16. Houseflies, annoying and dangerous

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Abstract

Musca domestica (Diptera: Muscidae), the common housefly, is found in close conjunction with humans and their livestock around the world. The flies cause annoyance to people and are vectors of several diseases. Commonly-used control methods (cultural, chemical, biological, traps and baits) do not result in reducing fly populations to acceptable levels. Research on integrated control approaches is required. Models based on expected climate changes predict a substantial increase in fly populations over the next decades, which may result in a considerable expansion in the incidence of fly-borne diseases, thereby endangering health and well-being of people globally. This strengthens the need for intensive studies on the behaviour, ecology, and vectorial capacity of houseflies.

Keywords: *Musca domestica*, common housefly, biology, behaviour, ecology, pest, control

Introduction

Musca domestica L. (Diptera: Muscidae), the common housefly, is one of the most widespread fly species in the world. The insect belongs to a group of domestic flies often called 'filth flies'. *M. domestica* is an eusynanthropic, endophilic species, i.e. it lives closely with humans and is able to complete its entire life-cycle within residences of humans and their domestic animals. The fly can be found in human dwellings, in dairies, poultry houses, horse stables, food processing factories, landfills, and in other domesticated areas and buildings (Hewitt 1910, 1912, West 1951, Hansens 1963, Lillie and Goddard 1987, Axtell and Arends 1990, Kettle 1995, Howard 2001, Steenberg and Jespersen 2002, Lole 2005).

Biology

M. domestica is a non-biting fly that undergoes a complete metamorphosis in its development from egg to adult. Its developmental time depends on food availability and temperature, and may take as little as 10 days. The reproductive potential of the flies is very high. A female may lay four to six batches of eggs consisting of 75 to 150 eggs each at three- to four-day intervals. The pearly white, ca. 1.2 mm long eggs are deposited in clumps in cracks and crevices of a moist medium to protect them from desiccation. Manure and food waste are known to be the principal breeding media for houseflies. The eggs hatch within 24 hours after oviposition. The whitish, legless, saprophagous larvae (maggots) develop through three larval stages within approximately a week. Fully-grown larvae migrate to drier conditions and bury themselves into the substrate where they pupate. After approximately 5 days, the adults, about 7 mm long, emerge from the reddish brown or almost black puparia. Females are usually bigger than males. The sexes can easily be distinguished by the dorsal space between the eyes which is wider in females. Adult houseflies may live 15 to 30 days (Hewitt 1910, 1912, West 1951, Kettle 1995, Anonymous 2000, Steenberg and Jespersen 2002). Males may already mate on the day of their emergence. Mating readiness of females which, contrary to males, are monogamous, is highest when they are three days old (Saccà 1964). Oviposition takes place a few days after copulation. Overwintering occurs in the larval or pupal stage (Hewitt 1910, 1912, West 1951, Kettle 1995).

During warm weather the life cycle, from egg to egg, takes two to three weeks. Because of this high rate of development and the large numbers of eggs produced by a female, large populations can rapidly build up. In temperate regions of the world ten to twelve generations a year may occur. In colder regions breeding is restricted to the warmer months, resulting in four to six generations a year (Hewitt 1910, 1912, West 1951, Barnard and Geden 1993, Kettle 1995). Organic waste materials and the relatively high temperatures in livestock farms promote rapid development and continuous presence of flies (Howard and Wall 1996b).

The activity of adult houseflies is affected by several physical variables such as temperature, humidity, light intensity, air currents, barometric pressure, and electrostatic fields. The flies are diurnal and are more active when temperature is high and humidity low, but they tend to become sluggish when both temperature and humidity are high. They remain active at lower temperatures down to about 7 °C, regardless of humidity; their activity optimum lies around 33 °C. Near 45 °C symptoms of heat paralysis become evident (West 1951, Kettle 1995). Although insects are usually tolerant of variations in barometric pressure which occur in their home range, their activities may be markedly affected by abrupt barometric changes. Flight activity of houseflies has been seen to increase instantaneously when a storm approaches and there is a rapid fall in atmospheric pressure (West 1951). Electric fields also affect the behaviour of insects and have been shown to deter houseflies and change their circadian rhythm of locomotion (Perumpral *et al.* 1978, Engelmann *et al.* 1996, McGonigle and Jackson 2002).

The flies are positively anemotactic, i.e. they tend to fly upwind possibly induced by airborne odours which direct them towards suitable food or oviposition substrates. Flight velocity is about 2 m/s (West 1951).

Houseflies as a pest

Houseflies are usually found within 500 m from a breeding source but are able to disperse over distances up to 30 kilometres. They are a nuisance to people living near breeding sites, resulting in poor community relations and legal conflicts; they irritate people and animals by flying around or landing on them or on their food and leave regurgitation and faecal spots on surfaces (Anonymous 2000, Hinkle 2002, Steenberg and Jespersen 2002, Winpisinger *et al.* 2005). High population densities of houseflies in poultry farms may cause nuisance to such an extent that chickens reduce their egg production. Furthermore, the faeces of houseflies decreases the aesthetic appearance and value of the eggs (Howard and Wall 1996b). Economical losses caused by *M. domestica* in poultry houses are reported to exceed 60 million US dollars per year in the United States (Anonymous 1976). These losses do not at all counterbalance the fact that the flies may serve as a protein source for chickens (Ocio *et al.* 1979, El Boushy 1991).

In addition to causing annoyance, houseflies may be vectors of several diseases. Their movements between human and animal food, organic waste, garbage, faeces, manure, and other sources of filth on which they may feed and breed make them ideal transmitters of human and animal pathogens. About a hundred different pathogen species have been found in and on houseflies. The flies may transmit pathogens in different ways. The surface of their body, particularly the legs and proboscis, may be contaminated; and because houseflies suck food after it has been liquefied in regurgitated saliva, pathogens may be deposited onto food with the vomit drops. Thirdly, pathogens may pass through the gut of the flies and be deposited with their faeces. Washes from the surface of houseflies yielded total bacterial counts from 2.5 to 29.5 million per fly and in the digestive system the presence of 84 thousand to 2 million bacteria per fly was demonstrated (Ostrolenk and Welch 1942).

Pathogens that may be transmitted by houseflies are, for example, viruses causing diarrhoea, cholera bacteria, *Salmonella* spp. and *Escherichia coli* bacteria causing enteric infections, haemolytic streptococci, and agents of typhoid, diphtheria, tuberculosis, leprosy and yaws. In addition, they may carry cysts of Protozoa, including those causing amoebic dysentery, and the eggs of nematodes. A relation between the necrotic enteritis causing bacteria *Clostridium perfringens* isolated from houseflies and an increase in chicken mortality has recently been suggested by Dhillon *et al.* (2004). Flies are also suspected to transmit the bacteria *Campylobacter jejuni* to chickens (Hald *et al.* 2004). Every year millions of people in Europe are seized by severe gastro-enteritis caused by this bacterium. Finally, houseflies may be vectors and intermediate hosts of certain cestodes of poultry and nematodes of horses (Hewitt 1910, 1912, Ostrolenk and Welch 1942, West 1951, Saccà 1964, Kettle 1995, Grübel *et al.* 1997, Tan *et al.* 1997, Kurahashi *et al.* 1998, Li and Stutzenberger 2000, Sasaki *et al.* 2000, Fotedar 2001, Howard 2001, Steenberg and Jespersen 2002, Graczyk *et al.* 2005, Kinde *et al.* 2005, Barro *et al.* 2006). Fly larvae have also been found to carry pathogenic bacteria, both externally and internally (Banjo *et al.* 2005).

Control of houseflies

Several techniques are used to control houseflies. Screening of windows and doors with gauze screens is an effective method of preventing houseflies from entering buildings. By establishing air currents in doorways houseflies can also be kept outside (Carlson *et al.* 2006). Proper management of locations where manure or garbage is present may prevent fly infestation. Outdoors and indoors baits and traps, and chemical and biological methods are used to reduce fly populations to acceptable levels.

Cultural control

Removal, sanitation and ventilation of possible breeding sites are probably the most effective control methods. Moist manure is highly attractive to female houseflies (Smallegange 2003) and provides a good breeding and feeding site for larvae (Achiano and Giliomee 2005). Hence, regular removal of manure in poultry houses, diaries, pig-sties and horse stables is advisable. Dry manure does not only prevent oviposition and larval development but also favours the development of housefly predators and parasitoids. Ventilation systems that control temperature may be used to create an airflow over the manure surface to facilitate drying. In addition this may diminish oviposition in the manure because houseflies avoid relatively strong air currents (Geden *et al.* 1999).

Garbage containers should have tight-fitting lids and should be cleaned regularly. Manure and spilled feed have to be removed at least twice a week and waste disposal sites covered with a layer of soil or other inorganic material every week (Kettle 1995, Anonymous 2000, Hinkle 2002, Steenberg and Jespersen 2002).

Traps and baits

A simple way to catch flies indoors is the use of sticky papers suspended from the ceiling or a lamp. However, apart from their unaesthetic appearance, they are unhygienic and not suitable for controlling fly pests. Large sticky traps may be effective for application at farms, but their use is often limited because of rapid accumulation of dust on the sticky material (Kaufman *et al.* 2001, 2005b). Despite their disadvantages, sticky traps are commonly used for indoor monitoring purposes (see Chapter 19; Geden *et al.* 1999, Kaufman *et al.* 2001, 2005b, Cornelius 2002, Jacobs *et al.* 2003, Lole 2005).

Light sources attract flies and other insects. Sources emitting light in the ultraviolet (UV: emittance peaks below 400 nm) attract much higher numbers of houseflies than light sources emitting wave lengths longer than 400 nm; within the UV region no preferences are found (Cameron 1938, Deay and Taylor 1962, Thimijan *et al.* 1973, Roberts *et al.* 1992, Smallegange 2003, Smallegange and Den Otter, unpublished data). Therefore, most commercially available light traps consist of UV lamps in front of which high-voltage electrocutor grids are mounted. However, outdoors and in illuminated areas the effectiveness of these traps is very low. In addition, we found that flies younger than 3 days of age are hardly or not at all attracted to the light. Even in a dark chamber only a maximum of 60% of the older flies is attracted to an UV lamp, which does not seem to be sufficient to reduce fly populations to acceptable levels (Smallegange 2003, Smallegange and Den Otter, unpublished data).

Since UV-light traps also attract other insect species, they often kill beneficial insects (Nabli *et al.* 1999, Mohan 2002). An additional disadvantage of electrocuting light traps is that bacteria and viruses present on the flies' bodies are spread into the air upon electrocution of the flies (Urban and Broce 2000). Moreover, enteric bacteria may survive to up to five weeks after the flies have been killed (Cooke *et al.* 2003). This implies that the traps should be designed in such a way that all parts of the electrocuted flies stay in or on the trap and cannot disperse from it into the surroundings. In addition, the traps should be emptied on a regular basis.

Oviposition substrates and food sources, especially putrefying and fermenting substances emanating amines, aldehydes, ketones and alcohols, and dairy products and sugar-containing substances have been shown to attract houseflies (Awati and Swaminath 1920, Brown *et al.* 1961, Künast and Günzrodt 1981, Skoda and Thomas 1993 in Cossé and Baker 1996, Smallegange 2003, Smallegange and Den Otter, unpublished data). However, commercially available baits show variable and often contradictory results (Browne 1990). This may result from the fact that in areas where houseflies are usually found, the flies are confronted with several olfactory stimuli, which may influence the effectiveness of odour traps negatively. Moreover, the attractiveness of odour sources to the flies depends on the physiological state of the flies. Although, in contrast to UV traps, odour-baited traps are equally attractive to mature as well as young flies, male and female flies and food-deprived and well-fed flies may respond differently to odours (Smallegange 2003, Smallegange and Den Otter, unpublished data).

(Z)-9-tricosene has been identified as a component of the female sex pheromone of *M. domestica* (Carlson *et al.* 1971). This compound, also known as muscalure, has been found to be attractive not only to male, but also to female houseflies in laboratory and field trials (Carlson *et al.* 1971, Van Oosten and Persoons 1981, 1982, 1983, Chapman *et al.* 1998, 1999, Noorman 2001, Hanley *et al.* 2004). Muscalure is often used to lure houseflies to electrocuting light traps or to toxic targets, although it was shown to be only a weak and short-range attractant (Morgan *et al.* 1974, Fletcher and Bellas 1988, Smallegange 2003, Van Deventer and Griepink 2006). Furthermore, it was shown that a combination of UV light and attractive odours decreases the luring capacity of the odours considerably (Smallegange 2003, Smallegange and Den Otter, unpublished data).

Finally, electrostatic charge built up on traps may deter houseflies. It has been shown that in a choice chamber houseflies prefer an uncharged cage over a highly charged one (Perumpral *et al.* 1978, McGonigle and Jackson 2002).

Chemical control

Application of insecticides may initially be effective, but muscids, such as houseflies, readily develop resistance to persistent insecticides either because enzymes enable the flies to break down the insecticides or because behavioural adaptations enable the flies to avoid these substances (Scott and Georghiou 1985, Meyer *et al.* 1987, Kettle 1995, Pospischil *et al.* 1996, Keiding 1999, Anonymous 2000, Scott *et al.* 2000, Akiner and Çağlar 2006). Because only a limited number of genetic factors are involved in the development of resistance which are not strictly bound to specific molecules, cross resistance to novel insecticides exists (Plapp 1986). In addition, these substances are toxic to non-target, beneficial animals.

A higher specificity was aimed with the development of insect growth regulators (IGRs). IGRs show some selectivity (Miyamota *et al.* 1993) and can be divided into three categories: juvenile hormones which suppress metamorphosis, chitin synthesis inhibitors which disrupt moulting and pupation, and cyromazine which interferes with moulting by disrupting the sclerotisation process (Graf 1993, Howard and Wall 1996a). However, widespread resistance against IGRs has developed (Silhacek *et al.* 1976, Pap and Farkas 1994).

Not only the increase of tolerance and resistance of flies to insecticides but also the increasing costs of the use of insecticides and their toxicity to other organisms make them less desirable for fly control. Moreover, it appears to be difficult and expensive to develop new insecticides (Pickens and Miller 1987, Scott *et al.* 2000, Wall 2002).

Biological control

Many natural enemies may kill housefly eggs, larvae or adults: entomopathogenic fungi (e.g. *Entomophthora muscae*, *Beauveria bassiana*), bacteria (e.g. *Brevibacillus laterosporus*) and nematodes; parasitoids (e.g. *Muscidifurax raptorellus*, *Spalangia cameroni*); and predatory mites (e.g. *Macrocheles muscaedomesticae*), flies (e.g. *Hydrotaea aenescens*), beetles (histerid and staphylinid species), spiders and birds. Mites and beetles pray on eggs and first instar larvae, predatory fly larvae eat housefly larvae. Various parasitoids oviposit on fly pupae which serve as food for the parasitoid larvae. Bacteria and fungi may also reduce fecundity or longevity of *M. domestica* (Geden *et al.* 1993, Glofcheskie and Surgeoner 1993, Møller 1993, Kettle 1995, Farkas and Pap 1996, Geden 1999, Hogsette and Jacobs 1999, Skovgård and Jespersen 1999, Anonymous 2000, Hinkle 2002, Hogsette *et al.* 2002, Skovgård 2004, 2006, Skovgård and Nachman 2004, Kaufman *et al.* 2005a, Lecuona *et al.* 2005, Achiano and Giliomee 2006a, 2006b, Geden and Hogsette 2006, Rossi and Godoy 2006, Ruiu *et al.* 2006).

Several authors examined these biological agents for control purposes. It appeared that release of the fungus *E. muscae* does not significantly reduce housefly populations (Geden *et al.* 1993), possibly because female flies are hardly attracted to infected conspecifics (Møller 1993) and the flies readily recover from the infection at higher temperatures (Hajek and St Leger 1994). *B. bassiana* treatments seem to be more promising since they were found to be able to decrease fly numbers to a significantly greater extent than the insecticide pyrethrin (Kaufman *et al.* 2005a). Muscovy ducks may also significantly affect housefly populations (Glofcheskie and Surgeoner 1993). The usefulness of the dump fly, *H. aenescens*, appears questionable since it does not seem to be able to keep housefly populations low when no additional control methods are used. In addition, its establishment and development depend on manure type and moisture, and it is more susceptible to insecticides than *M. domestica* (Farkas and Pap 1996, Hogsette and Jacobs 1999, Hogsette *et al.* 2002). Likewise the efficiency of predatory mites and beetles, and parasitoids greatly depends on moisture, composition and location of the manure. Finally, the effectiveness of the pupal parasitoid *S. cameroni* in stables appears to have unpredictable and variable effects on housefly populations (Skovgård 2004, 2006, Skovgård and Nachman 2004, Geden and Hogsette 2006).

Since in several cases significant reductions of housefly populations with natural enemies have been achieved, biological control appears to be an efficient alternative for or addition to chemical control. It may be expected that combinations of natural enemies will be more successful when circumstances are heterogeneous (Geden 1999, Skovgård and Jespersen 1999, Achiano and Giliomee 2006b, Skovgård 2006). However, it is evident that more research is needed to be able to design effective control programmes adjusted to local demands.

Integrated control

Integrated control programmes consider all available control tactics and evaluate the interaction among them. They use cultural practices, traps, natural enemies, messenger chemicals, not individually exclusive but in the best combination imaginable. They may also use pesticides, but only after natural control factors indicate a need. The programmes are dynamic, and may vary from field to field, from year to year, because no two pest situations are the same. Hence, to achieve successful housefly reductions in locations with fly problems, it is advisable to combine (some of) the above mentioned strategies into an integrated programme. Which methods have to be used depends on the local situation, density and age composition of the fly population, the degree of annoyance, economic costs, and the availability of biological control agents. As for the latter, very moist manure, thorough removal of manure and short fly reproduction cycles hamper establishment of fly predators and parasitoids.

Computer simulation models and expert systems have been developed for pest population management, including housefly pests in livestock and poultry facilities. The programme Fly Management Simulator incorporates chemical control measures, manure manipulation, and housefly predators and parasitoids (Axtell 1999, see also http://cipm.ncsu.edu/ent/vetent/expert.html, accessed 29 August 2007).

To keep track of housefly population growth and to know when special measures are needed, several monitoring tools are available such as scudder grids, baited jug traps, spot cards, and various types of sticky traps (Pickens and Miller 1987, Axtell and Arends 1990, Axtell 1999, Anonymous 2000, Geden and Hogsette 2001, Anonymous 2003, Jacobs *et al.* 2003, Williams 2003, Geden 2005, 2006, Kaufman *et al.* 2005b, Lole 2005). These devices are described in more detail in Chapter 19.

Conclusion

Adult houseflies are not only annoying for people and animals but also carry many pathogens which may cause a reduction in animal production resulting in considerable financial losses.

Moreover, flies are involved in the transmission of human diseases. In spite of this, basic knowledge of fly behaviour, ecology and vectorial capacity is still lacking.

Worldwide much money is spent on filth fly control. However, more scientific studies should focus on this topic. Until now it is hardly understood why biological control of houseflies sometimes fails, and sometimes is successful. In-depth studies on putative biological control agents have never been undertaken. The effects of sanitation and manure manipulation have hardly been investigated; these methods are time-consuming and not always as effective as expected. So far, the impact of traps and baits on fly populations is not satisfactory. To increase their effectiveness, the effects of trap design and siting, and of various visual and olfactory attractants and repellents, should be investigated in more detail. The use of chemical insecticides is restricted and limited due to the development of resistance and the negative effects on beneficial arthropods. Research on integrated control is required. Geden and Hogsette (2001) published a list of recommended research topics for integrated control applications. In addition, a shift in mind-set of people dealing with housefly control may be necessary to get these programmes accepted. Also a better insight in intervention thresholds is required (Wall 2007).

In 1993 the European Union decreed (Directive 93/43/EEC) that member states should adopt the main principles of the so-called Hazard Analysis of Critical Control Points (HACCP). HACCP is a total quality management system for food safety which, if implemented fully, would result in a minimum level of food contamination (Howard 1999). This requires that insect pests have to be considerably reduced in number or even totally eliminated, because only one single insect may transmit pathogens. With the present control methods (local) elimination cannot be achieved.

It is now evident that global temperature is rising (IPCC 2007). Models based on expected climate changes predict a substantial increase in *M. domestica* populations in the next decades, which may result in a considerable expansion in the incidence of fly-borne diseases (Goulson *et al.* 2005). This will endanger health and life of people all over the world, which strengthens the need of intensive studies on houseflies, which are and will not only be annoying but also dangerous.

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