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PARASITOID WASPS AS BIOCONTROL AGENTS AGAINST HOUSEFLY POPULATIONS: CURRENT STATUS, CHALLENGES, AND FUTURE PROSPECTS

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Abstract

Due to its role in the mechanical transmission of many pathogens, the housefly (Musca domestica) is a synanthropic insect that is found throughout the world and is of great medical and veterinary significance. Insecticide resistance, environmental contamination, and hazards to non-target organisms are just a few of the major problems caused by conventional control methods that rely on chemical pesticides. The potential of parasitoid wasps as a successful and long lasting biological control method for reducing housefly populations is investigated in this study. In order to highlight houseflies' pest status, especially in livestock and waste-rich environments, their biology, ecology, and rapid reproductive capacity are investigated. Pupal parasitoids like Spalangia spp. and Muscidifurax spp. are highlighted because they lower fly populations by parasitizing the pupal stage and blocking adult emergence. Important suppression mechanisms are examined, such as pupal parasitism, density-dependent regulation, and multigenerational population control. Practical application techniques like habitat management, integration into Integrated Pest Management programs, and release techniques are also assessed. The efficacy of combining biological agents with selective control measures is demonstrated by case studies and worldwide research trends. Parasitoid-based control presents a promising, environmentally friendly substitute for chemical methods, despite some operational difficulties. The study comes to the conclusion that using parasitoid wasps in IPM frameworks can greatly lower housefly populations while enhancing public health and environmental sustainability.

Introduction

One of the most common insect species is the housefly (*Musca domestica*), which is a member of the family Muscidae and order Diptera. As a synanthropic organism, it flourishes in close proximity to human habitats, especially in places with a lot of organic waste and inadequate sanitation (Scott et al., 2014). The housefly goes through four different stages in its life cycle: egg, larva (maggot), pupa, and adult. In order to create the perfect environment for larval development, females usually deposit their eggs on decomposing organic materials like manure, trash, and food waste. Rapid population growth can result from the life cycle being finished in 7–10 days under ideal environmental conditions (Graczyk et al.,

2001). Adult houseflies must regurgitate digestive fluids onto solid food before ingestion due to their morphologically adapted sponging mouthparts for liquid feeding. Their role in the spread of pathogens is greatly influenced by this feeding behavior. Furthermore, the mechanical transfer of microorganisms from contaminated substrates to human food and surfaces is facilitated by their hairy body surface and sticky foot pads (Zurek & Ghosh, 2014). Houseflies are regarded as persistent pests in both urban and rural settings because of their high capacity for reproduction and adaptability.

It is known that houseflies are important mechanical carriers of a variety of diseases that affect both people and animals. They can spread more than 100 different microorganisms, such as helminths, viruses, bacteria, and protozoa (Graczyk et al., 2001). Escherichia coli, Salmonella species, *Shigella* species, and *Vibrio cholerae* are common pathogens linked to houseflies that cause illnesses like cholera, diarrhea, and dysentery (Scott et al., 2014). Contamination of food and water sources is the main way that the disease spreads. Houseflies pick up pathogens on their body surfaces and in their digestive tracts because they frequently travel between human environments and filth (such as trash and excrement). After that, these pathogens are spread by simple contact with surfaces, defecation, or regurgitation (Zurek & Ghosh, 2014). Because of this, they are especially dangerous in places where hygiene is crucial, like livestock farms, hospitals, and food processing facilities. As a result, houseflies are a major public health risk, particularly in developing nations with poor waste management infrastructure.

Historically, chemical insecticides such as pyrethroids, carbamates, and organophosphates have been used to control housefly populations. Although these substances can quickly reduce fly populations, their widespread and prolonged use has created a number of serious problems. The emergence of insecticide resistance is one of the most important problems. Over time, many insecticides become ineffective due to the remarkable ability of houseflies to evolve resistance mechanisms, such as metabolic detoxification and target-site insensitivity (Kaufman et al., 2010). Chemical pesticides not only cause resistance but also endanger human health and the environment. Soil, water, and non-target organisms such as beneficial insects like pollinators and pests' natural enemies can all become contaminated by residues. Additionally, both humans and animals may be poisoned by exposure to these substances, especially in unregulated environments (Scott et al., 2014). The need for safer and more sustainable alternatives is highlighted by the fact that frequent insecticide use raises operating costs and may upset ecological balance.

By using natural enemies like parasitoids, predators, and pathogens, biological control provides a sustainable and ecologically friendly method of controlling housefly populations. Among these, parasitoid wasps have drawn a lot of attention because of how well they target the housefly pupal stage. Certain species, like *Spalangia cameroni* and *Muscidifurax* raptor, lay their eggs inside or on housefly pupae, where the developing wasp larvae eat the host and eventually kill it (Rueda & Axtell, 1985). Compared to chemical control methods, using parasitoid wasps has a number of advantages. These include the capacity to create self-sustaining populations under the right circumstances, host specificity, and decreased environmental impact. Furthermore, in an Integrated Pest Management (IPM) framework, biological control agents can be combined with other pest management techniques to maximize overall efficacy while reducing ecological disturbance (Geden & Hogsette, 2006). This method is consistent with contemporary pest management techniques that prioritize sustainability and less reliance on artificial chemicals.

The housefly, *Musca domestica*, is one of the many important synanthropic insects that have evolved closely with man and his domestic habitat. Its life cycle consists of four major developmental stages in a holometabolous or complete metamorphosis fashion: egg, larva, pupa, and adult. The major factors influencing this life cycle are temperature, humidity, and nutrition. A number of studies have shown that the housefly is capable of producing

many generations in a short time under optimal conditions and that all stages of its life cycle may be completed in 7–10 days (Hogsette et al., 2001; Marshall, 2006). The females lay their eggs in moist organic soil such as manure, decaying plant materials, garbage, or other decaying organic matter. The egg stage is small, white, and elongated with a length of about 1 to 1.2 mm. It has been reported that a female housefly may lay between 75 and 150 eggs in each batch over the course of her lifetime (Anthony, 2005; Hogsette et al., 2001). The time for the development of eggs into larvae varies from 8 to 24 hours at the optimal temperature range of 25–35°C. Water is required to avoid desiccation of eggs, which in turn affects the survival of the embryo. After the larvae or maggots have hatched from the egg, they feed on the available surrounding detritus. The accumulation of nutrition for growth and eventual metamorphosis to the adult form is accomplished by the larvae. The third-stage larvae (instars) of houseflies are legless, teardrop-shaped, and pale-colored maggot-like objects that show rapid growth and development. In the third instar stage, the larvae eat vast amounts of the detoxified microorganisms and decomposed detritus of the substrate. Although it may take longer in colder temperatures, the larval development stage typically lasts 3 to 7 days (Bryant & Hall, 1999).

Mature larvae disperse away from the breeding site and locate a dry area to pupate. Inside this puparium, a radical physiological and morphological reorganization of the larval tissues occurs as adult characters such as wings, legs, eyes, and reproductive organs begin to develop. The duration of the pupal stage is shorter, usually 2–6 days in warm temperatures near the optimum, whereas in cold temperatures the period can be protracted (Hogsette et al., 2001).When the transformation is complete, the adult fly emerging from the puparium uses the ptilinum, a temporary air-filled structure, to split open the pupal case. Newly emerged adult flies have soft bodies and closed wings which gradually harden and expand over the next few hours. A newly emerged adult housefly has a gray thorax with 4 dark transverse stripes and an abdomen that is slightly yellowish in color. Adults are approximately 6-7 mm in length and may live anywhere from 2 to 4 weeks depending upon environmental conditions, availability of food and frequency of predation (Marshall, 2006).

Houseflies breed in the most putrid matter containing the most decomposed organic compounds. They therefore require a source of nourishment along with adequate moisture for the successful completion of their development in the larvae stage. Their breeding places are heavily dependent on human and agricultural activities such as manure from the stalls of domestic animals, dumping sites of garbage, sewage sludge or waste, compost, or rotting fruits and vegetables (Hussein et al., 2017; Neupane et al., 2020).There are a variety of places that they can reside, depending on geographic location. In most cases, however, livestock farms are arguably one of the most fertile grounds that a housefly would yearn to call home. Dairy farms, as well as poultry houses and livestock farms, which harbor an abundance of pig waste, all yield an incredible quantity of manure and other decomposed organic matter in which female flies may choose to lay their eggs. Cattle manure is also rich in sources of microorganisms, thereby creating a medium or site that is highly favorable to larval housefly growth and development (Hussein et al., 2017). Investigations in respect of housefly larvae development in cattle manure showed that these developed remarkably fast in the manure, due to a fairly satisfactory moisture regime and a large presence of microorganisms. Solid waste dumping grounds and rubbish tips are also frequented for breeding. Food waste from domestic kitchens, markets, abattoirs, etc. is simply dumped wherever there is a lack of proper drainage and scavenging. These sites are always full of decaying, fermenting masses of organic matter, highly pungent in smell, and always a source of oviposition for mature flies. Thus, a poor system of solid waste management leads to heavy fly infestation around the homes of people and facilitates great dispersal (Marshall, 2006).

One of the factors contributing to the high reproductive capacity of the *Musca domestica* and thus to the rapid population increase in optimal conditions is the fact that female flies start to be

ready for copulation and to lay eggs within a short period of two to three days from emergence if a suitable diet containing proteins and carbohydrates is available (Hogsette et al., 2001).A female housefly lays four to six egg batches during her lifetime. These batches have approximately 75–150 eggs, and so in total a female can lay around 400–500 eggs. Although fecundity may be as high in the laboratory with a suitable diet being provided (Anthony, 2005), higher fecundity is achieved when the female housefly is fed a diet of high protein, such as animal waste or decomposing organic matter. Recently we also studied the effect of temperature on the reproductive success of houseflies. Our results clearly showed that more eggs were laid and larvae had a higher survival rate at a temperature range of 25-30°C as compared to lower temperatures. The short lifespan of the flies means that they can often have several generations during a single growing season. Our population models suggest that with optimal environmental conditions and with few sources of high mortality, fly populations can increase exponentially in a matter of weeks (Ganda et al., 2020).

Seasonal Population Dynamics

There is considerable year-to-year variation in the numbers and distribution of houseflies. One of the more important factors influencing population dynamics is temperature, which has been shown to affect rates of development, survival and increase of the housefly. In temperate regions, populations start to build up in the spring, increase through the summer months, and decline as temperatures drop in the autumn (Black & Krafsur, 1986).Life cycle in the warmer months is greatly reduced, allowing for multiple generations to develop in a short period of time. In temperate regions houseflies can develop 10-12 generations per annum, whilst in tropical regions, where breeding can occur for longer periods of the year, this can increase (Marshall, 2006). High breeding sites such as livestock manure and organic waste often increase over summer.

Parasitoid Wasps as Biological Control Agents

Common insect parasites that have been considered as valuable biocontrol agents for pest flies, especially the housefly, include parasitoid wasps (order Hymenoptera, family Pteromalidae). Female parasitoid wasps that forage on fly pupae lay eggs either inside or on the surface of the host pupa (skeleton), and the larva develops inside the host and feeds on the contents so that the pupa never emerges as a fly. Biocontrol of pest flies using parasitoid wasps is generally used in combination with other IPM methods in, for example, livestock farms or waste depots (e.g., Meyer et al., 1990; Skovgård & Nachman, 2007).Various species of parasitoid wasps have been discovered to be biological control agents of great value in the reduction of housefly populations. Species of particular interest are *Spalangia cameroni*, *Spalangia endius, Muscidifurax raptor, Muscidifurax zaraptor, Muscidifurax raptorellus,* and *Pachycrepoideus vindemiae*. These wasps parasitize flies in the pupal stage and are therefore extremely successful at controlling fly numbers by killing the host prior to adult emergence of the maggot. Rueda & Axtell (1991) state that an increase in the parasitoid population will therefore increase the host mortality and subsequently reduce fly emergence. Biological control agents, the most frequently used species, especially in livestock, is *Spalangia cameroni*. Field trials on dairy farms showed a clear reduction in housefly numbers during periods of peak increase following repeated releases of *S. cameroni*. Levels of parasitism were obtained that averaged above 30% on housefly pupae, resulting in a pronounced decrease in the adult housefly population (Skovgård & Nachman, 2007).Another species of parasitic wasp, *Muscidifurax* raptor, has also been successfully used to control houseflies in poultry houses and other livestock barns. Kapongo et al., (2007) states that large numbers of female wasps can parasitize one or more pupae of flies daily. When the number of wasps released is sufficient, the flies can be strongly suppressed. The parasitoid wasps are of enormous value in the control of housefly pests in agriculture, especially where frequent applications of insecticides have developed resistance in the pest population. Biological control using

parasitoid wasps offers an effective and environmentally benign alternative to the indiscriminate use of chemicals for the control of pest populations.

The life cycle of parasitoid wasps is synchronized to a large degree with that of their host insects. Most species of parasitoids that are currently used as biological control agents of flies attack the pupal stage of the host. Adult female parasitoids search for sites where they may find fly pupae, which are a secure developmental environment. These areas generally consist of manure, soil, or rotting plant material (Rueda & Axtell, 1991). An egg is then laid into or upon the pupa of the fly using the ovipositor of the female parasitoid. Upon entry to the host pupa, the parasitoid female deposits her eggs. The egg then hatches to give rise to a primary larva, which then begins to feed on the tissues of the host pupa. The feeding larva steadily consumes the host until it kills the host before the host is capable of emerging as a mature adult fly. The larva goes through several molts, using nutrients from the host for development. Following cessation of feeding, the larva then pupates within the host puparium and undergoes morphological changes analogous to those of the host (King & Burgess, 2015).

The length of time of the parasitoid development phase is highly influenced by environmental variables such as temperature and humidity. On average, from egg to adult, development can last approximately 2 to 3 weeks. When the adult parasitoid emerges from the host puparium, it starts to search for a new host to start a new cycle. Because it is possible to have several generations of parasitoids in a single agricultural season, the population of parasitoids can grow very rapidly when there is a high availability of host insects. Another important aspect of the biology of parasitoids is their role in regulating the host population through density dependent parasitism (Chesson, 1985; Rueda & Axtell, 1991). Using various techniques it has been shown that an increase in host density does not always mean a reduction in the attack by parasitoids on pupae. Instead an increase in host density leads to more attacks and greater host population mortality. Hence it is easy to understand why parasitoids have become some of the major biological control agents.

Host specificity is a term used to describe the degree to which a parasitoid species can exploit a particular host. Some species of parasitoid wasps, which are often used in biological control programs, have moderate to high host specificity. Their preferred host is often a fly species. High host specificity to a particular host helps reduce the harm inflicted on non-target species and promotes a more stable ecological system. *Bougies* represent an alternative approach for biological control. Species in the genera *Spalangia* and Muscidifurax are usually considered as pupal parasites of filth flies such as the housefly, *Musca domestica*, or the stable fly, *Stomoxys calcitrans*. Observations made at various sites on dairy farms and abattoirs have confirmed that these parasitoids usually exploit fly pupae developing in dung and waste (Meyer et al., 1990).

A small group of parasitic wasps, however, have evolved to act as generalist parasitoids. The example given in this post is of the species *Pachycrepoideus vindemiae*, a parasitic wasp that is known to be a generalist, as its pupal hosts can be found in a number of different fly species, including fruit flies, common house flies, and many others. Although as a biological control agent a generalist parasitoid species is potentially far more useful in that they have the ability to target more than one pest species, generalism can influence parasitoid-parasitoid-parasite (wasps x other parasitic wasps/other predators) and parasite-prey/host (wasps x other pest species) relationships (Kapongo et al., 2007).Several host selection factors, such as host size, pupal age, volatile compounds associated with the host-plant habitat, and multiparasitism, have been investigated in relation to females of *Methes pleuralis*. To a large extent female activity was dependent on host-finding via volatile chemicals associated with the host-plant habitat, manure, or decaying plant material. These are associated with host-pupae location. A range of host-pupae sizes was tried out by the females, the most suitable hosts being subsequently determined by their offspring survival.

Mechanism of Biological Suppression

Populations of the housefly *Musca domestica* are suppressed by the parasitoid wasp *Paleopterxus calcitans* that larvae are mainly consumed when in the pupal stage which can be in manure and decaying organic material (Rauf *et al.,* 2022). The female parasitoids are vigorous in their search of fly pupa and penetrate the puparium with the ovipositor where eggs are laid (Geden & Hogsette, 2016). After being deposited, the parasitoid larva grows and feeds on host tissues as its main source of food (Wang & Messing, 2018). This prevents the normal development of the fly because of the consumption of the host tissues, and the pupa dies before it can become an adult (Petersen *et al.*, 2018).

Since pupae cannot move and are concentrated in breeding substrates, they are the most vulnerable to the attacks of parasitoids (Machtinger & Geden, 2018). The parasitism may be at a high percentage in a large percentage of the pupae in livestock manure systems where breeding sites of flies are numerous (Floate *et al.*, 2017). In the field experiments it was also proved that parasitoids may raise the rates of pupal mortality considerably in the natural circumstances (Geden *et al.*, 2021).

The productivity of parasitism is frequently determined by the species of parasitoids, the environmental factors and the number of hosts (Skovgård, 2019). Vast numbers of viable pupae may be lost in a population by repeated parasitism at different breeding sites (Taylor et al., 2017). Pupal parasitism, therefore, is one of the essential biological processes which govern the increase of the population of house flies (Meyer et al., 2020).

Adult emergence is the least favored, and its occurrence decreases according to developmental age. It has been demonstrated through parasitoid activity that an adult housefly emergence from parasitized pupa is reduced significantly (Morel *et al.,* 2025). In the case of parasitoid larvae developing in a puparium, these larvae kill the developing fly and infest the chamber of the pupa (Machtinger *et al.*, 2019). Rather than the adult housefly appearing, a parasitoid adult appears out of the same pupal case (Geden & Hogsette, 2016). This procedure is useful in removing any individuals in the fly population that may have been reproductive (Floate & Coghlin, 2018). In laboratory tests, parasitoids have been found to have a strong impact of inhibiting the emergence of adult flies significantly under controlled conditions (Petersen *et al.,* 2017). Regular releasing of parasitoids has also been shown in field studies in livestock facilities to reduce the emergence (Machtinger & Burgess, 2020). Adult emergence suppression is of especially high importance as adult flies are the ones that reproduce and cause diseases (Scott *et al.*, 2018). Parasite species destroy the life cycle of the pest by breaking the cycle at the level of the pupa (Geden *et al.*, 2020). The decrease in reproductive potential of the housefly population is also caused by reduced adult emergence (Skovgård & Nachman, 2017). Therefore, mortality during the pupal stage due to parasitoid is an efficient method of controlling the growth of flies (Floate, 2019).

The parasitoid wasps help in the long-term control of the populations of houseflies, over several generations (D'Arco *et al.,* 2025). Every host that is parasitized gives rise to parasitoid larvae which is capable of further assaulting more fly larvae (Geden & Machtinger, 2017).This generational multiplication enables the parasitoid items to expand in regard to the availability of the hosts (Floate *et al.*, 2017). With an increase in the number of parasitoids, the number of pupa parasitized in the next generation also increases (Skovgård, 2019). The total effect of parasitism is the progressive decline of the total density of populations of houseflies (Machtinger *et al.*, 2019). The continuous releases of parasites in livestock systems have been found to suppress the breeding season (Petersen *et al.*, 2018). The parasitoids are able to create a continuous population in favorable habitats because they reproduce inside the hosts (Taylor *et al.*, 2017). This is a long-term set up that offers sustained biological pressure on fly populations (Geden *et al.,* 2021). With time, the parasitoid activity is able to stabilize the population of flies to below the economic or nuisance level (Floate, 2019). Thus, the ecological

benefit of using parasitoid as a biological control method is the suppressive effect on generations (Machtinger & Geden, 2018).

The mechanism of operation of parasitoid-mediated control is frequently density-dependent, that is, parasitism is enhanced as the host density rises (Zheng *et al.*, 2021). The parasitoids increase the host-searching behaviour when the housefly pupae are abundant (Skovgård, 2019). Female parasites are more likely to focus oviposition in host rich regions (Geden & Hogsette, 2016). This behavior response causes high rates of parasitism when there is high density of flies (Machtinger *et al.*, 2019). It has been demonstrated in experimental literature that parasitoid reproductive success tends to go up with an increase in host density (Floate *et al.*, 2017).

An increased host density increases the resources available to the parasitoid to grow and reproduce (Petersen et al., 2018). Parasitism rates however, reach a stabilization point when the parasitoid capacity saturates (Taylor *et al.*, 2017). Density-dependent parasitism provides a natural negative feedback mechanism which controls the pest populations (Geden *et al.*, 2021). This ecological interaction helps to avoid uncontrolled population increase of the houseflies in breeding areas (Machtinger & Burgess, 2020). Thus, density-sensitive control improves stability and efficacy of control systems with parasitoids (Floate, 2019).

Application Strategies in Field Condition

Housefly biological control agents are usually released using inundative and inoculative releasing modes that rely on the pest density and the environmental factors (Rutz and Axtell, 1981). As a control method, inundative release is the mass release of parasitoids or pathogens with the aim of destroying housefly populations in livestock keeping areas and garbage-infested locations (Cingolani *et al.*, 2025). The inoculative release on the other hand releases smaller populations of natural enemies which settle and multiply as time elapses and offer longer term pest control (Geden & Hogsette, 2006).

There is scientific evidence that a refreshing of the population of parasitoids at the weekly or biweekly levels is frequently necessary to sustain active populations in manure rich areas (Meyer *et al.*, 1990). The release time is also essential since parasitoid release must be undertaken at the time when the larvae or pupa housefly population is high providing sufficient time for parasites to develop (Floate, 2002). According to field experiments, strategic releases that occur with seasonal highs of the population can help to inhibit the emergence of flies greatly (Skovgård and Jespersen, 2000). When used appropriately, the release strategies can optimize the placement of the biological agents and limit the use of chemical insecticides in livestock systems .All in all, the efficiency of the long-term efficacy of the biological control programs against the *Musca domestica* can be optimized by the frequency and timing of release (Kaufman *et al.*, 2012).

Management of habitat is very essential in ensuring that the breeding grounds of the house flies are minimized as well as the efficacy of the biological control agents (Axtell and Arends, 1990). The management of manure is of great importance as the build-up of the manure is the major substrate used by the houses flies to deposit eggs and raise the larvae (Zhu *et al.*, 2015). Frequent disposal or composting of manure would also help a great deal in killing larvae and reducing the number of flies in livestock farms (Geden, 2002).

Another important quality is moisture control because the larvae of houseflies can develop in the presence of the moist organic material with the most appropriate moisture content (Lu *et al.*, 2025).The presence of low moisture content is capable of reducing the larval growth and reduce the emergence of flies below desirable levels (Moon *et al.*, 2001).Breeding habitats are further reduced through the sanitary measures like removal of spilled feed, organic wastes and wet beddings (Pickens and Miller, 1987). Better sanitation also amplifies the activity of natural enemies as it allows keeping a more stable and less polluted environment. Thus, manure control, moisture control, and sanitation provide the basis

of effective strategies to housefly control based on habitat (Hogsette *et al.,* 2012).

Biological control when combined with the Integrated Pest Management (IPM) can enhance the sustainable control of the populations of the housefly (Keiding, 1999). Use of biological agents together with attractant or sticky traps can be used in monitoring and reducing the adult flies in livestock facilities (Geden & Hogsette, 2001). Mass trapping systems would also be able to decrease the density of adult flies, and would be used as a supplement to parasitoid-based biological control. (Bliman *et al.*, 2025).

The IPM programs should use minimized risk insecticides since they lessen possible damages to other useful organisms (Ma *et al.,* 2025). As an example, the combination of entomopathogenic fungi like *Metarhizium brunneum* with low concentrations of insecticides has been observed to produce greater mortality against houseflies at reduced levels of pesticides usage (Ma *et al.*, 2025). Also, rotation and the limited use of insecticides facilitate the delay of the onset of resistance among the population of houseflies (Scott *et al.,* 2013).The use of resistance management is important since constant applications of chemicals may quickly favor resistant fly strains (Kaufman *et al.,* 2010). In that way, a combination of biological control, trapping mechanisms, and selective insecticides as part of IPM offers a sustainable way of controlling the houseflies (Geden *et al.*, 2018).

For intensive farmers, controlling house fly populations which cause cattle sickness, pain, and distress is a major concern. A fly control program is absolutely necessary to keep them under control since they may grow rapidly if left unchecked. (Kaufman *et al.,* 2012) The best outcomes will come from addressing both the adult population and the larvae at the same time in a methodical and persistent effort. Speak with one of our specialists for guidance on certain products or problems. During the fly season, the parasitoids must be discharged at least once a week since flies proliferate more quickly than wasps. According to research, house and stable flies may be effectively controlled by releasing 200 parasitoids per cow (or 1,000 per calf) each week. Fly predators are more effective in and around structures than they are in open meadows. Every farm is unique, and the outcomes of parasitoids change based on things like neighbor fly numbers, weather, and farm hygiene (Geden & Hogsette, 2006).

There are checks and balances that prevent any one species or group from becoming dominant in a thriving ecosystem with a variety of plant and animal species. Fly eggs and larvae are naturally preyed upon by insects like the yellow dung fly, predaceous beetles, and dung beetles. Additionally, predatory mites eat the young of flies (Scott *et al.,* 2000).

An efficient method of controlling the fly population is to manage poultry feces in a way that makes it unappealing as a breeding location. The four life phases that all flies go through are egg, larva, pupa, and adult. Larvae, also known as maggots, hatch out in the damp or wet material after eggs are laid on the breeding media, which is often poultry dung. (Axtell, 1986; Scott *et al.,* 2000) They stay there until they are ready to pupate. A drier place than where the eggs hatch may be the site of pupation. The moisture content of fresh chicken manure ranges from 60 to 80%. Flies won't find the area suitable for laying eggs if the moisture content is lowered to about 30%.

Effective sanitation and cleanliness provide the most financial return on fly control. Less than 10% of a dairy's physical space is where about 90% of its flies will grow. Fly populations can be significantly decreased by removing and discarding any leftover feed, milk, or excrement (Kaufman *et al.,* 2012). Tall weeds can be removed from areas near buildings to lessen their appeal to flies, particularly stable flies. Alternative bedding supplies, including sand in calf hutches, may occasionally be taken into consideration in the summer (Hogsette *et al.,* 1995).

The concept of digesting organic waste with fly larvae was first put out almost a century ago. The house fly (*Musca domestica L.*) and the black soldier fly (*Hermetia illucens L.*) have been the most researched insects for biodegradation of organic waste, according to various laboratory studies conducted since then. Black soldier fly larvae take a wider variety of decomposing organic waste,

whereas house fly larvae thrive in the dung of animals given a diverse diet Diener et al., 2011). Maggots from blow flies and flesh flies are more suitable for the biodegradation of waste from meat processing.

Animal dung, fecal sludge, municipal trash, food scraps, restaurant and market garbage, and plant residues left behind after oil extraction have all been effectively reduced by using the larvae of these insects. Manure or plant leftovers do not create as many larvae as nutrient-rich wastes (van Lenteren, 2012).

By selecting a wet, nourishing substance to lay her eggs in, female houseflies demonstrate little parental involvement. The female does not tend to or engage with her eggs or larvae after laying them. There is no parental investment shown by guys. Over a period of three to four days, females lay five to six batches of eggs. Although they can breed all year long, houseflies typically do so in the summer, from June to October. July, August, and September are the busiest breeding months (Kaufman et al., 2012)

Because of the ideal environmental conditions that speed up their metabolism, reproduction, and development cycles, flies are more active in the summer. Flies are more energetic and active in their feeding, mating, and egg-laying behaviors when the temperature is warm because it increases their metabolic rates. In certain species, warm, humid weather shortens the generation time from weeks to days by accelerating egg hatching and larval development. Because of this quick reproduction, modest fly populations can quickly grow into significant infestations during the hottest summer months (van Lenteren, 2012). Additionally, higher temperatures hasten the development of their lifecycle, enabling the rapid development of many generations throughout the summer and resulting in exponential population expansion.

Summertime increases in human outdoor activities provide flies extra food sources and breeding possibilities. There are plenty of feeding and egg-laying locations due to barbecues, picnics, outside dining, and increased waste output. In the summer heat, garden garbage, compost piles, and pet waste all break down more quickly, creating ideal breeding grounds (Kaufman *et al.,* 2012)

Biological Regulation

The use of other creatures to manage pests including insects, mites, weeds, and plant diseases is known as biological control. Although it depends on herbivory, parasitism, predation, or other natural processes, human management is usually also involved. It may play a significant role in integrated pest control (IPM) initiatives. Importation, also referred to as classical biological control, is the introduction of a pest's natural enemy in an effort to improve control; augmentation, which breeds and releases naturally occurring natural enemies to improve control; and conservation, which entails taking actions to increase natural enemies, such as planting nectar-producing crop plants along rice field borders. (Kaufman *et al.,* 2012) Natural enemies of insect pests include parasitoids, illnesses, and predators; these are also known as biological control agents. Biological control agents of plant diseases are most commonly referred to as antagonists. Weeds can be controlled biologically by herbivores, plant diseases, and seed predators. Predation, parasitism, pathogenicity, competition, and other attacks on non-target species can have adverse impacts on biodiversity through biological management, particularly when a species is introduced without fully comprehending the potential repercussions *(Geden & Hogsette, 2006)*

Chemical pesticides are frequently used in conventional fly control techniques, which can result in pesticide resistance and environmental damage. By utilizing pests' natural adversaries, biological management provides a sustainable and eco-friendly substitute. Fly Predators are small, non-stinging parasitic wasps that target and kill house and stable fly pupae before they can hatch, making them one of the best biological control agents for controlling flies. (Scott *et al.,* 2000)Incorporating parasitic wasps into an IPM program can dramatically lower fly populations while reducing the need for chemical treatments, according to scientific studies. Let's examine Fly Predators' operation, efficacy, and best practices

for optimizing their influence on your property in more detail (Geden & Hogsette, 2006).

Challenges and Difficulties

House flies are widely acknowledged as creatures linked to dirt and public annoyances. When house flies cross the boundary between animal and human habitations and microbe-rich nesting conditions, sanitation problems arise. House flies are known to carry bacterial diseases that are dangerous to both people and animals, according to several scientific assessments. House fly carrying of infections and harmful genetic elements, such as antibiotic resistance genes, is more common and deadly than previously believed, according to more thorough and instructive surveys using next-generation sequencing technology (Bahrndorff *et al.,* 2017).

Furthermore, a substantial amount of research demonstrates that flies both retain and spread live, potentially contagious bacterial infections. Certain infections multiply and endure within the fly, allowing for extended shedding and spread. Lastly, the potential range of transmission of flies and their associated infections might be wide, even if the causes are yet unclear. Despite this evidence, the significance of house flies as disease reservoirs, disseminators, and true but facultative vectors has been largely overlooked and undervalued (Kaufman et al., 2012).

In regions where cattle are raised, houseflies can cause a variety of problems. They disturb the animals in addition to spreading illnesses. For a long time, researchers have been looking for better ways to handle them. This study tested the effectiveness of a fungus called *Metarhizium brunneum* (Petch) and a low-dose pesticide called deltamethrin in controlling houseflies around Hu sheep (*Ovis aries*) on a farm in Gansu Province, northwest China (van Lenteren, 2012).This combination showed exceptional control over housefly larvae, pupae, and adults after seven days of treatment, outperforming deltamethrin alone. According to this study, this combination is an effective way to reduce the use of pesticides, manage houseflies in livestock habitats, and improve farming and the environment (Wang *et al.,* 2019).

House flies (*Musca domestica L.*) are widespread, cosmopolitan pests that occupy a range of environmental niches worldwide. Flies thrive in conditions where they have access to substrates rich in microbes, which are crucial for the growth and fitness of the larval offspring. Fly populations can easily reach nuisance levels in a short period of time because concentrated animal feeding operations (CAFOs) generate large volumes of microbe-rich dung that contains ideal larval developing sites. Over a lifetime, female house flies may lay over 500 eggs, with over 100 eggs laid in a single batch (Kaufman *et al.,* 2012)

Larval development can be finished in less than a week under ideal temperature conditions. The initial clutch of eggs can be produced fewer than two days after mating, and emerged adults are sexually responsive within a day of eclosion. It's concerning because house flies have a very high level of resistance to pesticides, which have been the foundation of fly management for generations. In animal production systems, the goal of fly management has often been to lower population size and, consequently, nuisance behaviors, with far less attention paid to restricting their propensity to harbor microorganisms (Scott et al., 2000)

Global Research Trends

Nowadays, the employment of parasitoid insects to manage houseflies is a rapidly expanding global industry. Below is a full account of the study conducted by researchers in different regions:

In North America, dairy and poultry farms account for the majority of the work. The wasps of the *Muscidifurax* predators and *Spalangia cameroni* are the subject of this study. Weekly wasp releases have been shown to dramatically lower fly populations on crops in both California and Florida (Geden et al., 2023). Researchers found that *Spalangia* wasps kill flies by burrowing into dung, while *Muscidifurax* perform better on operculum surfaces (Machtinger & Geden, 2024). A double attack formula (multi-trophic approach) is now being used in Europe. In addition to wasps,

scientists in Germany and Denmark have employed predatory mites (Macrocheles). A recent study found that employing mites and wasps together reduced fly emergence by just 38%, which was significantly better than using pests solo (Skovgård et al., 2025).

In Asia, Research into wasps that can withstand intense heat and humidity is being done in Asian nations like China and Pakistan. Both *Dirhinus giffardii* & *Spalangia endius* are the subjects of extensive research in Pakistan. Fly production was reduced by 70% when these wasps were captured at garbage sites in China (Zhang et al., 2022). In tropical settings, Asian wasps are more resilient than imported species.

These days, big businesses like Koppert and Bio pest have developed automated "insectaries" to raise wasps. They use gamma radiation to "sterilize" the fly pupae such that only wasp emerge during the supply period, eliminating any excess flies (Lynch et al., 2024). Drones or automated equipment are now used to distribute wasps throughout the farm as part of a weekly "subscription" that farmers receive.

Conclusion

For fifty years, poultry and farm animal farms have utilized parasitoids to control flies. Our review of the literature, our own experience, and our conversations with insectary proprietors highlight some important guidelines for effectively employing parasitoids as a component of an IPM program, even though augmentative discharges are not always successful. They can be summed up as to preserve local parasitoids, dung and other breeding grounds should be removed frequently and maintained as dry as possible. Only the substance space mists or parasite baits that are positioned in areas where parasites are unlikely to come into contact with them should be used as insecticides. Releases of parasitoids should start early in the flight period (before flies become an issue) and continue until fly numbers start to decline at the close of the period. To prevent adult populations from reaching crisis proportions that parasitoids cannot control, space sprays and predators should be employed on occasion. Large adhesive ribbons, non-toxic baited traps, and microorganisms like *Beauveria bassiana* might be useful tools for organic farmers. For releases to be effective, they must be made in large enough quantities. The parasites (deployed as parasitized hosts) should be released as close to the recognized fly-larval place of development as feasible. When releasing parasitized pupae, make sure they are protected from harm, rats, and ultraviolet rays (if in a hot area). When selecting a commercial insectary, find out what species are offered and steer clear of items that contain *N. vitrinids*. When releasing, save a small amount from every batch and check it a week afterwards for exit pores in pupae or emerging parasitoids to make sure it arrives undamaged. For future reference, keep track of the quantity of parasites released and record the state of the fly populations. If at all possible, measure populations of flies over time using common fly monitoring instruments. Spot credit cards, paddle grids, and sticky traps are examples of such gadgets.

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