954) and Siddiq (1938) incriminated this fly in the spread and transmission of the causal agent of catarrhal ophthalmia in India. Aside from taxonomic descriptions and treatment of some 30 species of *Siphunculina* in the Oriental region (Cherian 1977, Kanmiya 1982, 1989, 1994, de Meijere 1905), no information is available regarding the abundance, pestiferous nature, breeding niches, aggregation, and host-seeking behavior of species in this genus. The present studies were initiated to elucidate the pestiferous nature, sex ratio and fecundity, aggregation sites, aggregation, and host-seeking behavior of *S. funicola*. To obtain information on seasonal trends, repeated observations were made on this species in several provinces of central Thailand over the past two to three years and the results are reported here.

MATERIALS AND METHODS

Study sites and their physiognomy

Preliminary surveys of the oriental eye flies were carried out in some villages of Chachoengsao (March 2005), Nakhorn Ratchasima (June 2005, August 2006) and Chonburi (April 2006) provinces, and at the Medicinal Plant Garden in Chanthaburi province (February 2006), Thailand. More focused studies on abundance, host-seeking and aggregation behavior, sex ratio, and fecundity were carried out in Ban Mab Jaroen (village 2) and Ban Kainao (village 4) in Khao Mai Kaeo subdistrict; Bang Lamung district of Chonburi Province (Figure 1) during 2006-2007. These two villages are situated in a low-lying rolling hills area, surrounded by extensive cassava (*Manihot esculenta* Crantz) and pineapple (*Ananas comosus* Merr.) fields. There are no wooded areas and only a few trees are scattered in the fields. Village 2 is also next to a large golf course and country club on a hilly terrain. In Nakhorn Ratchasima province-limited studies were carried out in two villages Ban Vao (village 11) and Ban Pudsa (village 2), both with extensive farming of spring onions (*Allium cepa* var. *aggregatum* G. Don.). The soil in the cropping areas in all four studied villages was sandy and friable. The agricultural fields adjacent to the study villages are believed to be the breeding sites of *S. funicola*, based on the findings of David (1960) and those of Mulla (1962) on the closely-related species *Hippelates collusor* in California.

Surveys and sampling procedures

Surveys determined resting and host-seeking populations, abundance, sex ratio, fecundity, aggregation, and host-seeking behavior. Abundance was first estimated by counting the number of resting individuals on substrates (Figure 2) and then collecting them using insect killing jars or a stream of commercial insecticide aerosols. By pushing the killing jar against a vertically hanging resting site, practically all eye flies were dislodged and killed instantly in the jar. Similarly, most insects falling down from resting sites after treatment with aerosols were collected in insect nets. Each sample of the dead flies was transferred to screw-cap vials and labeled with date, time, and type of resting site. The insects were preserved in 70% alcohol or kept dry for identification, precise counting, sex determination, and fecundity rate in the laboratory. Surveys were carried out on June 7, 2005, and during February 2006 to April 2007 to determine the magnitude of these parameters during the 15 months of study.

To investigate the persistence and reformation of the cluster of *S. funicola* on resting sites, all the insects were sequentially removed from a few selected aggregation sites using the insect killing jar method mentioned earlier. At intervals (see Table 3), the same sites were sampled repeatedly and the reformed aggregations completely removed into killing jars. Samples were transferred to screw-cap vials and kept either dry or in 70% ethanol for counting and sexing in the laboratory using a stereomicroscope.

To study host-seeking activity and to determine whether one sex or both are attracted to feed on humans and animals, attack rates were assessed on human hosts by two methods: visual counting where sex could not be determined and sweeping by insect net where the sex of collected specimens was determined later in the laboratory. For visual counts of hovering and landing eye flies, the host was seated in a chair or on a deck and another individual estimated the number of eye flies approaching the front of the host for 1 min. This procedure was repeated five times every 2-3 min at each interval. A second sampling procedure used five sweeps with an insect net (30 cm opening) around the host at intervals of 2-3 min, repeated five times. After net sweeping, samples were transferred to killing jars and the dead flies were placed in alcohol in labeled vials with date and time of collection. The insects were counted and sexed in the laboratory using a stereomicroscope.

The fecundity of eye flies was determined by dissecting females (33-500 depending on sample size) preserved in alcohol from several collections under a dissecting microscope. Mature eggs in each dissected female were counted and the % gravids and the mean number of eggs per female was determined.

To determine the nature and extent of attraction to wounds on humans, observations were made in Ban Mab Jaroen village on two children (8-10 years old) with scratches, wounds, scabs, and sores on their legs, knees, and feet. Collections of the eye flies were made by an aspirator tube from the wounds. Eye flies were also collected by aspiration or net sweeping from a dog and a tethered cow. All the samples were taken to the laboratory for identification and sex determination. Several specimens from some collections were measured for body length using a stereomicroscope with calibrated ocular micrometer.

RESULTS

Aggregation size, sex ratio, and persistence

During 2006, 30 collections (1 in 2005) of aggregations were made by the killing jar method and during 2007, 24 collections by the insecticide aerosol knockdown method (Tables 1, 2, and 4). Additionally, other aggregations, some very large, were collected by both methods and those collections giving similar information as the 54 collections in Tables 1, 2, and 4 are omitted. The number of eye flies per aggregation substrate depended on the size, location, and nature of the substrate (Tables 1, 2, and 4). The resting and aggregation sites of the eye flies consisted of many types, such as trailings, chains, wires, electric lines, strings, ropes, cords, thatch sheaths, abandoned cob webs, and other mostly vertically hanging thin stringy objects in buildings, structures, cabañas, open storage sheds, breezeways, and other sheltered areas close to human and animal habitations. Heavy aggregations were also noted on automobile antennae and metal arms of side view mirrors (data omitted). High numbers of eye flies in aggregations were found on hanging trailings from bird nests, thatch roofs, abandoned cob webs, strings, ropes, twines, wires, hanging decorations, and electrical wires inside the villages (Figure 2). Also some leaves on lower branches of mango

trees on one occasion were found supporting aggregations of the eye flies (Figure 2). The aggregations on the substrates were quite stable, essentially the same number of flies occupying the niche during the day and night. Up to about 1,000 flies were noted on some of the small aggregation sites, while some sites such as an electric cord or ropes extending vertically or horizontally had approximately 5,000 to 10,000 flies (Figure 2B, 2G). Most of the sites, because of their small size, were occupied with lower numbers, the males generally predominating in the aggregations in most of the 2006 collections (Table 1). Overall male to female composition for the 25 collections was 65.2% and 34.8%, respectively (Table 1). Collections made in August 2006 in Ban Kainao also had higher proportions of males, but in the collections made in February 2007 in Ban Mab Jaroen, the females were predominant (Table 2). It is surmised that in this area in the dry-hot weather, there were low levels of oviposition activity in the field and that the females were prevailing in resting mode.

The return of eye fly aggregations after disturbance and their complete removal was investigated. After complete removal of aggregations from the trailings or strands sequentially, new flies recolonized most of the resting sites within an hour or two, although the numbers settling were smaller (Table 3), but in some cases reconstitution took two to three days. To determine the persistence of aggregations they were sequentially removed from substrates and then monitored at varying intervals. These removals were followed by subsequent reoccupation by the flies reaching capacity of the site in a day or two (Table 3). The size and formation of aggregations seem to be stable, with flies occupying the niche to capacity during night and daytime hours. After disturbance, several sites, including an electric cord with initially about 10,000 flies, were reoccupied to full capacity the next day or so. Both sexes were present in the aggregations collected sequentially (Table 3), with males (*S. funicola*) generally outnumbering females (males 60.1% and females 39.9%) following the same trend of sex ratio of collections made in 2005-2006 (Tables 1 and 2).

Fecundity

In order to determine the fecundity in field populations, female eye flies were dissected to determine the number of gravids and the number of mature eggs in each gravid female. The magnitude of gravid females and egg load were determined for five collections in Ban Kainao village (collections of August 30, 2006 rainy season) and 11 collections in Ban Mab Jaroen village (February 3, 2007). In the former, all collections had 25% to 46% (mean 36.8%) of the females gravid with an average of 44 eggs per female (Table 2). In the dry season, however, collections from Ban Mab Jaroen contained very few gravids (mean 3.6%), with an average of 42.2 eggs/female (Table 2).

After noting the marked difference in gravid rates between the two sets of collections from aggregation sites (August 2006 and February 2007), we wanted to investigate

Table 1. Aggregation size and sex ratio of eye flies resting on substrates in various villages in three provinces of central Thailand collected by the killing jar method (2005 and 2006).

Date 2006	Village and No.	Province (district)	Type of substrate	No. of eye flies	
				Males	Females
June 7 2005	Ban Vao (11)	Nakhorn Ratchasima (Muang)	Strand**	661	347
August 16	Ban Pudsa (2)	Nakhorn Ratchasima (Muang)	Rope	350	73
			Plastic twine	136	41
			Onion sheath	191	64
February 14	MPG*	Chanthaburi (Makham)	Strand 1**	202	137
February 14	MPG*	Chanthaburi (Makham)	Strand 2**	50	15
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 1	105	49
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 2	56	4
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 3	576	276
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 4	174	141
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 5	321	226
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 6	592	236
April 5	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	Strand 7	629	491
August 19	Ban Mab Jaroen (2)	Chonburi (Bang Lamung)	String	157	84
			Bird nest trailing	161	54
			Plastic rope	241	186
April 5	Ban Kainao (4)	Chonburi (Bang Lamung)	Mango leaf 1**	45	20
April 5	Ban Kainao (4)	Chonburi (Bang Lamung)	Mango leaf 2**	28	33
April 5	Ban Kainao (4)	Chonburi (Bang Lamung)	Mango leaf 3**	25	11
April 5	Ban Kainao (4)	Chonburi (Bang Lamung)	Mango leaf 4**	24	11
June 1	Ban Kainao (4)	Chonburi (Bang Lamung)	Strand 1	557	346
			Steel wire	207	78
August 20	Ban Kainao (4)	Chonburi (Bang Lamung)	Coconut hairs	107	41
May 11	Ban Kao Talo (10)	Chonburi (Bang Lamung)	Strand 1	9	31
May 11	Ban Kao Talo (10)	Chonburi (Bang Lamung)	Strand 2	44	25
			Total	5,671	3,032
			%	65.2	34.8

*MPG : Medicinal Plant Garden. **Mites found on eye fly samples.

Table 2. Aggregation size, sex ratio, and gravid females of the eye-fly *Siphunculina funicola* collected by the killing jar (Ban Kainao village, August 30, 2006) and aerosol* knockdown method (Ban Mab Jaroen village, February 3, 2007) in Bang Lamung district, Chonburi, Province, Thailand.

Village	Aggregation site	Eye fly numbers		Females dissected	Gravid (%)	Mean no. Eggs/female
		Males	Females			
Ban Kainao	Plastic rope 1	201	162	162	25.3	45.0
	Plastic rope 2	350	305	100	46.0	41.8
	Nylon string	260	133	100	43.0	42.7
	Wire coil	233	192	100	30.3	43.1
	Decoration tassel	57	33	33	39.3	47.0
	Total	1,101	825	495	183.9	219.8
	%	57	43	60	36.8	43.9 (mean)
Ban Mab Jaroen	Plastic rope	936	884	400	2.0	49.5
	Rusty wire	41	47	47	4.3	40.0
	Cob web, rope	112	106	106	5.7	42.4
	Thatch sheath 1	196	338	250	1.6	38.3
	Thatch sheath 2	175	198	198	3.0	36.4
	Thatch sheath 3	508	622	300	2.0	48.0
	Thatch sheath 4	54	51	51	2.0	46.5
	Rope, electric cord	5,128	5,392	500	3.2	39.3
	Cob web – diffuse	323	329	200	7.0	41.6
	Electric cord	993	1,232	500	5.4	42.6
	Rope strand	627	659	300	4.0	40.0
	Total	3,965	4,466	2,352	39.6	464.6
	%	47.0	53.0	52.6	3.6	42.2 (mean)

*Aerosol: 0.2% d-tetramethrin + 0.1% permethrin. Aerosol stream directed at the aggregation substrate, the knocked down insects collected in an insect net.

both locations at the same time for gravid rates in the dry and hot season (April 19-21, 2007). At this time we also determined the gravid rates in collections from humans. All three collections from humans and 13 collections from resting sites or those entering automobiles contained very few if any gravids <1% (Table 4). We noted a low number of gravid females for all collections in the dry and hot season (February and April) in both villages (Tables 2 and 4).

Host-seeking behavior and diurnal activity

The sweepings in general captured only a small number of eye flies that were hovering on or attacking the host. This is because due to disturbance or only a slight air movement, the flies dive down to the ground and avoid capture by sweeping. It is interesting to note that in every sample, larger numbers of males were attracted to humans (Table 5) than the females. Of all the flies collected from human hosts, 74.5% were males and 25.5% were females (Table 5). This behavior of feeding is in contrast to the eye gnats in the Western hemisphere where only females seek human hosts. In the southeast U.S.A., Jay (1962) recovered mostly females (over 96%) of *H. pusio* feeding on humans, dogs, and calves. Mulla and Axelrod (unpublished data) collected 498 eye gnats by sweeping in mobile home parks and date gardens in the Coachella Valley, CA, and noted that only females of *H. (Liohippelates) collusor* were attracted to humans.

The hovering and landing rates of eye flies attracted to hosts showed diurnal rhythm. The flies were active throughout the daylight hours with little or no activity before sunrise and after sunset. Soon after sunrise (06:00), there was little or no host-seeking activity as determined by both visual counts and sweepings. The two counts at 06:15 and 07:00 gave very few eye flies. Their numbers substantially increased at 08:00 to 09:00, increasing further from 09:45 to 11:45 (Table 5) by both methods. The numbers in the visual counts decreased due to stiff breezes at 13:30, increasing back in numbers at 15:00 to 18:00 due to subsidence of the breezes.

Temperature also had effects on flying activity. When the ambient temperature was 34-35° C, as many as 100 eye flies were noted and counted around the host at a given time (Table 5). Maximum activity was noted at ambient temperatures of 32-35° C. One other important aspect of the flying and host-seeking activity of flies noted was that at low temperatures, most of the flies flew and hovered at the lower extremities of the host near the ground. But as the temperature increased, greater numbers of flies targeted the upper portion of the body, face, ears, and eyes.

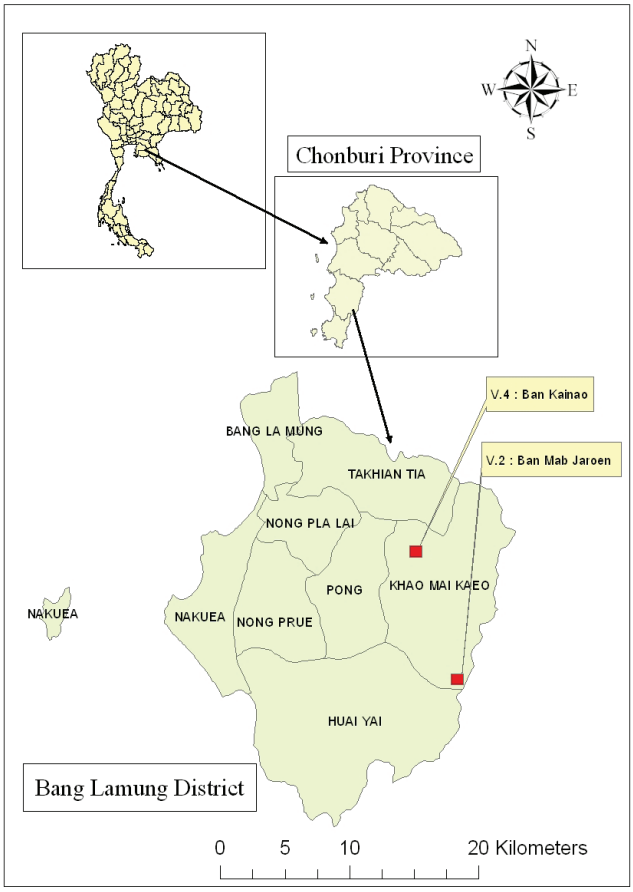

Figure 1. Map of Bang Lamung district in Chonburi Province showing study areas of eye flies. Village 2 and village 4 are noted in the Khao Mai Kaeo subdistrict.

Attraction to wounds and sores

Eye flies were attracted to wounds and open sores (Figure 3). Both male and female flies were captured with males greater in number (Table 6), all specimens were identified as *S. funicola*. The eye flies having lapping and sucking mouthparts fed voraciously along the edges of lacerations, scratches, and wounds. With their labellar bristles they were able to scarify, enlarge, and deepen the wounds to keep them oozing for feeding. They kept the wounds from healing and infected them with a variety of infectious agents. Because of their attraction to wounds and sores, they have been recovered from a tumor in the eyelid (Brownstein et al. 1976). The wounds in the children observed in Ban Mab Jaroen village lasted for more than two months and recovery from this affliction was not in sight yet. It is noteworthy that both male and female flies visited the wounds and fed on them voraciously (Figure 3 and Table 6), and that the feeding behavior where both sexes feed is in contrast to the feeding activity of eye gnats in the western hemisphere. The proportion of males (74.1%) and females (25.9%) (Table 6) was similar to that of flies collected from humans by sweeping (Table 5).

Large animal hosts

Observations were made on the hovering and landing behavior of eye flies on dogs and cows. Hundreds of eye flies were noted to hover and land on dogs, especially in the anal and perianal area, the head region (eyes, mouth, and ears) and on the top of the back and under belly areas. Fifty-six eye flies were collected from a dog by sweep net, recovering 38 males and 18 females. Similar hovering and landing behavior was noted on a cow, where 29 eye flies (six males and 23 females) were collected. The eye flies hovered and landed on the belly, back, and head regions of the cow, annoying the animal incessantly. As on dogs and humans, the eye flies hovered and landed on the cow during the daylight hours. As noted above, both males and females attracted to humans also attacked dogs and cows. More females than males were collected from the cow, but due to the small numbers collected, this trend in sex ratio on the cow may not hold true. Further detailed studies on their feeding behavior on large domestic animals are warranted.

Morphometric measurements

With an ocular micrometer fitted on a stereomicroscope, the length of 50 flies (males and females) from some of the collections was measured (Table 7). The mean length from front to the tip of abdomen was 1.528 to 1.644 mm. On engorgement, the flies become greatly enlarged but the body length essentially remains constant. Because of this increase in size on feeding, we did not measure the thickness or width across the abdomen.

DISCUSSION

The Oriental eye fly, *S. funicola,* seems to have widespread distribution in central Thailand and possibly other areas. Aside from taxonomic treatment, very little is known about its prevalence, seasonal population trends, breeding habits, and host range. An interesting behavior of the eye flies found in our studies was their resting and aggregation behavior and the fact that both males and females were found in the aggregations, males generally predominating. This unique behavior of *S. funicola* does not occur in any species of eye gnats in the neotropics. We postulate that the aggregation behaviors of eye flies *S. funicola* in or near human habitation and domestic animal shelters are pheromone-based that may be excreted in the feces. The aggregations are quite large and persistent, reforming after disturbance. Aggregations in or adjacent to human habitations or animal quarters possibly avail targets for eliminating or excluding flies adjacent to residences or animal shelters. Eye flies in agricultural fields, golf courses, and recreational areas have widespread distribution throughout the infested landscape, and therefore no control measures seem to be practical against the dispersed populations. The use of insect repellents for personal protection may be another alternative, but no information on the effectiveness of repellents against eye flies is available. Selective and focused control measures of eye flies on their resting sites close to and in human habitations offer good possibilities. The eye flies are considered to be important pests of humans (especially in residential and recreational areas), dogs, cattle, and horses by local

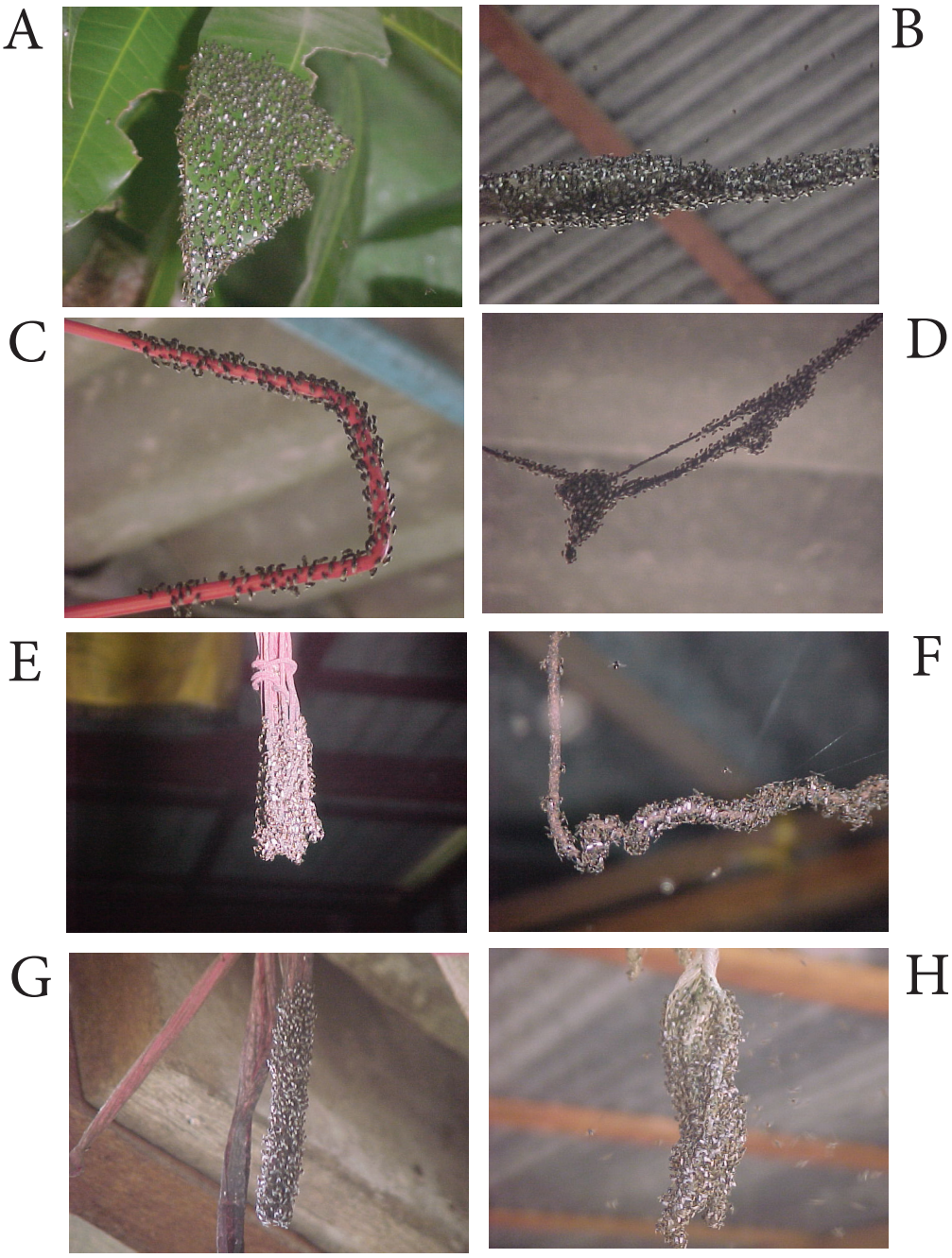

Figure 2. Resting sites of the eye flies on various substrates in villages in Chonburi and Nakhorn Ratchasima Provinces of Thailand. (A) Eye flies on leaf of a mango tree, leaf damage not due to eye fly feeding, (B) Large number of eye flies on electric line running through a covered passageway between two buildings, (C) Temporary aggregation of eye flies on a clothes hanger, (D) Eye flies on abandoned spider web trailing hanging from beams of roof of a community hall, (E) Eye flies on a decoration tassel hanging from the door jamb opening into the house, (F) Eye flies on a rusty wire in an open tool shed, (G) Eye flies on a nylon rope hanging from the ceiling of a house; (H) Eye flies on a plastic rope hanging from eaves of a house.

Table 3. Aggregation size, sex ratio, persistence, and reformation of eye flies on complete sequential removal (by killing jar) of aggregation on substrates hanging from the ceiling and eaves of a community hall (open on all sides) in village 2 (Ban Mab Jaroen), Bang Lamung district, Chonburi Province, Thailand.

Date 2006	Substrate strand or other	Removal sequence	No. of eye flies	
			Males	Females
May 10*	1,2	1st	110	51
	1,2	2nd	51	25
	1,2	3rd	218	114
	1,2	4th	139	47
	3	1st	704	641
	4	1st	92	58
	4	2nd	77	38
	4	3rd	73	14
	5	1st	224	197
May 11	1,2	5th	33	19
	4	4th	38	6
	5	2nd	200	92
		Total	1,959	1,302
		%	60.1	39.9

*The time between sequential removals during the same day was 1-2 h. The day following removal or disturbance most of the resting sites were recolonized with large numbers as before disturbance or removal.

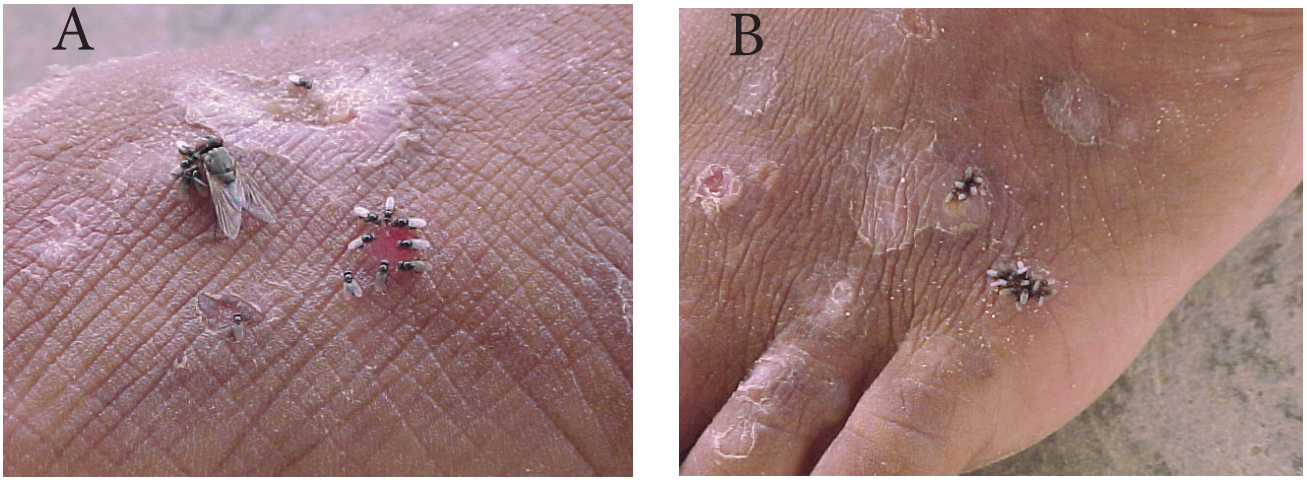

Figure 3. Feeding activity of *Siphunculina funicola* on wounds of an 8-year-old boy that were highly attractive to eye flies in Village 2 in the Bang Lamung district of Chonburi Province. (A) Eye flies feeding in wounds on the knee. Note feeding by a house fly and the relative size of the eye flies as compared to the house fly. (B) Eye flies feeding in wounds on foot. Note numerous denuded wounds.

Table 4. Aggregation size, sex ratio, and gravid females of the eye fly *Siphunculina funicola* from Ban Kainao and Ban Mab Jaroen villages during heavy population peak (April 19-21, 2007) in Chonburi Province, Thailand.

Village	Aggregation sites or off humans		Eye fly numbers Males	Eye fly numbers Females	Female dissected	Gravid Females*
Ban Kainao	Off human (cassava field)		93	160	160	0
	Off human (pineapple field)		609	526	200	1
	In car		315	279	200	2
		Total	1,017	965	560	3
		%	51.3	48.7	58.0	<1
	Electric cord A		1,181	1,274	200	2
	Electric cord B		615	514	200	0
	Electric cord C		747	1,013	200	0
	Electric cord (2)		775	1,316	200	0
	Rope (4)		529	232	200	2
	Sack strand (5)		56	42	42	1
	Sack strand (7)		211	292	200	0
		Total	4,114	4,683	1,242	5
		%	46.8	53.2	26.5	<1
Ban Mab Jaroen	Bamboo stick (9)		1,470	1,610	200	1
	Cob web (12)		253	295	200	0
	Rusty wire (13)		1,936	2,153	200	3
	Bird trail (18)		2,271	2,121	200	0
	Rope (19)		1,556	1,562	200	0
	Plastic rope (20)		1,252	1,083	200	0
		Total	8,738	8,824	1,200	4
		%	49.8	50.2	13.6	<1

*The few females that were gravid had a full complement of eggs ranging from 31 to 46 eggs per female.

Table 5. Attraction of *Siphunculina funicola* to human hosts as measured by visual counting (for 1 min) and sweep nets (five sweeps) at various intervals. Host-seeking and landing behavior were studied in village 2 (Ban Mab Jaroen) and village 4 (Ban Kainao) during May 9-11, and June 1-2, and November 23, 2006.

Ambient temp	Village 2 (mean number)		Village 4 (mean number)				
					Sweeping		
(˚C)	Time/mo	Visual count	Time/mo.	Visual count	Males	Females	Weather
23-24	06:15* May	1	07:00/May	2	-	-	Calm
29	08:00 May	33	09:00/May	24	17	7	Calm
30	08:30 May	51	09:45/May	57	35	20	Calm
32	10:30 May	92	11:45/May	72	17	5	Calm
28	13:30 May	0**	13:30/May	0**	0	0	Breezy
27	18:20 May	5	15:00/May	36	18	6	Calm
28	18:30 May	0**	16:00/May	37	6	2	Breeze
27	-	-	17:00/May	40	15	6	Calm
26	-	-	18:00/May	37	6	2	Calm
27	-	-	18:00/May	3	0	0	Breezy
34	12:00 June	90.0	14:45/June	50	84	17	Calm
34	13:00 June	100.0	15:00/June	100	52	30	Calm
32	-	-	10:35-16:00/Nov	-	106	26	Calm
				Total	356	122	
				%	74.5	25.5	

*No or little eye fly activity after sunrise (06:00) until 08:00, and activity ceased at sunset (18:30).
**Stiff breeze.

Table 6. Feeding activity of eye flies (*S. funicola*) on wounds, scabs, and scratches on feet, legs, and knees of a 8-year-old child in village 2 (Ban Mab Jaroen) in Chonburi province. Eye flies removed by an aspirator while feeding.

Date 2006	Time	Sample	No. eye flies collected	
			Males	Females
May 10	11:30-12.30	A	8	1
		B	13	1
		C	14	2
		D	4	1
		E	9	2
May 12	08:30	F	8	5
June 1	16:00	G	53	26
		Total	109	38
		%	74.1	25.9

people, and they related to us that eye flies are the cause of conjunctivitis, especially in children in the infested areas. The locals are quite familiar with the conjunctivitis that they encounter frequently in the eye fly infested areas of central Thailand. This circumstantial evidence necessitates further definitive studies on the role of eye flies in the spread and incidence of eye diseases in Thailand.

Another important finding of our studies is the host-feeding behavior of *S. funicola.* We found that both males and females are attracted to humans and animals, and especially to wounds, scratches, and sores. This behavior of the fly (feeding by both sexes) has not been reported for any species in the Oriental region or for the eye gnats in the Neotropical region. Because both sexes of eye flies are attracted to and feed on vertebrate hosts, it is expected that they will be attacking hosts in larger numbers and therefore will have a greater impact on human health as compared to their related species in the Western hemisphere where only females are attracted to vertebrate hosts.

The fecundity of *S. funicola* seems to be high, as gravid females were quite abundant in aggregations studied in the rainy season. The proportion of gravids, however, was quite low in the dry season (February to April). A possible explanation for this difference is that the gravid females are in ovipositional mode in the open fields and they are not visiting the aggregation sites in the dry and hot season. The gravid females, whether in low or high numbers, usually had 31-50 eggs each. Estimating the gonotropic cycle of three to four days, this fly can produce a large number of progeny in a short period of time.

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REFERENCES CITED

Basset, D.C.J. 1967. *Hippelates* flies and acute nephritis. Lancet (March) 4: 503.

Bengston, I.A. 1933. Seasonal acute conjunctivitis occurring in the southern states. Publ. Hlth. Repts. 48: 917-926.

Brownstein, S., A.I. Bernardo, Suprapto, and I. Salim.1976. Neurofibromatosis with the eye fly *Siphunculina funicola* in an eyelid tumor. Canad. J. Opthal. 11: 261-266.

Cherian, P.T. 1977. The genus *Siphunculina* (Diptera: Chloropidae). Orient. Insects 11: 636-368.

Dawson, C.R. 1960. Epidemic Koch-Weeks conjunctivitis and trachoma in the Coachella Valley of California. Am. J. Ophthamol. 49: 801-808.

de Meijere, J.C.H. 1905. Note XI. S*iphunculina funicola* n. sp., eine neue javanische Diptren-Art. Notes Leyden Mus. 25: 160-162.

Dow, R.P. and V.D. Hines. 1957. Conjunctivitis in southwest Georgia. Publ. Hlth. Repts. 72: 441-448.

Graham-Smith, G.S. 1930. The Oscinidae (Diptera) as vectors of conjunctivitis and the anatomy of their mouth parts. Parasitology 22: 457-467.

Table 7. Measurement of length of eye flies obtained from different collections in village 2 (Ban Mab Jaroen) and village 4 (Ban Kainao); Bang Lamung district, Chonburi Province, Thailand during May 10-11, 2006.

Collection	Sex of flies	n	Mean length (mm)	SD
Resting sites	Male	50	1.536	0.179
	Female	50	1.554	0.181
Human hosts*	Male	50	1.644	0.150
	Female	50	1.558	0.130
Wounds	Male	50	1.528	0.191
	Female	30	1.607	0.174
		Mean	1.57	0.145

*Swept off human hosts.

Jay, E.G. 1962. Species of *Hippelates* (Diptera : Chloropidae) gnats collected from mammals. J. Econ. Entomol. 55: 1011-1012.

Kanmiya, K. 1982. Two new species and three new records of the genus S*iphunculina* Rondani from Japan (Diptera : Chloropidae). Jpn. J. Sanit. Zool. 33: 111-121.

Kanmiya, K. 1989. Study on the eye-flies, *Siphunculina* Rondani from the Oriental region and Far East (Diptera : Chloropidae). Jpn. J. Sanit. Zool. 40 (Suppl): 65-86.

Kanmiya, K. 1994. Studies on the eye-flies S*iphunculina* Rondani from Nepal (Diptera : Chloropidae). Jpn. J. Sanit. Zool. 45 (Suppl): 55-69.

Kumm, H.W. 1935. The natural infections of *Hippelates pallipes* with the spirochetes of yaws. Tr. Roy. Soc. Trop. Med. Hyg. 29: 265-272.

Muirhead-Thomson, R.C. 1954. The identity of eye-flies in Assam. Ann. Trop. Med. Parasitol. 48: 121.

Sabrosky, C.W. 1941. The *Hippelates* files or eye gnats: preliminary notes. Canad. Entomol. 73: 23-27.

Sabrosky, C.W. 1980. New genera and new combinations of nearctic Chloropidae (Diptera). Proc. Entomol. Soc. Wash. 82: 412-429.

Schneider, A. 1927. An introductory report on pseudo-trachoma endemic in the Salton Sea Region of California. Med. Sentinel 35: 154-161.

Siddiq, M.M. 1938. *Siphunculina funicola* (eye-fly). Ind. Med. Gaz. 73: 17-18.