BIOLOGICAL CONTROL OF HOUSE FLIES

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Introduction

All animals are vulnerable to a variety of natural enemies, and the house fly is no exception. Mostly unaided and unnoticed by us, a community of natural biocontrol agents is constantly at work keeping fly populations at levels far below what they would be otherwise. Beetle and mite predators feed on fly eggs and larvae. Other fly species compete with the house fly for food. Larvae of some fly species (eg. *Ophyra*=black dump fly) attack larvae of the house fly, while others (*Hermetia illucens* = black soldier fly) modify the physical characteristics of the manure to render it unsuitable for house fly larvae. Nematodes can parasitize fly larvae, and parasitic wasps parasitize the pupae. If, in spite of all these obstacles, the fly makes it to the adult stage, it is then vulnerable to fungal diseases that will shorten its life and reduce its reproductive output. The purpose of this chapter is to review these natural enemies and to identify areas where we can help make them be more effective.

Predators of Fly Eggs and Larvae. The predator fauna in manure is similar across broad geographic areas. Fresh manure or bedding often is first colonized by parasitid mites (esp. *Poecilochirus monospinosus*), followed by the principal species of histerid beetles (small, oval, black, slow beetles=*Caricnops pumilio*.) and macrochelid mites (*Macrocheles muscaedomesticae*), which persist in the accumulating manure as long as prey are available. As the manure continues to age and compost it is invaded by the small, round, slow moving uropodid mites (*Fuscuropoda vegetans*) and by larger beetles in the families Staphylinidae and Histeridae.

The two most important species in this group are *C. pumilio* and M. *muscaedomesticae*. Although they have very different life histories and behaviors, both species have high attack rates on fly immatures, both are present when fly pressure on the manure habitat is great, both occupy microhabitats that assure contact with house fly eggs, both have immature stages that feed on house flies, and both have mechanisms to leave the ecosystem when prey populations become sparse. Moreover, because both *M. muscaedomesticae* and *C. pumilio* feed on a variety of alternative prey as well

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as house fly immatures, high predator populations can remain even if pest flies are not present.

C. pumilio and *M. muscaedomesticae* compliment one another in regulating populations of house flies and other pest species (Table 1). *M. muscaedomesticae* invade fresh manure when fly oviposition pressure is greatest in the habitat. Populations of this mite are volatile and increase rapidly in the early weeks of manure accumulation. In contrast, *C. pumilio* beetles are slow to colonize fresh manure accumulations but build slowly to high population densities if proper manure conditions are maintained. The mites kill fewer fly immatures per capita than do the beetles, but they are often more numerous. The two predators prefer somewhat different microhabitats. No parasites of predators of these predators are known, but both species are cannibalistic and feed on each other as well.

Table 1. Comparison of *C. pumilio* and *M. muscaedomesticae*:

Characteristic	*C. pumilio*	*M. muscaedomesticae*
Development time (egg to adult)	21-40 days	2-3 days
Attack rate (fly eggs killed/day)[1]	35-40	5-10
Adult longevity	90 days-2 years	10-25 days
Fecundity (eggs laid/day)	5	10
Relative abundance	less numerous	more numerous
Volatility of populations	relatively stable	highly volatile
Manure age preference	older manure	fresh manure
Manure moisture preference	10-70% water	50-70% water
Main alternate prey	other flies, mites	nematodes, other flies
Parasites/pathogens	none known	none known

[1] Estimates from field experiments.

Other predator species contribute to total fly mortality by filling more specialized niches. Parasitid mites attack fly immatures in very fresh manure where *C. pumilio* is lacking, and uropodids deeper in the manure attack fly larvae that escape predation by surface-dwelling predators that prefer the eggs. Minor beetle predator species such as *Dendrophilus xavieri* can play important roles in managing flies, especially in older or stockpiled manure that is less attractive to *M. muscaedomesticae*.

Altogether, these predators can kill 70-95% of the immature house flies in the manure if favorable conditions for predators are maintained. Beetle and mite predators are particularly sensitive to manure wetness. *C. pumilio* adults are found in manure with 10 to 70% moisture, and the larvae are most abundant in manure in the 50-70% moisture range, as is *M. muscaedomesticae*. In general, high beetle and mite populations are favored by relatively dry manure and predator performance is poor in manure with greater that 75% moisture. Because the house fly can tolerate wetter conditions, up to ca. 82%, wet manure promotes fly problems by limiting the impact of these important natural enemies.

***Hydrotaea (Ophyra) aenescens* and the Black Soldier Fly.** *Hydrotaea aenescens* is a shiny black fly that is similar in size and appearance to the house fly. The larvae of this species are found in the same substrates as house flies, where they feed on the manure and are also facultative predators of house fly larvae. Because the adult *H. aenescens* are thought by many to be less pestiferous than the house fly, there has been considerable interest in developing methods for establishing dominance of this species over the house fly. Generally this has been accomplished in a two stage process in which house fly populations are first reduced with insecticides, growth regulators, or manure cleanout, followed by mass rearing and release of *Hydrotaea* larvae into the manure. In some cases, commercial poultry producers have even installed on-farm *Hydrotaea* production units for raising their own flies. This approach is still quite experimental, however, and may not be applicable in all situations. For example, in cases where flies have become a source of contention between producers and their neighbors, it may not be sufficient to replace the house fly with a second fly species, no matter how innocuous the second species is.

House fly development is also limited by high populations of larvae of the black soldier fly, *Hermetia illucens*. Soldier fly adults are large black flies that somewhat resemble wasps. They are outdoor-loving flies that do not readily enter buildings but rather lay their eggs on the edges of retaining walls and other objects along the sides of the buildings. The larvae then churn through the manure and change its physical characteristics to a form that no longer supports house fly development. The soldier fly larvae also seem to emit a chemical that house fly adults can detect; house flies will not lay their eggs in manure containing even small numbers of soldier fly larvae. These flies are very common in the southeastern US, and research is under way to determine how they can be integrated with other control components in IPM programs. Soldier flies and black dump flies are most common in poultry and swine production systems but may also occur on dairies.

Nematode Parasites. Nematodes are extremely common organisms that are present in virtually every habitat known. Many nematode species are parasitic in insects and have been the subject of considerable biocontrol research. In particular, there are nematodes in the families Steinernematidae and Heterorhabditidae that are being raised and sold by commercial producers for control of a variety of pests, including house fly larvae. Although house fly larvae are indeed susceptible to these nematodes, these species do not survive well in animal manure.

There is one nematode species that parasitizes house fly larvae and which occurs in the natural fly larval habitat. This species, *Paraiontonchium muscadomesticae*, has a free living stage in manure that invades developing fly larvae. The nematodes continue developing within the fly until it reaches the adult stage. At this point thousands of young nematodes invade the ovaries of the fly, thus deceiving the fly into thinking that she is full of eggs. The fly then attempts to lay her eggs and in the process lays nematode instead, which start the cycle anew. This nematode was just discovered a few years ago, and we are perhaps 10 years away from using it in a practical way in fly IPM programs.

Pupal Parasitoids. Parasitoids that attack fly pupae are among the most important natural enemies of house flies, and offer the most immediate promise for manipulation. There are about a dozen species of these parasitoids, all of which have a similar life cycle. The adult female parasitoid is like a "smart bomb" that has a sophisticated array of sensory equipment that help her accomplish her one task in life; to locate, kill, and lay eggs on fly pupae. Although she has a stinger and is, taxonomically speaking, a type of wasp, the stinger is used exclusively to sting fly pupae and not people or livestock/poultry. When she finds a fly pupa, she stings and feeds on it, then lays an egg (more, for some species) inside the pupal shell. The egg hatches, and the parasitoid larva feeds on the dead fly. The young adult parasitoid then chews its way out of the fly's pupal case and searches for new pupae to kill. Development from egg to adult is completed in 3-4 weeks (about twice as long as the fly).

The two most important genera of fly parasitoids are *Muscidifurax* and *Spalangia*. Both genera include several important and unique species of parasitoids, but we can still recognize biological features that make the two genera complimentary, as illustrated in Table 2. Here, *Muscidiufrax raptor* is compared with *Spalangia cameroni*. *M. raptor* has a higher attack rate (kills more fly pupae) and a shorter development time than *S. cameroni*, but *S. cameroni* lives longer, is not susceptible to *Nosema* disease, it is more tolerant of pesticides, has greater heat tolerance, and is better at digging through manure to find hidden pupae. There are also important differences among species within each genus. For example, *Muscidifurax raptorellus* produces ca. five adult parasitoids from each fly pupa that it kills, compared to one for the other species. *Spalangia endius* performs well in hot outdoor conditions, whereas *S. cameroni* is better suited to dark indoor barn conditions. These distinctions notwithstanding, the two genera (*Muscidifurax* and *Spalangia*) compliment each other to such a degree that it is advantageous to have at least one species from both genera present. Ways to use parasitoids in IPM programs are discussed later in this chapter.

Table 2. Comparison of *Muscidifurax raptor* and *Spalangia cameroni.*

Characteristic	*M. raptor*	*S. cameroni*
Development time (egg to adult)	ca. 21 days	ca. 28 days
Adult longevity	ca. 10 days	ca. 21 days
Attack rate (pupae killed/day)	10-20	5-10
Winner in multiparasitism	yes	no
Light preference	light or dark	dark
Substrate preference	dryer	wetter
Searches where	near surface	deeper in manure
Sensitivity to pesticides	very sensitive	tolerant
Heat tolerance	lower	higher
Susceptible to *Nosema* disease	yes	no

Diseases of the Adult Fly. Adult house flies are susceptible to infection with two important fungi, *Entomophthora muscae* and *Beauveria bassiana. E. muscae* is an elegant pathogen that lives in careful balance with the fly. Adult flies become infected when fungal spores attach to their cuticle (skin) and germinate into the body cavity. The fungus then multiplies within the fly and, about 7 days after infection, kills it. Infected flies attach themselves to building supports, strings, etc. immediately before death. Several hours later the dead fly produces a fungal bloom that results in a conidial shower (rain of spores), that scatters spores over other flies nearby. Male flies also acquire the infection by attempting to copulate with dead infected flies. Natural epizootics of *E. muscae* are very common in the Fall months, when infection rates of 60-80% are not uncommon. Our ability to manipulate this disease to our advantage for fly control is limited by the fact that the fungus can only be grown in living flies (no artificial media is known for it), and the delicate nature of the spores, which only live for several hours after being shed.

In contrast, *B. bassiana* is a pathogen whose spores have a long shelf life and which can be easily mass-produced on inexpensive diets. Although infections of house flies with *B. bassiana* are somewhat rare in nature, the flies can be readily infected and killed by eating spores in a bait form or by resting on spore-treated building surfaces. There is considerable commercial interest in developing this pathogen into a practical fly control product. The major constraints on successful use of *B. bassiana* for fly IPM are the relatively long time that it takes to kill the fly (several days to a week), and concerns about human allergic reactions to the spores. These obstacles can be overcome by careful screening and formulation efforts, but it will be probably be 5 years before fungal control products appear on the market.

Using Natural Enemies for Fly Control Today

Strange as it may seem in light of the large populations of flies that we sometimes encounter, the natural world is a very dangerous place for the house fly. Altogether the community of natural enemies takes a heavy toll on each generation of flies; eating, invading, parasitizing, infecting the fly at virtually every turn in its life cycle. As a result, everyone who engages in fly control uses natural enemies whether they realize it or not. The challenge is to learn how to harness these natural biological control agents to take full advantage of their fly control potential. There are three ways in which we can do this; conservation, inoculation, and sustained releases.

Conservation. Robust, stable populations of beetles, mites and parasitoids can be conserved by first using cultural control and manure management practices that keep manure and/or bedding as dry as possible. This includes correcting problems with leaking waterer tanks, drainage and ventilation. Second, if possible, manure should be cleaned out as infrequently as possible to allow natural enemy populations to build. For example a calf-barn cleanout interval of 2-3 weeks is the worst-case scenario; this is neither short enough to break the life cycle of the fly nor long enough to allow good establishment of natural enemies. Third, pesticides should only be used in a manner that limits the risk to beneficials. In particular this means that manure and bedding should never be treated directly with pesticides except as a spot treatment in areas with very high maggot densities. If pesticides must be used to manage adult fly populations then it is best to choose baits and non-persistent space sprays. Residual premise treatments should be made sparingly and only in areas of high fly activity. Fourth, if biocsecurity concerns allow it, a residue of old bedding should be left behind after cleaning calf pens or hutches to facilitate repopulation of fresh bedding.

Inoculation. In some cases biosecurity or other considerations may prevent the producer from leaving residues of old manure and bedding at cleanout. Fly invasion in the "sterile" manure that accumulates after total cleanouts often lead to fly explosions. In such instances it can be helpful to inoculate the fresh manure with small populations of natural enemies to help them get started. If biosecurity concerns permit, this can be accomplished by seeding with manure or bedding from another production unit that contains natural enemies. At present the only natural enemies that can be purchased commercially are the pupal parasitoids. The rates at which parasitoids are released must be determined by the specific needs of the producer's farm at that point in time, but a good starting point is 500-1000 parasitoids per calf for dairies. At less than a dollar for a thousand parasitoids, this is a small investment in fly control that may well pay off in the weeks ahead.

If you do purchase parasitoids, keep in mind that they are living creatures and need to be handled with care. Parasitoids are shipped as young wasps inside fly pupae, usually a few days from being ready to chew their way out of the pupae. These pupae should be protected from intense heat or cold until they are deployed in the field. When placing them in the field it is often a good idea to put the pupae in hardware cloth bags to protect them from rodents. These bags should be placed in areas near fly larval (not necessarily adult) activity, and be left in place for 2-3 weeks to allow complete parasitoid emergence.

Sustained Releases as Part of an Integrated Management Program. In sustained release efforts, releases of parasitoids are made over a longer period of time, perhaps the entire fly season, to help maintain fly populations below the nuisance threshold. Sustained releases help give parasitoid populations an edge in the race against fly populations, a race in which nature has given the advantage to fly by virtue of its faster development rate and high reproductive output. As before, release rates are site-specific and need to be adjusted until a rate is found that is both effective and economical for a given producer. Using parasitoids in a sustained release program requires a commitment to an integrated management program that includes good sanitation, cultural practices that keep manure dry and conserve natural enemies, and restraint in the use of chemical insecticides to minimize harmful effects on beneficials. Long-term suppression of flies requires starting parasitoid releases early in the season or flock, before flies become a problem.

A good integrated management program should include a method of monitoring flies. This allows you to maintain long-term records of fly populations, which can be useful in the event of disputes with non-farm neighbors over flies. Although there are many methods for doing this, the best is the use of "spot cards". These are blank 3 in. by 5 in. index cards that are labelled with the date then placed in various locations around the facility where fly activity has been observed. The cards are replaced weekly and the number of fly specks are counted. The average weekly speck count can be used as a barometer of the success of your fly program. Every farm is different and the speck count varies greatly depending on where the cards are placed, but most people find that their nuisance threshold occurs at between 30 and 100 specks per card per week.