

## Review of the flies (Diptera) associated with animal dung and human feces in Japan

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(Received: 9 March 2007; Accepted: 24 May 2007)

**Abstract:** Dipterous flies of Brachycera and Cyclorrhapha associated with animal dung and human feces in Japan are reviewed. This paper describes a total of 128 species belonging to 13 families of bred in or attracted to the dung of cows, horses, pigs, chickens, dogs, wild brown bears, and human feces. Information concerning faunal compositions, dung preferences, and larval food habits is provided for each family and species.

Key words: review, dipterous flies, animal dung, human feces, Japan

### INTRODUCTION

Dung or feces of animals and humans supports many dipterous flies as sources for breeding. Some dung-breeding flies occur in human dwellings and livestock farms are significant from medical, hygienic and veterinary points of view. Comparative studies of flies associated with various types of dung have been conducted by Hafez (1939), Bohart and Gressitt (1951), Schoof et al. (1954), Siverly and Schoof (1955a, b), and Coffey (1966). Extensive works on the flies associated with a single type of dung have been performed by Howard (1900), Mellor (1919), Hammer (1941), Mohr (1943), Lawrence (1954), Sanders and Dobson (1966), Poorbaugh et al. (1968), Blume (1970), Poorbaugh and Linsdale (1971), Merritt (1976), and Skidmore (1991). Faunal compositions of the flies in this literature are often considerably different among localities and countries.

In Japan, studies of the flies occurring from several types of cattle and animal dung have been conducted in several locations (Niko and Ogata, 1958; Suenaga,

1959; Nezu and Matsushashi, 1960; Oshio et al., 1962; Oshio and Ikeuchi, 1964; Nishijima and Iwasa, 1979, 1984; Iwasa and Watanabe, 2007). Amassing records of dung-frequenting flies has been performed by Shinonaga and Kano (1971, 1974a), Shinonaga et al. (1975), Iwasa (1980b, 1984a), Hayashi (1986), and Shinonaga (2003). Though the elucidation of fly fauna in all types of dung is far from completion in Japan, the state of knowledge of the flies associated with dung in Japan needs to be presented to consolidate data for future investigations.

The present paper reviews the known knowledge of the flies (excluding Nematocera) associated with various types of animal dung and human feces in Japan, and it includes their larval feeding habits.

Table 1 shows the Japanese species of Cyclorrhapha and Brachycera which are known to the author to have been associated with dung of cows, horses, pigs, chickens, dogs, wild brown bears, and human feces, with information on larval feeding habits. Dung types were divided into droppings (D) and manure (M). References are also given for each observation to show the history of research in this

field.

#### DUNG PREFERENCES AND LARVAL FOOD HABITS

**Stratiomyiidae.** *Ptecticus tenebrifer* (Walker) emerges from dung of cows, pigs, chickens, dogs, and humans (Suenaga, 1959), showing itself as general scavenger by adapting to a wide range of dung types from herbivores to omnivores. *Sargus metallinus* Fabricius was bred from brown bear dung (Nishijima and Iwasa, 1979); this species may also be associated with dung of other wild animals in wooded areas.

**Syrphidae.** *Eristalis cerealis* Fabricius, *E. rossica* Stackelberg, *E. tenax* (Linnaeus), *Eristalinus tarsalis* (Macquart), and *Helophilus virgatus* Coquillett were bred from reflux fluid of cow manure (Sasaki and Mikami, 2007). Though *E. tenax* also emerged from pig dung (Nezu and Matsuhashi, 1960), these syrphid species apparently prefer reflux fluid of cow manure. *Rhingia laevigata* Loew lays eggs on leaves overhanging cow droppings, and hatched larvae fall on cow droppings and breed in them (Iwasa, unpublished data).

**Drosophilidae.** *Drosophila melanogaster* Meigen and *D. buskii* Coquillett are attracted to human excrement (Hori, 1953), but these are probably not true excrement breeders.

**Sepsidae.** Thirty-six species have been recorded from many types of dung in Japan (Iwasa, 1980b, 1981, 1984a, 1995), but the present paper considers 12 species whose emergence from dung were confirmed. In Japan, *Sepsis cynipsea* (Linnaeus), *S. duplicata* Haliday, *S. nigripes* Meigen, *S. flavimana* Meigen, *S. thoracica* (Robineau-Desvoidy), and *Saltella sphondylii* (Schrank) prefer cow droppings (Iwasa et al., 2005a, b; Iwasa and Watanabe, 2007); this agrees with data from Europe reported by Pont and Meier (2002). *Meroplus minutus* (Wiedemann) was bred from pig and cow dung, having a

preference for pig dung (Iwasa and Watanabe, 2007). *Sepsis latiforceps* Duda breeds in a wide range of dung (cow, horse, pig, and brown bear), and it especially favors pig dung (Iwasa and Watanabe, 2007). *Sepsis punctum* (Fabricius) and *S. violacea* Meigen inhabit wooded areas, and brown bear dung is one of the breeding media in Japan (Nishijima and Iwasa, 1984). *Nemopoda nitidula* (Fallén) and *N. pectinulata* (Loew) gather on human excrement in Japan (Iwasa, 1984a), and their larvae probably breed in it.

**Sphaeroceridae.** Hayashi (1986) recorded 40 species of synanthropic sphaerocerid flies from Japan; many species were collected on compost, manure heaps of horse and cattle, and other animal dung. In the present paper, however, only the species bred from dung were treated. Iwasa and Watanabe (2007) bred 11 species of sphaerocerid flies from dung of cows, horses and pigs, and ten of these species occurred from horse dung. In particular, *Lotobia pallidiventris* (Meigen), *Norrbomia sordida* (Zetterstedt), *Coproica acutangula* (Zetterstedt), and other *Coproica* spp. apparently prefer horse dung (Iwasa and Watanabe, 2007).

**Heleomyzidae.** Suenaga (1959) bred a large number of *Heleomyza eoa* (Gorodkov) from chicken dung under the name of *Helomyza modesta* (Meigen) in Nagasaki, Japan; this species may be specific to chicken dung. Niko and Ogata (1958) confirmed the occurrence of *Tephroclamys japonica* Okadome from chicken dung under the name of *Tephroclamys* sp. in Honshu; this species also prefers chicken dung. *Orbellia tokyoensis* (Czerny) was observed in outdoor toilets in Japan (Okadome, 1990); human feces are probably one of the breeding media for this species.

**Dryomyzidae.** *Dryomyza formosa* (Wiedemann) was bred from dog feces and was attracted to human feces (Suenaga, 1959); it probably prefers dog and human feces for larval media. The larvae of *Stey-*

Table 1. List of flies associated with dung of six species of animals and human feces in Japan. Dung types were divided into dropping (D) and manure (M). ⊙, Bred; ○, Attracted; \*, Bred in reflux of manure; FH, Food habits; C, Coprophagous; FC, Facultative carnivorous; OC, Obligative carnivorous; S, Sarcophagous.

Fly species	Species of animals							References	
	Cow	Horse	Pig	Chicken	Dog	Brown bear	Human		
	Dung types								
	D	M	D	D+M	M	D	D	D	
FH									
Stratiomyidae									
<i>Pecticus tenebrifer</i> (Walker)	C	⊙			⊙	⊙		⊙	Suenaga (1959) etc.
<i>Sargus metallinus</i> Fabricius	C							⊙	Nishijima and Iwasa (1979)
Syrphidae									
<i>Eristalis cerealis</i> Fabricius	C	⊙*							Sasaki and Mikami (2007)
<i>Eristalis rossica</i> Stackelberg	C	⊙*							Sasaki and Mikami (2007)
<i>Eristalis tenax</i> (Linnaeus)	C	⊙⊙*		⊙					Nezu and Matsushashi (1960) etc.
<i>Eristalis tarsalis</i> (Macquart)	C	⊙*							Sasaki and Mikami (2007)
<i>Helophilus virgatus</i> Coquillett	C	⊙*							Sasaki and Mikami (2007)
<i>Rhingia laevigata</i> Loew	C	⊙							Iwasa (unpubl. data)
Drosophilidae									
<i>Drosophila melanogaster</i> Meigen	C							○	Hori (1953)
<i>Drosophila busckii</i> Coquillett	C							○	Hori (1953)
Sepsidae									
<i>Saltella sphondylii</i> (Schrank)	C	⊙							Iwasa et al. (2005a, b)
<i>Meroplius minutus</i> (Wiedemann)	C	⊙		⊙					Iwasa and Watanabe (2007)
<i>Nemopoda nitidula</i> (Fallén)	C							⊙	Iwasa (1984a)
<i>Nemopoda pectinulata</i> (Loew)	C							○	Iwasa (1984a)
<i>Sepsis cynipsea</i> (Linnaeus)	C	⊙							Iwasa et al. (2005a, b)
<i>Sepsis duplicata</i> (Haliday)	C	⊙		⊙					Iwasa et al. (2005a, b)
<i>Sepsis flavimana</i> Meigen	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
<i>Sepsis latiforceps</i> Duda	C	⊙		⊙	⊙			⊙	Nishijima and Iwasa (1979) etc.
<i>Sepsis nigripes</i> Meigen	C	⊙							Iwasa and Watanabe (2007)
<i>Sepsis punctum</i> (Fabricius)	C							⊙	Nishijima and Iwasa (1984)
<i>Sepsis thoracica</i> (Robineau-Desvoidy)	C	⊙							Iwasa et al. (2005a)
<i>Sepsis violacea</i> Meigen	C							⊙	Nishijima and Iwasa (1984)
Sphaeroceridae									
<i>Sphaerocera curvipes</i> Latreille	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
<i>Sphaerocera pseudomonilis</i> Nishijima et Yamazaki	C			⊙	⊙				Iwasa and Watanabe (2007)
<i>Lotobia pallidiventris</i> (Meigen)	C			⊙	⊙				Iwasa and Watanabe (2007)
<i>Ischiolepta scabricula</i> (Haliday)	C	⊙							Iwasa and Watanabe (2007)
<i>Ischiolepta draskovitsae</i> Roháček et Papp	C	⊙		⊙					Iwasa and Watanabe (2007)
<i>Norrbomia sordida</i> (Zetterstedt)	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
<i>Coproica acutangula</i> (Zetterstedt)	C			⊙					Iwasa and Watanabe (2007)
<i>Chaetopodella scutellaris</i> (Haliday)	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
<i>Opalimosina mirabilis</i> (Collin)	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
<i>Spelobia bifrons</i> (Stenhammar)	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
<i>Spelobia luteilabris</i> (Rondani)	C	⊙		⊙	⊙				Iwasa and Watanabe (2007)
Heleomyzidae									
<i>Heleomyza eoa</i> (Gorodkov)	C				⊙				Suenaga (1959)
<i>Orbellia tokyoensis</i> Czerny	C							○	Okadome (1990)
<i>Tephroclamyx japonica</i> Okadome	C			⊙	⊙				Niko and Ogata (1958)
Dryomyzidae									
<i>Dryomyza formosa</i> (Wiedemann)	C							⊙	Suenaga (1959)
<i>Steyskalomyza hasegawai</i> Kurahashi	C	⊙							Iwasa (2002)

Table 1. (Continued)

Fly species	Species of animals								References	
	Cow		Horse	Pig	Chicken	Dog	Brown bear	Human		
	Dung types									
	D	M	D	D+M	M	D	D	D		
FH										
<b>Scathophagidae</b>										
<i>Scathophaga stercoraria</i> (Linnaeus)	C	⊙							○	Suenaga (1959)
<i>Scathophaga scybalaria</i> (Linnaeus)	C	⊙								Iwasa and Watanabe (2007)
<i>Scathophaga suilla</i> (Fabricius)	C	⊙								Sasaki (1980)
<i>Scathophaga mellipes</i> (Coquillett)	C	⊙				⊙				Suenaga (1959)
<b>Anthomyiidae</b>										
<i>Anthomyia illocata</i> Walker	C				⊙	⊙			⊙	Suenaga (1959) etc.
<i>Emmesomyia villica</i> (Meigen)	C	⊙								Iwasa and Watanabe (2007)
<i>Emmesomyia oriens</i> Suwa	C	⊙								Iwasa and Watanabe (2007)
<i>Emmesomyia hasegawai</i> Suwa	C	⊙								Iwasa and Watanabe (2007)
<i>Lasiomma octoguttatum</i> (Zetterstedt)	C							⊙		Nishijima and Iwasa (1979)
<i>Lasiomma iwasai</i> Suwa	C							⊙		Nishijima and Iwasa (1979)
<i>Paregle cinerella</i> (Fallén)	C	⊙								Iwasa et al. (2005a, b)
<b>Fanniidae</b>										
<i>Fannia canicularis</i> (Linnaeus)	C			⊙	⊙				○	Niko and Ogata (1958) etc.
<i>Fannia prisca</i> (Stein)	C	⊙		⊙						Nezu and Matsushashi (1960)
<i>Fannia scalaris</i> (Fabricius)	C								○	Ishijima (1967)
<b>Muscidae</b>										
<i>Muscina angustifrons</i> (Loew)	FC?				⊙					Niko and Ogata (1958) etc.
<i>Muscina stabulans</i> (Fallén)	FC	⊙	⊙	⊙	⊙	⊙			⊙	Nezu and Matsushashi (1960) etc.
<i>Azelia cilipes</i> (Haliday)	FC	⊙						⊙		Nishijima and Iwasa (1984) etc.
<i>Azelia monodactyla</i> (Loew)	FC		⊙							Iwasa and Watanabe (2007)
<i>Hydrotaea albipuncta</i> (Zetterstedt)	OC	⊙								Iwasa (1980a)
<i>Hydrotaea chalcogaster</i> (Wiedemann)	FC?⊙			⊙	⊙				⊙	Suenaga (1959) etc.
<i>Hydrotaea ignava</i> (Harris)	OC	⊙	⊙	⊙	⊙				○	Iwasa and Watanabe (2007)
<i>Hydrotaea meteorica</i> (Linnaeus)	OC	⊙								Iwasa (1980a) etc.
<i>Hydrotaea parva</i> (Meade)	OC?		⊙							Iwasa and Watanabe (2007)
<i>Huckettomyia watanabei</i> Pont et Shinonaga	FC							⊙		Nishijima and Iwasa (1984)
<i>Mesembrina resplendens</i> (Wahlberg)	C							⊙		Nishijima and Iwasa (1979)
<i>Polietes domitor</i> (Harris)	FC		⊙							Iwasa and Watanabe (2007)
<i>Polietes nigrolimbatus</i> (Bonsdorff)	C?⊙									Iwasa (1980a)
<i>Musca bezzii</i> (Patton et Cragg)	C	⊙								Iwasa et al. (2005a, b)
<i>Musca conducens</i> (Walker)	C	⊙								Shinonaga (2003)
<i>Musca confisicata</i> (Speiser)	C	⊙								Shinonaga (2003)
<i>Musca convexifrons</i> (Thomson)	C	⊙								Shinonaga (2003)
<i>Musca crassirostris</i> (Stein)	C	⊙								Shinonaga (2003)
<i>Musca domestica</i> (Linnaeus)	C	⊙	⊙	⊙	⊙					Suenaga (1959) etc.
<i>Musca hervei</i> (Villeneuve)	C	⊙								Shinonaga (2003)
<i>Musca sorbens</i> (Wiedemann)	C	⊙								Shinonaga (2003)
<i>Musca tempestiva</i> (Fallén)	C	⊙								Shinonaga (2003)
<i>Musca ventrosa</i> (Wiedemann)	C	⊙								Shinonaga (2003)
<i>Morellia aenescens</i> (Robineau-Desvoidy)	C	⊙								Shinonaga (2003)
<i>Morellia asetosa</i> (Baranoff)	C	⊙								Shinonaga (2003)
<i>Morellia hortensia</i> (Wiedemann)	C	⊙								Shinonaga (2003)
<i>Morellia hortorum</i> (Fallén)	C	⊙								Shinonaga (2003)
<i>Neomyia coeruleifrons</i> (Macquart)	C	⊙								Shinonaga (2003)
<i>Neomyia cornicina</i> (Fabricius)	C	⊙								Iwasa et al. (2005a, b)
<i>Neomyia indica</i> (Robineau-Desvoidy)	C	⊙								Shinonaga (2003)
<i>Neomyia lauta</i> (Wiedemann)	C	⊙								Shinonaga (2003)

Table 1. (Continued)

Fly species	Species of animals								References				
	Cow		Horse		Pig		Chicken			Dog	Brown bear	Human	
	D	M	D	D+M	M	D	D	D		D			
	FH												
<i>Neomyia laevifrons</i> (Loew)	C	⊙										Shinonaga (2003)	
<i>Neomyia timorensis</i> (Robineau-Desvoidy)	C	⊙										Shinonaga (2003)	
<i>Pyrellia vivida</i> Robineau-Desvoidy	C	○		⊙								Iwasa and Watanabe (2007)	
<i>Eudasyphora cyanicolor</i> (Zetterstedt)	C	⊙										Shinonaga (2003)	
<i>Eudasyphora tateyamensis</i> (Shinonaga)	C									⊙		Nishijima and Iwasa (1979)	
<i>Haematobia irriatans</i> (Linnaeus)	C	⊙										Suenaga (1959)	
<i>Haematobosca sanguinolenta</i> (Austen)	C	⊙										Shinonaga (2003)	
<i>Stomoxys calcitrans</i> (Linnaeus)	C	⊙	⊙	⊙	⊙							Suenaga (1959) etc.	
<i>Helina deleta</i> (Stein)	OC?	⊙								⊙		Nishijima and Iwasa (1979) etc.	
<i>Helina impuncta</i> (Fallén)	OC?	○										Iwasa (unpubl. data)	
<i>Helina quadrum</i> (Fabricius)	OC?	○										Iwasa (unpubl. data)	
<i>Helina reversio</i> (Harris)	OC?	⊙										Iwasa and Watanabe (2007)	
<i>Brontaea ascendens</i> (Stein)	OC	⊙										Iwasa (1983)	
<i>Brontaea ezensis</i> (Shinonaga et Kano)	OC			⊙								Iwasa (1983)	
<i>Brontaea flexa</i> (Wiedemann)	OC?	○										Shinonaga (2003)	
<i>Brontaea humilis</i> (Zetterstedt)	FC			○								Iwasa (1983)	
<i>Brontaea lasiopa</i> (Emden)	OC	○										Iwasa (1983)	
<i>Brontaea nigrogrisea</i> (Karl)	OC	○										Iwasa (1983)	
<i>Brontaea tohokuensis</i> (Shinonaga et Kano)	OC			⊙								Iwasa (1983)	
<i>Mydaea urbana</i> (Meigen)	OC	⊙										Iwasa et al.(2005b)	
<i>Myospila bina</i> (Wiedemann)	OC	○										Iwasa (1984b)	
<i>Myospila laevis</i> (Stein)	OC	○									○	Iwasa (1984b) etc.	
<i>Myospila lenticeps</i> (Thomson)	OC?	○										Shinonaga (2003)	
<i>Myospila mediatubunda</i> (Fabricius)	OC	⊙			⊙							Iwasa (1984b) etc.	
<i>Myospila pudica</i> (Stein)	OC?	○										Shinonaga (2003)	
<i>Hebecnema fumosa</i> (Meigen)	OC	⊙										Nezu and Matsushashi (1960)	
<i>Hebecnema umbratica</i> (Meigen)	OC	⊙										Iwasa et al. (2005a, b)	
<i>Graphomya maculata</i> (Scopoli)	OC										○	Hori (1953)	
Calliphoridae													
<i>Aldrichina grahami</i> (Aldrich)	S, C											⊙	Kano and Shinonaga (1968) etc.
<i>Calliphora nigribarbis</i> Vollenhoven	S, C							⊙				⊙	Niko and Ogata (1958) etc.
<i>Calliphora vomitoria</i> (Linnaeus)	S, C											⊙	Kano and Shinonaga (1968) etc.
<i>Triceratopyga calliphoroides</i> Rohdendorf	S											○	Hori (1953)
<i>Lucilia caesar</i> (Linnaeus)	S											○	Hori (1953)
<i>Lucilia illustris</i> (Meigen)	S	⊙										○	Suenaga (1959) etc.
<i>Lucilia papuensis</i> (Macquart)	S											○	Hori (1953)
<i>Lucilia sericata</i> (Meigen)	S					⊙						○	Suenaga (1959) etc.
<i>Lucilia cuprina</i> (Wiedemann)	S											○	Hori (1953)
<i>Hemipyrellia ligurriens</i> (Wiedemann)	S					⊙						○	Suenaga (1959) etc.
<i>Chrysomya pinguis</i> (Walker)	S					⊙							Nezu and Matsushashi (1960)
Sarcophagidae													
<i>Parasarcophaga melanula</i> (Meigen)	S, C				⊙	⊙	⊙					⊙	Suenaga (1959) etc.
<i>Parasarcophaga albiceps</i> (Meigen)	S, C	⊙			⊙		⊙					⊙	Suenaga (1959) etc.
<i>Parasarcophaga misera</i> (Walker)	S											○	Hori (1953)
<i>Parasarcophaga similis</i> (Meade)	S				○							○	Hori (1953) etc.
<i>Boettcherisca peregrina</i> (Robineau-Desvoidy)	S, C				⊙	⊙	⊙					⊙	Suenaga (1959)
<i>Ravinia striata</i> (Fabricius)	S, C	⊙			⊙	⊙							Iwasa et al. (2005a, b) etc.

*skalomyza hasegawai* Kurahashi feed on cow dung and grew to mature larvae as coprophagous, but they easily did not pupariate (Iwasa, 2002); this species is rarely found on cow droppings in forested area around the pasture in northern Japan, but its true breeding medium is unknown.

**Scathophagidae.** *Scathophaga stercoraria* (Linnaeus), *S. scybalaria* (Linnaeus), *S. suilla* (Fabricius) and *S. mellipes* (Coquillett) breed in cow droppings (Suenaga, 1959; Sasaki, 1980; Iwasa and Watanabe, 2007). *Scathophaga mellipes* was also bred from dog feces (Suenaga, 1959). These larvae are coprophagous, but adults are known to be predacious (Hammer, 1941).

**Anthomyiidae.** *Anthomyia illocata* Walker occurred from dung or feces of chickens, dogs, cats, goats, and humans (Niko and Ogata, 1958; Suenaga, 1959), showing adaptation to many kinds of animal dung. *Emmesomyia villica* (Meigen), *E. oriens* Suwa and *E. hasegawai* Suwa, and *Paregle cinerella* (Fallén) are probably specific to cow droppings. *Lasiomma iwasai* Suwa and *L. octoguttatum* (Zetterstedt) emerge from wild brown bear dung (Nishijima and Iwasa, 1979). Collin (1939) reared *L. octoguttatum* from the nests of birds. These *Lasiomma* species may utilize wild animal dung or feces in forested area.

**Fanniidae.** Several common *Fannia* species are known to develop in a wide range of different substrates such as decaying fungi and vegetables, bird nests, and burrows of Hymenoptera, dung, manure, and feces (Chillcott, 1961; Ferrar, 1987). *Fannia canicularis* (Linnaeus) has occurred in chicken and pig dung (Niko and Ogata, 1958; Nezu and Matsushashi, 1960), while *F. scalaris* (Fabricius) was observed in outdoor toilets (Ishijima, 1967). Nezu and Matsushashi (1960) confirmed the occurrence of *F. prisca* (Stein) from cow and pig dung. In Japan, cattle dung and human feces comprise only some of breeding media for these common

*Fannia* species.

**Muscidae.** *Muscina stabulans* (Fallén) is known to occur from a wide variety of breeding sources, and the larvae are facultative carnivores (Skidmore, 1985). This species occurs in Japan from dung of all animals except for brown bear (Niko and Ogata, 1958; Suenaga, 1959; Nezu and Matsushashi, 1960; Ohtaki et al., 1964). *Muscina angustifrons* (Loew) was bred from chicken dung in small numbers (Niko and Ogata, 1958), but the larvae were observed to develop in mushrooms (Shinonaga and Mitsui, 1993; Akaishi and Nakamura, 2005); therefore, this species may not be a true dung breeder, and the larvae are suspected to be carnivorous. *Azelia cilipes* (Haliday) emerges from cow droppings (Iwasa and Watanabe, 2007), and also from brown bear dung (Nishijima and Iwasa, 1984). Its larvae are facultative carnivores (Skidmore, 1991). *Azelia monodactyla* (Loew) frequents horse dung (Shinonaga et al., 1975) and actually emerges from horse dung (Iwasa and Watanabe, 2007); so it is a horse dung breeder, and the larvae may be facultative carnivores. *Hydrotaea albipuncta* (Zetterstedt) and *H. meteorica* (Linnaeus) breed in cow droppings; their larvae are obligative carnivores (Iwasa, 1980a; Iwasa and Watanabe, 2007). *Hydrotaea ignava* (Harris) and *H. chalcogaster* (Wiedemann) breed in a wide range of animal dung, but they apparently prefer pig and chicken dung (Suenaga, 1959; Oshio et al., 1962; Iwasa and Watanabe, 2007). *Hydrotaea parva* Meade and *Pyrellia vivida* Robineau-Desvoidy are specific to horse dung (Shinonaga, 2003; Iwasa and Watanabe, 2007); the larvae of the former are probably carnivorous. *Brontaea ascendens* (Stein) and *B. ezensis* (Shinonaga et Kano) breed in cow droppings and horse dung, respectively (Iwasa, 1983). In addition, *B. flexa* (Wiedemann), *B. lasiopa* (Emden) and *B. nigrogrisea* (Karl) were collected on cow droppings (Iwasa, 1983; Shinonaga, 2003) and were found to breed in them. The larvae of all *Brontaea* are obligative carni-

vores (Iwasa, 1983; Ferrar, 1987). *Mesembrina resplendens* Wahlberg, *Eudasyphora tateyamensis* (Shinonaga), and *Hucketomyia watanabei* Pont et Shinonaga emerge from wild brown bear dung; the former two species are coprophagous, and the latter one is a facultative carnivore (Nishijima and Iwasa, 1979, 1984; Iwasa and Nishijima, 1984). These three species may be specific to brown bear dung in forested areas. *Polietes domitor* (Harris) is specific to horse dung in Japan (Iwasa and Watanabe, 2007); the larvae of *P. domitor* are known to be obligative carnivores (Portchinsky, 1910). The larvae of *Polietes nigrolimbatus* (Bonsdorff) breeds in cow droppings and are coprophagous (Iwasa, 1980a), but further observation on food habits may be needed. *Musca* species prefer cow droppings, except for *M. domestica* (Linnaeus) which breeds in cow manure and dung of other animals. *Morellia* and *Neomyia* species also prefer cow droppings, and their larvae are coprophagous (Shinonaga and Kano, 1973, 1974b). *Helina deleta* (Stein) and *H. reversio* (Harris) emerge from cow droppings; the former was bred also from wild brown bear dung (Nishijima and Iwasa, 1979; Iwasa and Watanabe, 2007). According to Skidmore (1991), *H. impuncta* (Fallén) and *H. quadrum* (Fabricius) are members of the cow-dropping community but only very rarely, and the larvae are obligative carnivores. In Japan, also these two species are observed uncommonly on cattle droppings (Iwasa, unpubl. data), but their detailed biology is unknown. Almost all species of *Myospila* probably prefer cow droppings, but *M. laevis* (Stein) is attracted to human feces. Its larvae are carnivorous (Iwasa, 1984b). *Mydaea urbana* (Meigen), *Hebecnema fumosa* (Meigen) and *H. umbratica* (Meigen) also breed in cow droppings in Japan (Nezu and Matsushashi, 1960; Iwasa et al., 2005a, b), and the larvae of *Mydaea* and *Hebecnema* are recognized obligative carnivores (Hammer, 1941).

**Calliphoridae.** According to Kano and

Shinonaga (1968), *Aldrichina grahami* (Aldrich), *Calliphora nigribarbis* Vollenhoven, and *C. vomitoria* (Linnaeus) breed in human feces. *Calliphora nigribarbis* was also bred from chicken dung (Niko and Ogata, 1958). Hori (1953) observed that *Triceratopyga calliphoroides* Rohdendorf, *Lucillia caesar* (Linnaeus), and *L. papuensis* (Macquart) were attracted to human excrement, but there is no information on their growth from it. *Lucillia illustris* (Meigen) was bred from cow dung and *Lucillia sericata* (Meigen), *Hemipyrellia ligurriens* (Wiedemann), and *Chrysomya pinguis* (Walker) were bred from pig dung (Suenaga, 1959). Probably none of the larvae in this family are true dung breeders.

**Sarcophagidae.** *Parasarcophaga albiceps* (Meigen) and *P. melanura* (Meigen) are common dung breeders and emerge from dung of cows, pigs, dogs, cats, and human feces (Suenaga, 1959). *Boettcherisca peregrina* (Robineau-Desvoidy) is a common dung and carrion breeder and was bred from dung of pigs, goats, chickens, dogs, and human feces (Niko and Ogata, 1958; Suenaga, 1959; Nezu and Matsushashi, 1960; Oshio et al., 1962). According to Ishijima (1967) and Kano et al. (1967), *Parasarcophaga misera* (Walker) and *P. similis* (Meade) breed in human feces, but they may be not true dung breeders. *Ravinia striata* (Fabricius) breeds in droppings of cows, pigs, and horses (Iwasa et al., 2005a, b; Iwasa and Watanabe, 2007), are more prevalent in cow droppings.

**Other families.** Other dipterous families such as Ceratopogonidae, Chironomidae, Sciariidae, Empididae, and Phoridae etc. apparently occurred from cow droppings in comparatively large numbers (Iwasa et al., 2005a, b), but they were excluded in this paper because their specific names are not determined yet.

#### GENERAL DISCUSSION

**Cow dung.** Cow dung is roughly divid-

ed into two groups: droppings in pastures and manure (piles) in the vicinity of barns. Cow droppings yielded the most variety of species and largest numbers among various types of animal dung (Skidmore, 1991). Hammer (1941) reported 64 species of flies associated with cow droppings in Denmark. In the USA., 46 and 48 species of the flies were reared from cow droppings in southeastern Washington (Coffey, 1966) and in northern California (Poorbaugh et al., 1968), respectively. In Japan, Suenaga (1959) reared 11 species of flies from cow droppings in Nagasaki, but acalypterate flies were excluded. Iwasa and Watanabe (2007) confirmed the occurrence of 44 species of flies from cow droppings in Hokkaido, finding that they were composed of many Palaearctic members inhabiting cow droppings in Europe and a few East-Asian species. Merritt (1976) pointed out that there were only a few predacious fly larvae in cow droppings in California in contrast to northern Europe where Hammer (1941) investigated. Anderson and Poorbaugh (1968) implied a relationship between fewer numbers of horn flies (*Haematobia irritans*) and face flies (*Musca autumnalis*) in Europe with higher levels of predacious fly larvae, as compared to the situation in the USA where there are fewer species of predacious larvae and higher populations of pestiferous flies. In Hokkaido, the species composition of predacious fly larvae inhabiting cow droppings, represented by *Hydrotaea albipuncta* (Zetterstedt), *H. meteorica* (Linnaeus), *Myospila mediatribunda* (Fabricius), and *Hebecnema umbratica* (Meigen), resembles that of northern Europe. However, fly fauna in cow droppings differ from location to location even in Japan. Throughout Japan, obligative or facultative carnivorous fly larvae make up over 30% in Muscidae that inhabit cow droppings (Table 1). Further investigation is required for the prey-predator relationships among larvae in cow droppings in each locality.

In Japan, Oshio et al. (1962) confirmed

that *Musca domestica* Linnaeus and *Stomoxys calcitrans* (Linnaeus) were the predominant flies that emerged from cow manure near a barn, showing a considerably different comparison of fly fauna from that of cow droppings in pastures. Surveys on acalypterate flies in cow manure still need to be done.

**Horse dung.** Skidmore (1991) listed British dipterous flies associated with horse dung, showing that Sphaeroceridae and Muscidae were well represented. In Japan, Iwasa and Watanabe (2007) bred 23 species of flies from horse dung in Hokkaido; the fauna is also well represented by Sphaeroceridae and Muscidae and is composed of the widespread Palaearctic species and two endemic species, *Brontaea ezensis* (Shinonaga et Kano), and *B. tohokuensis* (Shinonaga et Kano). Of ten muscid species bred in horse dung in Japan, the larvae of seven species are obligative or facultative carnivores; they probably feed on small coprophagous larvae such as Sphaeroceridae.

Hafez (1939) noted that horse and pig dung are favorable breeding media for *M. domestica* and *S. calcitrans*. Siverly and Schoof (1955a) also showed that *M. domestica* was the most abundant of the flies emerging from horse dung. In a comparative study of the flies associated with various dung of cattle (Coffey, 1966), however, no *M. domestica* emerged from horse dung. In a survey of the flies emerging from horse dung in Hokkaido (Iwasa and Watanabe, 2007), very few *M. domestica* and *S. calcitrans* were found, whereas, Oshio et al. (1962) reported that the numbers of *M. domestica* were the second most abundant in horse dung among the flies that emerged from dung of cows, horses, pigs and goats. Oshio et al. (1962) also found that the emergence of the flies increased in the case of dung mixed with feeds compared to that of dung alone. Faunal composition of flies on horse dung is largely affected by various conditions such as localities, weather, fecal composition, water content of dung, and the pres-

ence of other animal dung.

**Pig dung.** Coffey (1966) reared 25 species of flies from pig dung; the most abundant species was *Leptocera exiquella* Spuler Complex, followed by *Paregle cinerella* (Fallén), *M. domestica*, and *Ravinia lherminieri* (Robineau-Desvoidy). In Japan, Suenaga (1959) reported that the most abundant species emerging from pig dung was *Ptecticus tenebrifer*, followed by *Parasarcophaga melanura* (Meigen), *Hydrotaea chalcogaster*, and *Parasarcophaga albiceps*. It has been reported that pig dung yielded large numbers of *M. domestica* and *S. calcitrans* (Nezu and Matsushashi, 1960; Oshio et al., 1962). Iwasa and Watanabe (2007) reared 23 species of flies from pig dung in Hokkaido; the most abundant was *Sepsis latiforceps*, followed by *M. domestica*, *Opalimosina mirabilis* (Collin), and *Spelobia bifrons* (Stenhammar). They also found that some sphaerocerid flies from pig dung are common to those from cow and horse droppings, whereas, some species of Muscidae and Sarcophagidae that emerge from pig dung are also found in chicken dung and human excrement. It will also be noticed that some calliphorid flies coincidentally occur from pig dung.

**Chicken dung.** It has been reported in the USA that chicken dung yielded *M. domestica*, *Muscina stabulans* and *Fannia canicularis* (Siverly and Schoof, 1955a; Coffey, 1966). In Japan, Ohtaki et al. (1964) reported that *Muscina stabulans* was the most abundant in a survey of pesticide control tests in poultry farms. Niko and Ogata (1958) reared 15 species of flies from chicken dung, finding that the most predominant species was *Fannia* sp. 1, followed by *Tephroclamys japonica* Okadome (as *Tephroclamys* sp.), *Ptecticus tenebrifer*, *Fannia* sp. 2, *S. calcitrans*, *Hydrotaea ignava*, and *Calliphora nigribarbis*. Howard (1900) noted that *Calliphora* species gather on human excrement, but they are not true excrement flies. It is noteworthy that *C. nigribarbis* occurs in chicken dung in Japan, because

of recent report of avian influenza virus isolated from the adult of this fly (Sawabe et al., 2006). Suenaga (1959) also confirmed the occurrence of 9 species of the flies from chicken dung: in order of greatest abundance, *Heleomyza eoa*, *Hydrotaea chalcogaster*, *S. calcitrans*, and *M. domestica*. In addition, some species of Heleomyzidae and Fannidae apparently have a preference for chicken dung. Though no detailed survey has been done on the occurrence of acalypterate flies such as Sepsidae and Sphaeroceridae, fly fauna of chicken dung is similar to that of pig dung. This may be due to similar food habits of both animals, they are both omnivorous.

**Dog feces.** Dog feces is generally important as a breeding source of flies in urban areas. Of the previous surveys of flies that emerge from dog feces, *Sarcophaga* spp. were predominant in West Virginia (Schoof et al., 1954) and Arizona (Siverly and Schoof, 1955a), USA. Wilton (1963) showed that *M. domestica*, *M. sorbens* Wiedemann, and *Sarcophaga occidua* (Fabricius) comprise 99% of the total numbers reared from dog feces in Honolulu, Hawaii. Poorbaugh and Linsdale (1971) bred 15 species of flies from dog feces in California, finding *Hylemya radicum* (Linnaeus) to be the most predominant species, followed by *Hylemya nidicola* Aldrich and *Ravinia sueta* (Wulp). In Nagasaki, southern Japan, Suenaga (1959) reared eight species of flies from dog feces, showing that *Parasarcophaga melanura* was the most abundant, followed by *Parasarcophaga albiceps* (Meigen) and *Scathophaga mellipes*. Larviparous sarcophagid flies whose larvae apparently develop rapidly could adapt to small feces of dogs, so desiccation of feces is not a serious growth inhibiting factor. Flies emerging from dog dung also have a wide geographic range and are common to those from human feces and other animal dung, carrion, garbage, etc., exhibiting some versatility in the utilization of different types of media.

**Human feces.** Howard (1900) bred 36 fly species belonging to 16 families from human excrement in California, well represented by Anthomyiidae, Muscidae, and Sarcophagidae. In Japan, Suenaga (1959) confirmed the occurrence of seven species of flies from human excrement; *Parasarcophaga melanura* was the most abundant, followed by *Hydrotaea chalcogaster*, *Parasarcophaga albiceps*, *Ptecticus tenebrifer*, *Muscina stabulans*, *Anthomyia illocata* and other species. These species almost always also occur from dung of pigs, chickens, and dogs, showing these flies have a preference for dung of omnivorous animals.

**Brown bear dung.** Fourteen species of flies emerged from dung of wild brown bears, *Ursus arctos yesoensis* Lydekker in Hokkaido, Japan (Nishijima and Iwasa, 1979, 1984). Of these, *Mesembrina resplendens*, *Huckettomyia watanabei*, and *Pyrellia tateyamensis* were recorded also from dung of Asiatic black bears, *Ursus thibetanus japonicus* Schlegel which live mainly in Honshu, Japan (Shinonaga, 2003). Dung pats of wild bears in forested area are important breeding sources for these medium- to large-size flies. Flies associated with brown bear dung inhabit forested areas, but *Sepsis latiforceps*, *Azelia cilipes*, and *Helina deleta* also occurred from cow droppings (Iwasa and Watanabe, 2007), so they can inhabit natural forests and livestock areas, perhaps traveling to and from both types of environments.

#### ACKNOWLEDGEMENTS

I thank Drs. Shinonaga of Tokyo Medical and Dental University, T. Hayashi and H. Kurahashi of the National Institute of Infectious Diseases, K. Nishida of Kobe Institute of Health, H. Sasaki of Rakuno Gakuen University, T. Okadome of Meijyo University, and Ms. T. Watanabe of the University of Tokyo for their kindness in offering valuable information. My thanks are also due to Assistant Prof. G. A. Hill of

Obihiro University of Agriculture and Veterinary Medicine for checking the English of this manuscript.

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