FLIES OF PUBLIC HEALTH IMPORTANCE

Portions of this chapter were obtained from the University of Florida and the American Mosquito Control Association Public Health Pest Control website at http://www.vector.ifas.ufl.edu.

Order Diptera, the flies, is one of the largest and most dynamic orders of insects. Adult insects in this vast order are characterized by having only one pair of wings and one pair of halteres, which are small knob-like structures located behind the wings.

Flies create some of the most common insect public health problems. Important around the world as vectors of major disease such as sleeping sickness, leishmaniasis and typhoid fever, in the U.S. they can be a major source of mechanically transmitted diarrheal illnesses and occasional cuticular disorders, such as pink eye. Because they can be associated with human excreta, flies can become involved in enteric (intestinal) disease cycles. Besides being annoying, some biting fly species may transmit pathogens that cause tularemia.

Some species deposit eggs or larvae on the flesh of living animals. Larvae then invade host tissues producing a condition known as myiasis, which occurs infrequently in humans in the U.S. Through sheer numbers, domestic non-biting flies can be a nuisance to people in their work, home, or recreational environment. Several species of flies and gnats are important household pests, not only because of the general annoyance, but also because of their association with filth and ability to harbor pathogenic organisms on their mouth and body parts.

I. DEVELOPMENTAL STAGES

Eggs. Most species of flies lay eggs, but a few species, such as flesh flies (Sarcophagidae), retain the eggs in the body and give birth to larvae. Flies are very specific in selecting oviposition sites. Such selectivity causes many females to oviposit at the same site, e.g., many filth flies oviposit preferentially on manure. This mass oviposition results in large egg clusters and concentrated masses of larvae in isolated spots instead of larvae being uniformly distributed throughout the breeding media.

Larvae. Larvae of most flies are thin-skinned, legless, cylindrically tapered maggots with a pair of mouth hooks at the tapered end, and a pair of breathing spiracles at the blunt end. Larvae can be identified to family and sometimes to species by the characteristic shape of the posterior spiracle. The mouth hooks are used primarily for tunneling. Larvae are able to eat solid food only after it has been liquefied by being predigested externally with secreted enzymes. The larvae, after reaching full development by going through several instars (usually three), migrate to a drier habitat if the media is too moist and enter a prepupal state in which they cease to feed before actually pupating. Larvae of most species will burrow about an inch into the soil to pupate. This burrowing ability is well developed. Larvae of certain species can easily tunnel to the surface when buried under 12 to 48 inches of soil.

Pupae. During the prepupal stage, the skin of the larva contracts and hardens into a protective shell for the fly developing within. This shell, called a puparium, is usually capsule-shaped and brown. The fly, after undergoing metamorphosis, escapes the puparium by breaking off a section

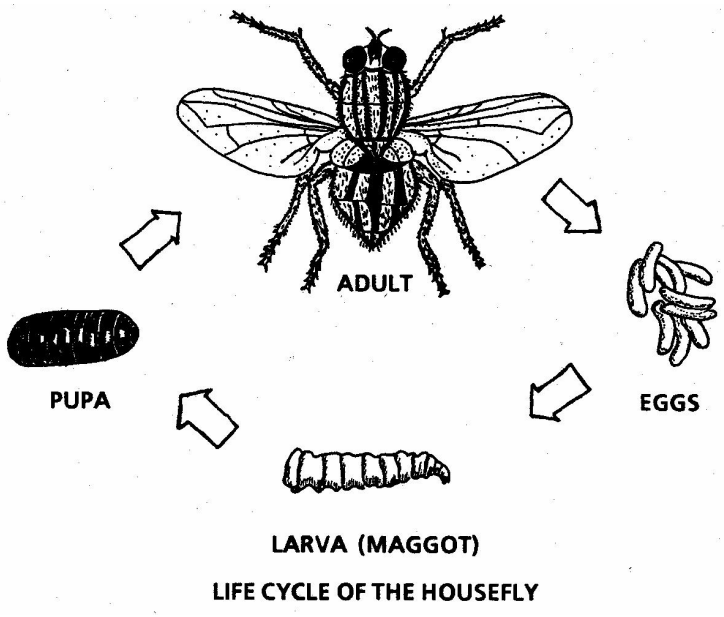
at one end of the puparium. Houseflies and most larger filth-inhabiting flies escape with the aid of an inflated balloon-like sac, called a ptilinum, that protrudes from the frontal portion of the head between the eyes. This sac, which is used to apply pressure to break the puparium, is withdrawn into the head after use. Newly emerged flies have shriveled wings and are usually pale and soft-bodied. They do not acquire their typical colors and shape until they have had sufficient time to dry and harden. The soft-bodied condition of newly emerged flies aids them in working their way through crevices in the soil. Newly emerged flies can easily reach the surface after being buried under 12 to 48 inches of moderately packed soil.

Adults. With a few exceptions in which the adult is wingless, adults have in common the single pairs of wings and halteres. Many flies have lapping-sponging mouthparts that require all solid food to be liquefied before ingestion. However, many other species are blood feeders and have various specialized piercing-sucking mouthparts adapted to their needs. In some groups both sexes feed on blood, whereas in others only the females do so. Flies have from one to several generations per year and exhibit a wide variation in this parameter, dependent on species and environmental conditions.

II. BIONOMICS AND HABITAT

FILTH FLIES

The housefly (*Musca domestica*) is one of the most common of all insects. It is worldwide in distribution and is a pest in homes, barns, poultry houses, food processing plants, dairies and recreation areas. It has a tremendous breeding potential and during the warmer months can produce a generation in less than two weeks.



LIFE CYCLE OF THE HOUSEFLY

Housefly eggs are laid in almost any type of warm organic material; animal or poultry manure is ideal. The eggs are laid in clusters of 75-150 and hatch within 24 hours into tiny larvae or maggots. After feeding constantly for four to five days, the larvae migrate to drier portions of the breeding medium to pupate. The pupal stage may vary considerably but in warm weather can be about three days. The adult fly emerges and crawls about rapidly while the wings unfold and the body dries and hardens. Mating occurs immediately and the cycle begins again. During warm weather the housefly may go through its entire life cycle in 8 to 12 days.

The adult housefly may live an average of 30 days and produce two or more generations per month. Because of this rapid rate of development and the large numbers of eggs produced by the female, large populations build up. Houseflies are strong fliers and can become widely distributed by flying, wind currents, vehicles and animals. Generally they are most abundant in the immediate vicinity of their breeding site, but may migrate one to four miles to find sources of food.

Houseflies feed by using sponging type mouthparts. As the fly moves about from one food source to another, it samples and eats its food by regurgitating liquid and dropping it on the food to liquefy it. Light colored spots called flyspecks are visible signs of this type of feeding. Darker flyspecks associated with houseflies are fecal spots. Because of their feeding habits, houseflies act as mechanical vectors of diseases such as typhoid and dysentery.

Other filth flies are the lesser housefly, face fly, blowfly, flesh fly and phorid fly.

BITING FLIES

Each year throughout the U.S., rivers, lakes and wetlands produce enormous hordes of blood sucking dipterans that are strong fliers and aggressive biters. Seldom is pathogen transmission an issue, but the severity of attacks is indicated by the fact that wild and domestic animals can be stampeded by these biting flies and many records exist of animal suffocation resulting from the overwhelming onslaught of these pests. Years of severe activity tend to coincide with or follow periods of above average rainfall that cause elevated surface water levels and an expansion of breeding habitat.

Tabanids. Horse flies are large, heavy-bodied flies which may reach up to 1 inch in length. Deer flies (yellow flies, green heads, etc.) are generally smaller (1/4 to 1/2 inch long) and their wings are often patterned with dark areas. Both groups belong to the family Tabanidae, in which only the females take blood meals. Tabanids range from green to tan and black in color, often with distinct markings with brightly colored or iridescent eyes in many species. Their bites are painful, and deer flies may serve as mechanical vectors of tularemia.

The larvae of most species are aquatic or semi-aquatic and are thus often associated with moist situations such as marshes, swamps, and shorelines of lakes and ponds. Deer fly larvae feed primarily on decaying organic matter, whereas horse fly larvae prey upon a wide variety of invertebrates, including each other. The larvae may molt well over 10 times before pupating and emerging as adults.

Although strong fliers, adults are often found around the larval habitat. But they may move considerable distances to find a blood meal. Both sexes feed on plant nectar and pollen to obtain energy. The female feeds on blood to develop eggs. Mating takes place soon after emergence. Once mated, the female deposits an egg mass on plants, rocks, sticks, or other similar objects usually over water or other favorable larval habitat. Egg masses are deposited throughout the life cycle of the female. Upon hatching, the larvae burrow into mud or moist earth and begin feeding. Depending upon the species and climatic region, there are usually one or two generations per year.

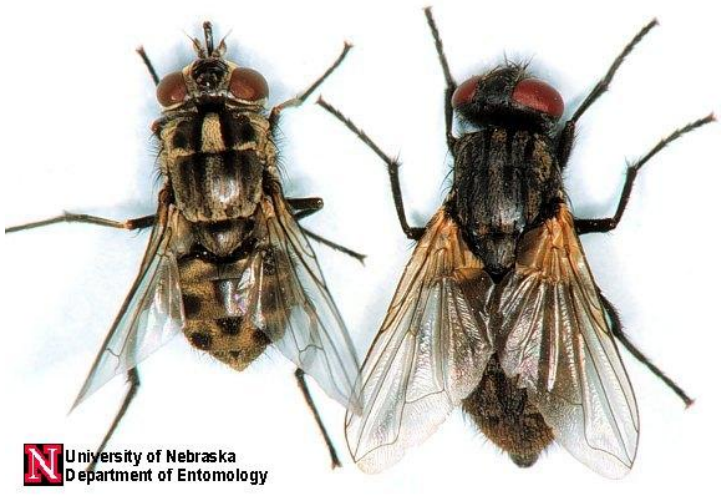
Black flies. Black flies (family Simuliidae) are found throughout the U.S. For example, over 30 species are found in the state of New York. They are also called turkey gnats and buffalo gnats. At least one species is known to be a mechanical vector of tularemia in humans, and they transmit some serious disease organisms to turkeys and ducks. Only the females are capable of taking a blood meal. When black flies bite, most people react rather violently to the anticoagulants that are pumped into the wound made with blade-like mouthparts. The bite may cause itching and swelling that sometimes persists for a week or more. Black flies are often present in very large numbers.

The eggs of black flies are dropped during flight into streams, where they settle to the bottom and accumulate in the quiet eddy pools of the stream, or they are laid in the stream on rocks or other objects over which is flowing a very thin film of water. Some eggs hatch within a few days and others may not hatch for months or until the next spring. Eggs survive even when the streams dry up and then hatch almost as soon as the streams start to flow and the larvae are found in great numbers attached to stones, sticks, and vegetation that trails in the water. The larva moves about either by attaching to small pads of silk that it secretes or by hanging to a silken thread. Large mouth brushes screen food from flowing water. The food is largely bacteria, algae and protozoa. The mature larva spins a slipper-shaped cocoon that is attached to the surface on which the larva fastened. Within the cocoon the larva transforms to the pupal stage. In a few days the pupa transforms to an adult.

The adult black fly emerges from the pupa and rises quickly to the surface of the water. It can immediately fly away and, with large flight muscles, is a strong flier. They disperse rapidly and flights of more than a mile are common. Some species have a single brood each year that may emerge very early in the spring or in early summer. Species that produce several broods each year are commonly found in the warmer streams.

Stable fly. The stable fly or dog fly, *Stomoxys calcitrans*, is similar in appearance to the house fly in size and coloration but the mouthparts of both sexes are adapted for piercing the skin and taking blood. Larvae and pupae are similar to those of the housefly. The life cycle of the stable fly is similar to that of the housefly but takes about twice as long under similar conditions. The stable fly breeds in urine-soaked straw, spilled green chop or manure if it contains a high proportion of straw, and in vegetation strewn along shorelines of lakes and bays. Accumulations of wet grass clippings from yards and golf courses, spilled straw, and compost piles also are breeding places. The stable fly prefers a more moist breeding area than the housefly and larval development takes 10 days to two weeks.

Stable flies are capable of long distance movement, which occurs when they are picked up by weather fronts and carried for several hundred miles. Uninfested areas thus can become heavily infested almost overnight. This phenomenon can occur often and has been documented with observations of flies moving from Nebraska to Florida in this manner. These aggressive and painful biters can disrupt recreational activities and are capable of mechanical transmission of some animal disease pathogens.



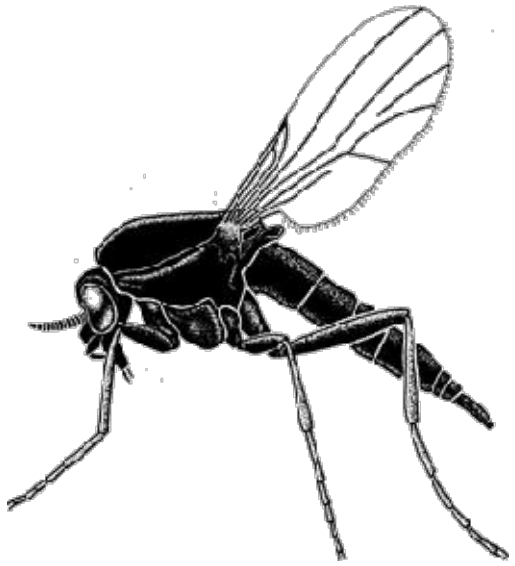
Comparison of the stable fly (left) and housefly (right). The stable fly has a mouthpart adapted for piercing the skin and sucking blood. The housefly has a sponging mouthpart for feeding on liquefied food. Photo courtesy of Jim Kalisch, University of Nebraska-Lincoln.

Biting midges. These insects in the family Ceratopogonidae are tiny, but very aggravating biters sometimes called "no-see-ums, “punkies" or "salt marsh sand flies". Belonging to the genera *Culicoides* and *Leptoconops*, they breed in intermittently inundated fresh, brackish and salt-water habitats or in moist soil, often associated with specific marsh or pasture grasses. Intertidal areas along the coasts are prolific development sites for biting midges, often with enough species to ensure that at least one is actively foraging each morning, afternoon or evening of every day in every season where climate allows continued breeding. Upland farm ponds provide breeding habitat along the edges. Only the females bite.

Culicoides larvae develop in moist soil rich in organic matter. Damp areas at the edges of ponds, swamps and manure lagoons are the more favored breeding sites. Several generations can be produced each year. Adult stages rarely fly far from breeding sites. Most biting occurs at dusk with a secondary peak period of biting at dawn. Where conditions allow, breeding adult insects can be present and produce problems for months. In New Mexico, *Culicoides sonorensis* is the vector of blue tongue virus, a disease of sheep and cattle.

The vicious daytime biting midge belongs to the genus *Leptoconops*. Persistent attacks by swarms of biting midges inflict painful bites and frequently result in allergic reactions characterized by intense itching and swelling. Work and recreational activities in affected areas often are impossible during peak fly activity. Control of biting midges is extremely difficult. The small size of the fly allows it to penetrate most mosquito screening and netting. In addition, the known habitat consists of moist sandy alkaline or saline soils spread over large expanses, increasing both the costs and potential environmental damage from attempted larval control. Protective clothing and repellents are probably the only cost-effective means of relief for humans entering habitats of biting midges during peak activity periods. These peak periods usually occur during a single period of the year, lasting about three to four weeks. Emergence of the adult insects usually follows late spring or early summer rains. Emergence may be delayed by drought.

Because the breeding sites are widely dispersed and often inaccessible, control of larvae is impractical. Effectiveness of adult control through area-wide insecticide sprays has never been successfully demonstrated and would likely produce poor results because the adult insects may fly considerable distances from breeding areas. The insect repellent DEET is effective against these insects.



Biting midge

III. CONTROL

Filth fly problems represent excellent opportunities to apply sanitation and environmental tactics to manage the pest populations. Common pests, such as the housefly, have been exposed to so many pesticides over the years that many populations are highly resistant to most classes of insecticides. But, where they can be a problem, strict attention to management of breeding sites is highly effective. Through this mechanism the need to control adult flies can be minimized.

For many other flies, especially the blood feeders, larval habitat can be large, diverse, and ecologically sensitive. In many situations, control technology for adults is simply not available or is often uneconomical because of the dimension of the problem. However, in most cases there are ways to get relief and maintain activities in their presence.

FILTH FLIES

Sanitation. Environmental control consists of cleaning garbage collection areas and the residues found at bottoms of trashcans, keeping loading docks clean, and using other physical measures to prevent breeding. Twice-a-week garbage collection is the minimum recommended frequency for adequate fly prevention. Plastic bags should be used for storage and disposal of wet garbage and food wastes. Garbage cans and dumpsters should have tight-fitting lids and be kept closed. Open dumps have been replaced by sanitary landfills that compact the daily dumping and cover it with soil. This method reduces odors and fly breeding. Daily compaction and twice-a-week soil cover is the minimum frequency for adequate fly control.

Human excrement, loaded with pathogenic organisms, is a dangerous source of fly breeding. Open pit privies, cesspools and surfacing sewage from failed systems must be replaced with properly working systems or community sanitary sewers.

The primary cause of excessive fly breeding at animal farms is often poor water management. Manure that is wet but not saturated is conducive to fly production. Poorly constructed effluent ditches and leaking watering systems account for much of the wetting of manure that causes fly breeding. Any recommendations for fly control should give water management first priority for the permanent reduction of fly breeding. Proper grading of the land to ensure rapid drainage during the rainy season is an important feature.

Regular removal of accumulated manure from dairy buildings and outdoor animal pens should be practiced as a routine management feature, at least twice per week. Collected manure should be spread to dry (if there is adequate agricultural land). Housefly breeding can be eliminated in manure where the moisture content is 30 percent or less. Alternately, large dairy farms often have lagoons in which water is added to the manure to liquefy it. Drying usually is preferable because dry manure can be handled more easily, occupies less space, and creates fewer odor problems than does liquid manure. If using a liquid manure pit, do not allow accumulations of manure above the water line, either floating or sticking to the sides, since this is ideal for fly production. Do not let wet straw or other decaying organic matter accumulate in or near the buildings.

Dry manure is also the key to fly control at poultry farms. Collected manure should be stored in cone-shaped piles; these piles reduce the surface area for breeding while the heat from fermentation makes the interior unsuitable for the flies. The outer surfaces of these piles dry rapidly and tend to narrow the zone in which the larvae can develop. Leaking watering systems should be repaired and manure cones under cages not removed unless absolutely necessary since they act as a sponge to rapidly dry the fresh manure. House fly breeding occurs under cages in which manure cones have been removed because of the slower drying of the fresh droppings.

Daily washing of hog pens and adequate wash water lagoons greatly minimize fly breeding at hog farms. Breeding along effluent ditches can be eliminated by construction of concrete-lined ditches, an expensive action often rejected by farmers. But with the rapid suburbanization of rural areas, and the ensuing complaints of fly nuisance, it may turn out to be the cheapest and most effective method of control.

Indoor pests, such as the phorids and filter flies, fungus gnats, and fruit flies can also be controlled by sanitation measures, repair and cleaning of pipes and drains, and reduction of moisture levels in potted plans and other breeding sites.

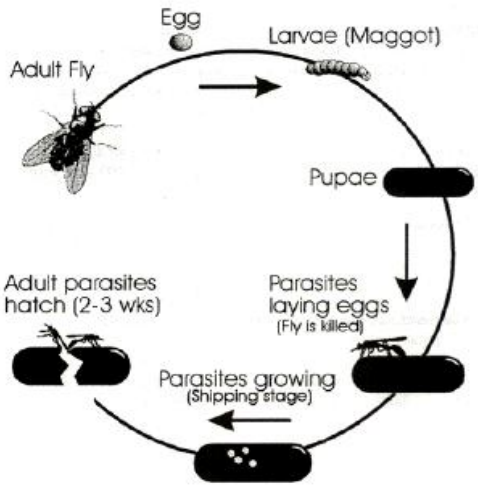
Screening and caulking Window and door screens are the most effective fly exclusion method, although occasionally tiny flies, such as fungus gnats, will pass through 16-mesh window screens. While these tiny flies can be prevented from entering by painting the window screens with varnish to reduce the mesh size to 23 mesh equivalent, that also reduces movement of air through screens. Paying special attention to gaps, tears and failure to close by sealing, caulking, repairing and installing automatic door closers can be highly effective at reducing entry.

Commercial establishments successfully utilize air curtains that are created by specially manufactured fans placed above doorways to produce a draft that is strong enough to prevent flies from entering. Air conditioning has significantly reduced the presence of flies indoors in stores and in homes.

Electrocution devices. Electric zappers are effective only in the context of the overall program. By themselves, they cannot control a fly population. Often such devices are used in conjunction with a black light attractant. This ultraviolet light may be harmful to eyes under prolonged exposure so their placement should be done with care, beyond the range of other lights. However, because zappers cause insects to explode and fragment and thereby contaminate nearby objects and space, their use indoors has been replaced in commercial establishments with low voltage traps. These traps use ultraviolet black lights to attract the flies. The electronic grid in front of the black light disrupts the fly's nervous system, causing it to fly down onto a non-toxic adhesive trapping board. These traps are only for use indoors and must not be visible from the outside, to avoid attracting flies into the building. Replacing white security bulbs with yellow bulbs can also reduce attraction of flies to buildings.

Fly traps. In addition to the electronic traps mentioned above, several other fly traps have been developed. The original fly trap was fly paper that was placed or hung in areas where flies frequent. Other fly traps use an attractant to entice flies into a container where they cannot escape or will drown in liquid. Traps are most effective when used in conjunction with sanitation.

Biological control. Several natural parasites and predators forage on fly larvae and pupae. Fly programs based on sanitation, rather than pesticides, are more likely to benefit from these influences. One type of natural predator is the parasitic wasp. These wasps (which are not harmful to humans or animals) lay their eggs in the fly pupae; the wasp larvae feed on the fly pupae and kill them. The wasps live their entire life cycle on or near the surface of the manure and other decaying organic matter where the flies are breeding.



Life cycle of a Parasitic Wasp

Parasitic wasp preparing to lay egg
(Photo courtesy of Jim Kalisch,
University of Nebraska-Lincoln)

Poison baits. A liquid bait trap works well for blowflies and houseflies and is capable of eliminating temporary infestations in small areas and reducing fly populations in larger areas if many traps are used. Dry, commercially prepared sugar-based baits are effective if properly used, and become more effective when placed in plywood trays or other shallow containers that retain dead flies. The decaying odor of accumulated dead flies makes the trap even more effective. Dry bait must be scattered, not placed in a pile, and placed where animals cannot eat or lick the bait. Dry sugar baits are generally unattractive in areas that are hot and dry; wet baits should be used in these dry areas.

Outside residual sprays. Flies alighting on surfaces treated with residual sprays either absorb the toxicant through the feet or ingest it with the mouthparts. However, because flies have become resistant to most insecticides this method is now seldom practiced.

Larvicides. Larviciding with insecticides is not recommended unless judicious care is made in its application. Indiscriminate larviciding kills valuable parasites and predators of flies. That most nuisance flies have specific preferred breeding sites makes possible the treatment of those breeding areas that contain only the nuisance species. Long lasting residual insecticides are unnecessary since the exact conditions that attract egg-laying lasts only for a short period and makes continued breeding in the same spot unlikely. These spot treatments will not appreciably affect fly parasites since most usually attack the pupal stage. Predators are also not greatly affected since they do not congregate in large numbers at these sites. Larviciding should be used only when other measures are either not possible or are unsuccessful. Spot treatments with insect growth regulators are preferable and more beneficial than those made with other types of chemical larvicides.

The most effective filth fly control involves an integrated approach using sanitation, mechanical and biological control. Pesticides should only be used as an adjunct to these other methods, not as a substitute for it.

BITING FLIES

Some of the measures used for non-biting flies are effective at reducing human exposure to biting flies - screens and other exclusion devices for most species and management of breeding habitat for stable fly control. But for the most part, control of these pests is quite specialized, and often economically restrictive.

Larval control. Black flies are highly susceptible to *Bacillus thuringiensis* var. *israelensis* (Bti). When applied to the streams where black flies breed, their filter-feeding behavior effectively captures the particles containing the bacterial spores that contain toxins specific for Diptera. Ingestion of these particles releases the toxins from the dead bacteria into the larval gut, thus killing the larvae. Treatments are conducted either by air or by point application from bridges or other fixed locations on the river or stream. The bacterium remains suspended in the moving water for several miles downstream and is picked up by black fly larvae as it passes.

Stable flies can be controlled in the larval stage by application of insecticide to the breeding habitat (freshly cut and rotting plant materials) or by removal or covering (exclusion) of the breeding substrate.

Adult control. Stable fly adults frequent the beaches in the southern U.S., where they drive tourists and residents alike away from their vacation and entrepreneurial activities. The resulting impact on the local economy is such that aerial insecticide application is routinely called upon to provide relief. Application designed to drift the formulation onto the beaches provides temporary control of these vicious biters.

Most blood feeding dipteran adults, including black flies, tabanids, and biting midges, can be controlled by ULV applications of the appropriate pesticide. However, the relief is very temporary, as these pests quickly re-infest the treated areas and nullify the control achieved. Thus, while effective, this type of control is not commonly conducted. Homeowner outdoor space spraying using a power mister to clear a back yard for a few hours is a relatively common occurrence.

These same insects can be managed with residual applications of insecticides. For example, homeowners can apply insecticides to window screens to kill biting midges that are trying to access the interior of the house. These applications may persist and remain effective for several weeks. In similar fashion, insecticides can be applied to shrubbery and other resting sites of these biting flies to serve as an effective barrier to pest infiltration for a week or two.

Carbon dioxide trapping of biting midges has been shown to protect guests and residents residing within a perimeter of such traps. As long as the carbon dioxide is released, the midges are trapped and do not reach their normal hosts. Similar findings have been reported with mosquitoes.

Tabanid flies are fairly strongly attracted to movement and dark objects. Some species can be controlled on a backyard or community basis by hanging insecticide-treated black spheres from branches and other suitable supports. Personal protection with repellents should not be underestimated. Several commercially available repellents are quite effective against biting flies.