VECTORS AND CONTROLLING THE RISKS THEY POSE TO DISEASE TRANSMISSION

Maxcy P Nolan, III, Ph. D. *NIPCAM*

OVERVIEW

Nolan Integrated Pest Management (NIPCAM)'s approach to Integrated Pest Management (IPM) addresses five individual zones: the living area of the birds, the interface wall or fence between that living area and the immediate outside environment, a 'buffer zone' of approximately 30m surrounding the house in all directions, a broader 300m zone surrounding the farm, and the greater outside world. Within each of these zones, the identification of vectors is key to a sound IPM program. The scope of this paper includes specific descriptions of the five environmental zones designated by NIPCAM, vectors common to each, identifying features of those vectors, and management techniques as applicable.

Vectors are defined as any agent, person, animal or microorganism that carries and transmits an infectious pathogen into another living organism. Therefore, it is crucial to identify vectors and to establish programs designed to keep them from contacting your flocks. The goal of the combined IPM program is to reset the vector and pathogen loads to as close to 0 as possible. It is important to implement monitoring between or before flock placements to determine the levels of various key pathogens and vectors.

Currently, NIPCAM's concept of IPM maintains that there are three areas that are of concern when establishing a robust program for the control of vectors.

1) Microorganisms inside the bird: The first line of defense, and important part of the IPM program, is a sound vaccination plan that provides the birds with a high level of protection from pathogens. This is the poultry veterinarian's responsibility.

2) Microorganisms in the first two zones of protection (inside of house, interface wall/fence): These pathogens should be eliminated by a thorough cleaning and disinfection program. The efficacy of these treatments should be evaluated before birds are introduced into the housing areas of the farm. It is important to note that pathogens can be broadly categorized into two types: those that cause harm to the poultry, and those that do not seem to affect the birds, but instead cause problems for humans. Examples of the latter include Salmonella, Campylobacter, and some types of E. Coli. Both types are harbored by the vectors noted below.

3) Vectors (or carriers) of those microorganisms: Common vectors include rodents, insects, larger mammals, reptiles, and other birds. However, air, water, vehicles, and even other people can serve as carriers as well. Vectors must be identified, monitored, and, if plausible, controlled. Further, programs must be implemented to evaluate and manage any new or emerging threats in the same way. NIPCAM's primary focus is here, on the vectors that carry microorganisms, rather than the microorganisms themselves.

The task of controlling poultry exposure to vectors is a challenging one. Poultry raised outdoors, in particular, are at a higher risk of contact with vectors that could cause mortality or pass on disease than those raised in confined areas. This is why over time it has been proven prudent to house poultry in spaces that do not provide open opportunity to the vectors. However, regardless of whether poultry are raised in confined or outdoor environments, the fact remains that the entire outside world cannot be regulated, nor controlled, to prevent the potential movement of vectors into close proximity. It is therefore important that risk zones be established to help delineate areas of most concern and aid in determining the best use of the IPM budget.

NIPCAM has identified such zones as displayed in Figure 1. They include:

1) Zone 1: The actual living area of the birds, i.e. inside the poultry house or barn. In free-range operations, this zone is still applicable.

2) Zone 2: The interface wall/fence between the area where the birds are and the immediate outside environment.

3) Zone 3: A 30 metre zone containing the access to the houses or barns and the movement between them. It should also include any feed holding areas, supply storage areas, and required biosecurity/office areas of the farm managers and workers.

4) Zone 4: The area within 300 metres of the facility.

5) Zone 5: The area beyond 300 metres of the farm.

ZONES

ZONE 1

The first zone is the most critical area in inspecting, identifying, and controlling the pests that can cause concerns as vectors. The birds' living space must be inspected for cracks, crevices, and similar areas that may exist as harborage areas, or places where small pests reside. A good flashlight is critical for this purpose.

Feed lines and bins are other areas require special consideration. Beetles in particular have been observed emerging from feed systems prior to birds even being placed. Likewise the number of darkling beetles and the presence of pathogens on them can be determined by visually assessing their population between flocks and the carcasses of the killed beetles removed to the greatest extent possible before new birds are placed into the new farm.

Pests commonly found in this zone include beetles, stored grain pests, flies, and rodents. Control programs for each identified pest should be implemented or anticipated based on the stage of the flock. Spec cards, moving tapes, traps, and bait stations are all control measures typically found in Zone 1.

ZONE 2

The second zone, or interface wall/fence between the area where the birds are and the immediate outside environment, must be similarly inspected. Zone 2 inspections involve checking the soundness of the doors, observing feedline penetrations, and identifying harborage areas located along the perimeter of the facility. Caulking that has aged and peeled from the exterior should be noted, as it can harbor pests as well. Particular attention should also be paid to eaves and overhangs where birds often build nests.

Common pests seen in this area are rodents, wild birds, reptiles, amphibians, and beetles. In some geographic areas, ants may be found in this zone as well. Zone 2 provides a convenient space in which to place outside monitoring and control devices for house flies and rodents. These devices include baits and traps.

ZONE 3

A 30m buffer zone surrounding the houses or barns constitutes Zone 3. This zone should also include any feed holding areas, supply storage areas, and required biosecurity/office areas of the farm managers and workers. The sophistication and requirements of this area should be determined by the risk and the value of the poultry housed on the facility.

Once inside Zone 3, the vegetation should either be eliminated or kept to a minimum, utilizing either close mowing of grass or placement of landscape cloth and gravel. This both eliminates harborage areas for vectors and allows for effective inspection. Owner/managers may choose to mark the outside border of Zone 3 with fencing (including electric), thus providing further security for Zones 2 and 1 at the same time. Jug traps are a means of house fly monitoring and control that are commonly utilized in Zone 3.

ZONE 4

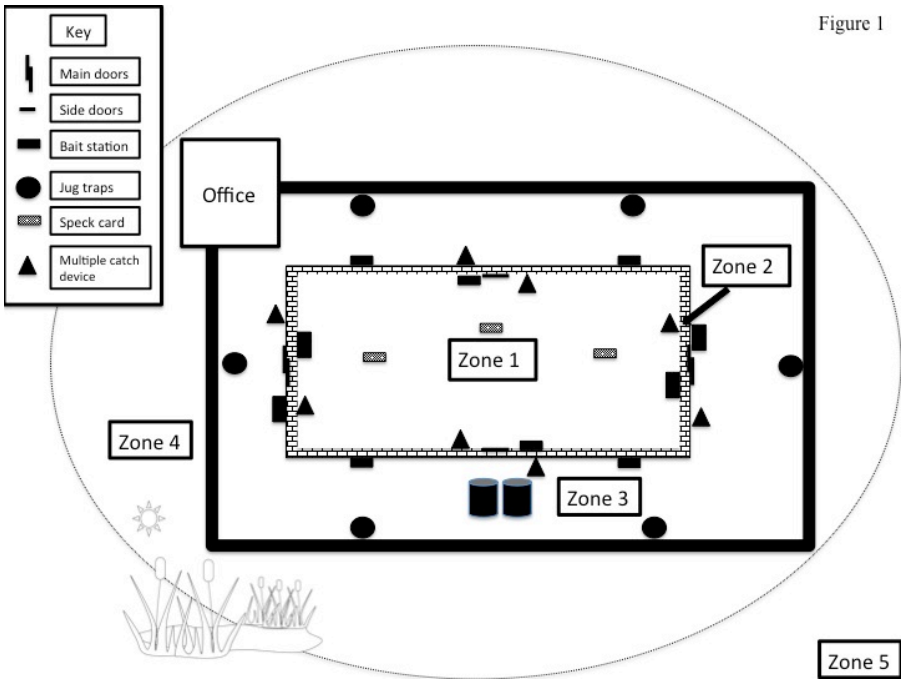
Zone 4 essentially extends the 30m buffer zone surrounding facilities to 300m. All brush and building debris should be removed from the entire farm area to reduce the amount of harborage areas available to rodents, wild birds, and other animals.

It is also important to note that the farm site should not contain bodies of standing water. They attract waterfowl and other animals looking for drinking water, as well as provide breeding grounds for insect pests. Additionally, when the water dries, animals may move closer to poultry houses, providing opportunities for disease transmission. For vehicles travelling into Zone 4 from outer locations, tyre disinfectant is a sound contagion control option.

ZONE 5

Unlike its predecessors, Zone 5 does not have a finite end point; it begins at approximately 300m out from facilities and extends indefinitely. The important differentiation here is that control of vectors in Zone 5 is virtually impossible. It is simply too vast and contains too many variables that are out of the poultry house owner's control. For that reason, monitoring is the aim here. It is critical to be aware of neighbouring farms and of both current and recent disease outbreaks, to start. Although it is impossible to control what your neighbours do and to completely isolate your farm from microorganisms, basic knowledge of what's going on around you is an important part of the monitoring program.

Figure 1



COMMON VECTORS

RODENTS

The Norway rat, Roof rat, and House mouse are the three rodents responsible for most of the damage to the poultry industry. They damage poultry housing, consume and contaminate feed, and harbor and transmit disease. Their control is dependent upon a thorough understanding of their individual habits, food and harborage requirements, capabilities and points of vulnerability. However, a successful rodent control and monitoring program is possible with IPM.

INSPECTION

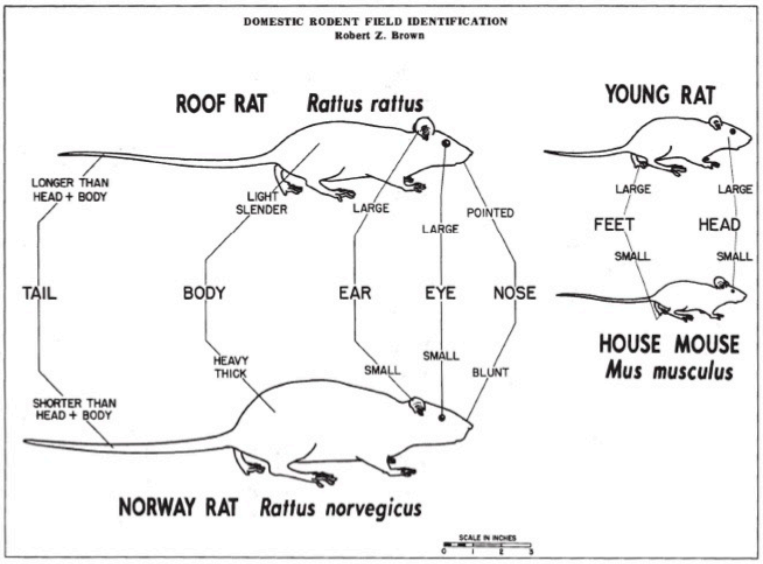
Indications that rodents are present include:

1) Visual sightings of rodents or droppings.
2) Burrows in walls, floors, and pits.
3) Signs of fresh dirt when burrowing outside.
4) Chewed wires and water lines.
5) Dark/oily stains along walls at the floor and ceiling.
6) Gnawing marks that are pale in colour.
7) Areas where insulation has been removed.
8) Presence of wood chips around boards, bins, or crates.
9) Areas where dust was brushed away near holes, cross beams or running areas.

IDENTIFICATION

The three rodent species, while superficially similar, are easily distinguished from one another. Not only are these animals relatively easy to tell apart, but their behaviour and biology help to make them even easier to identify. Each has key physical and behavioural features which separates it from the others and which are essential to identify in setting up an effective control program. For a key to common rodents, please see Figure 2.

Figure 2



The largest species is the Norway or gray rat. This animal is large, weighing up to ½ - ¾ pound (230 – 340 g, even though it may seem larger), achieving almost a foot (30 cm) in length. Its tail is shorter than its head and body combined and its head is blunt with rather small eyes and ears. Juvenile gray rats have heavy tails and feet with relatively large heads as compared to roof rats or mice. Norway rats are extremely social, usually maintaining burrows in the soil (to keep an even cool temperature). A cornered rat, however, can be a substantial adversary even for a large dog or cat.

Roof rats are smaller than gray rats, with a tail that is longer than the head and body, a more slender torso and abdomen, a large head with somewhat pointed nose and moderately large ears (compared with the gray rat). These animals are more independent than gray rats and are often found nesting above ground within structures. They seldom achieve the high population density found in gray rats but, with their flexible habitat requirements, can be more difficult to isolate and exterminate.

The house mouse is sometimes confused with infant rats. They are easily distinguished once one has seen the two side by side. Mice have thin feet and tails, a small pointed snout and relatively large, thin ears. They are much more rapid in their motions and vicious in their temperament, even towards each other. Since they weigh only a few ounces, have a pointed skull, and are physically flexible, they can move through openings that seem smaller than the animal.
The three species can be separated by identification of their faeces. This can be complicated, however, by the presence of roach faecal pellets and by the fact that a variety of faecal-feeding (scatophagous) insects are often in the same area of poultry farms infested by these rodents.

All three species can migrate moderate distances in order to find food sources, even swimming up to ½ mile (804 m) to cross small lakes and streams. Rats can jump as much as three feet (91 cm) vertically from a standstill and survive a 50-foot (15.2 m) fall without serious injury. Both Norway and roof rats range 100-150 feet (30.5 – 45.7m) from their burrows in search of food and require an ounce of water per day to survive while the house mouse tends to stay within 14 -30 feet (4.5 – 9.1 m) of its burrow and can survive using water in its food for several days. All prefer cooler temperatures and dark conditions. Therefore, they are most active at night or in the subdued light found in poultry houses. Since they tend to avoid brightly lit areas that have lots of human traffic, they are seldom visible unless there is a very high infestation.

MONITORING

Rodents are one of the key vectors that can, and should, be reset to 0. This can be achieved by effective monitoring in Zones 1 and 2 and follow-up treatment as necessary.

All too often, rodent control breaks down during a flock as a result of a lack of monitoring. With no measurable indications of the level of a rodent population, the first indication of a mouse or rat problem is frequently the appearance of large numbers of rodents. A large population, unfortunately, is necessary for a typical poultry worker to visually notice the presence of live rodents.

Rodent inspection must be performed at regular intervals of no longer than 2 weeks. Rodent indications of harborage (burrows, tunnels and holes in the structure) should be baited and covered. Numbers and locations of these sealed rodent burrows must be recorded. Traps are helpful in monitoring the rodent population as well. Multiple catch devices can catch and hold mice for several days, and can be checked on a two-week monitoring schedule. Rats are a bit more difficult, as they tend to avoid traps that contain other live rats. Therefore, traps need to be checked and emptied more frequently. Evidence of rodent feeding on baits in rodent bait stations and the capture of mice or young rats in multiple catch rodent traps should be recorded. For an example of an appropriate rodent record form, see Figure 3.

Rodent Monitoring Check List for Poultry Facilities

Figure 3

I. Bait Station Inspections

Date of Insp.	Station No.	Activity Sign (bait feeding, etc.)	Date of Insp.	Station No.	Activity Sign (bait feeding, etc.)

II. Multiple Catch Rodent Trap Inspections

Date	Trap No.	No. of Mice	Date	Trap No.	No. of Mice	Date	Trap No.	No. of Mice	Date	Trap No.	No. of Mice

III. Incident Report (Rodent Sightings, etc.)

Date of Incident	Description (rodent sighting, feces found, burrow found, etc.)

CONTROL

Visual inspections should be augmented with trapping, whereby multiple catch devices and bait stations are deployed throughout the area and consumption of bait and the numbers of captured rodents are recorded. It is advised to delay flock placement until the population levels have been reduced to 0.

Rodent baits should be rotated regularly. Rodents can become behaviorally and biochemically resistant to baits, so changing the active ingredient with every couple of months is helpful. Mouldy or old bait should be replaced, and bait stations that are fed heavily on refilled.

Norway rats drink daily, so liquid baits are a good addition to dry baits. Provide a variety of baits at first, observe daily what is eaten, and then give rats as much as they can eat on a daily basis. Burrows should be heavily baited, sealed with dirt or gravel, and then rebaited and resealed daily until there is no more activity.

Additionally, all rodent harbourage areas, both in inner and outer zones, should be sealed or removed as applicable.

With birds present:

1) Identify, bait, and seal all rodent burrows. Be attentive to building deficiencies.

2) Maintain all multiple catch traps and baited bait stations by inspecting them at least once every 14 days.

3) Bait rotation and other specifics should be determined in an ongoing manner

4) Ceiling openings can be baited and sealed with tape.

As soon as birds are removed:

1) Remove all feed from feeders, hoppers, lines, etc. and clean any spilled feed.

2) Turn off all waterers, if necessary, place rodent bait watering stations.

3) Remove all multiple catch traps and bait stations from barn. Clean and replace them after house has been blown down and passed inspection. Make every effort to keep all traps and stations in barn as much as possible.

4) Identify, bait, and seal all rodent burrows. This includes baiting and taping all openings in the ceilings and insulation.

5) Bait for rodents by alternating between bait blocks, pellets, and/or place packs by placing bait at the base of every other cage support leg at the floor and every 15 feet (4.5 m) along dropping boards.

6) House should be baited with fresh bait until new birds are housed.

7) If applicable, litter, including manure, should be removed for cleanup as per the integrator's instructions. Be especially sure to remove any caked litter that is against the walls since this harbors darkling beetles, house flies and rodents.

8) Open cracks in concrete block foundations should be resealed at this time. Openings into concrete block walls offer perfect rodent nest sites so they must be sealed with mortar.

HOUSE FLIES

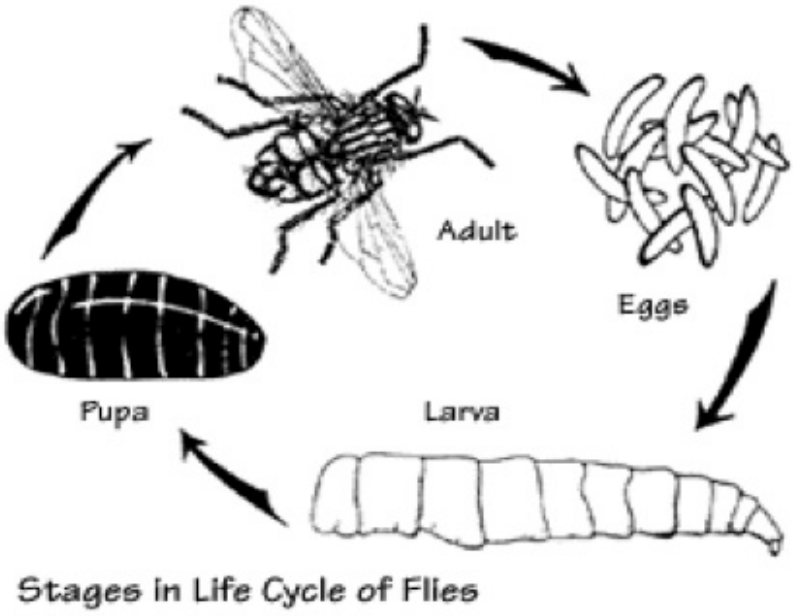
Several fly species are commonly found on the premises of poultry facilities. House flies (*Musca domestica* L.) constitute the biggest problem since they breed rapidly in chicken manure, litter, and feed spills. They require moist to moderately wet environments and can generally be kept in check by controlling moisture and food sources. The lesser housefly, black soldier fly, and dump flies are also found growing in chicken manure, but each has its own habitat requirements that usually limit them from being pests. In fact, the black soldier fly and dump fly can be used for housefly control since they either feed on housefly larvae or liquefy the manure to a point that house flies cannot use it.

Adult flies are the transmitter of many of the most serious diseases of man including Salmonella, cholera, and dysentery. Because of this, their numbers should be routinely monitored to determine if treatment is necessary. Although house fly problems can emerge anywhere, cage layer and slatted breeder houses seem to have more issues with flies than broiler houses.

LIFE CYCLE

The house fly life cycle is typically 10-28 days depending on the weather conditions. House flies have complete metamorphosis, meaning they have a 4 stage life cycle consisting of eggs, larvae, pupae, and adults. For a visual representation of the house fly life cycle, see Figure 4.

Figure 4



Stages in Life Cycle of Flies

House flies typically lay eggs on animal feces and garbage. The eggs are small, white, ovate structures, and they typically hatch in 24 hours. White, legless maggots (the larval stage) hatch from the eggs and grow to about ½ inch (1.3 cm). The maggots grow by consuming stratus located in the manure in which they reside. As the maggots feed, they moult three times in order to become large enough to pupate.

When fully grown, maggots crawl away from their food source to undergo the pupal stage. They form a dark brown cocoon, known as a puparium, and later emerge as adult house flies that can fly one or two miles (1.6 – 3.2 km) in search of suitable egg-laying sites.

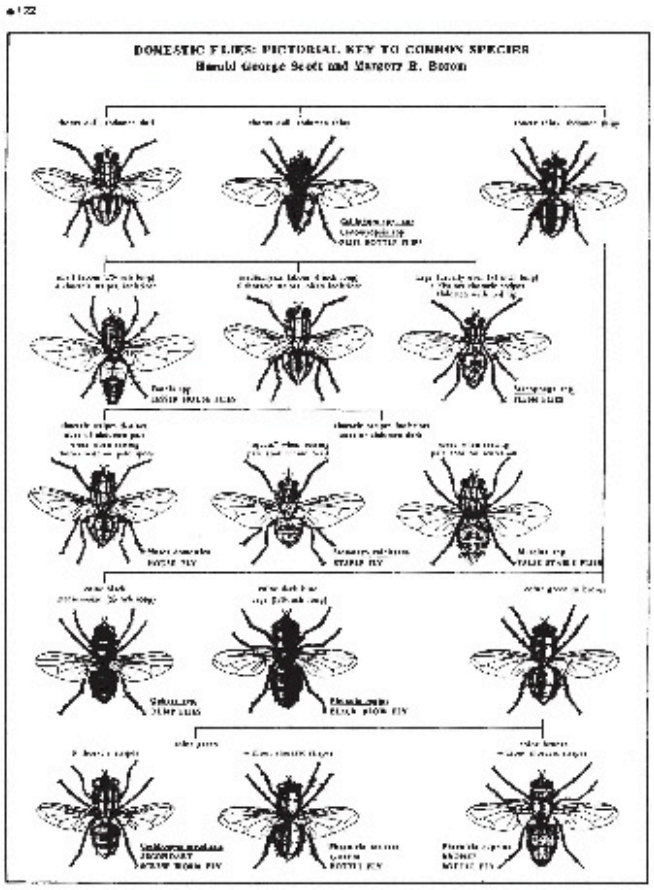
INSPECTION

Adult house flies are readily visible within the poultry house. Generally, house fly larvae are found in wet manure in the poultry house, or where rain has moistened the dry litter that has been spilled at clean out. Careful observation of the manure conditions will reveal coffee-ground-appearing areas that contain large numbers of maggots. These areas should either be removed or treated with an acceptable larvicide to prevent them from pupating and becoming adult flies.

IDENTIFICATION

The common house fly is a dull gray fly, ¼-inch (0.6 cm) long with four dark stripes on the middle section (thorax) of its body. For a visual comparison of the house fly to other flies, see Figure 5.

Figure 5



MONITORING

Speck cards, moving sticky tapes, and bait stations can all be used to determine the number of house flies present in the facility. All are placed within Zone 1.

SPECK CARDS

These are commonly used in houses where manure is allowed to accumulate, either under slats or in cages. Speck cards consist of 3x5 index cards posted in each house. Cards should be evenly spaced throughout the house, at approximately 30m intervals. Cards will be replaced weekly. The count on the card will be the number of flyspecks counted on the lower half of the card front. The correlation between the historical number of flies present with the number of specks deposited on the card allows for determination of a threshold. This threshold should be modified depending on how close the farm is to neighbors. The cards need to be saved as a record of the fly population at any given time. Speck cards are also useful in determining historical house fly populations as they can easily be catalogued and stored.

MOVING STICKY TAPES

These are often utilized in houses in which manure accumulates. To conduct a sticky tape test:

1) One commercial sticky bug and fly ribbon tape should be unwound so that it hangs fully extended.

2) The person performing counts should hold tape beside them so that it hangs about waist high.

3) Holding tape in this manner, counter should walk down the row next to outside row (not outside row itself) at a normal walking pace.

4) Upon reaching the opposite end of house, counter should proceed to other side of same house and walk down the row on that side next to outside row at a normal walking pace.

5) Upon completing this walk, counter should count the number of house flies on each side of tape and record on a fly monitoring form; see Figure 6.

6) If total house flies on one-tape number more than 50 house flies, supervisor should be notified for further action. Further action could include, but is not limited to, spraying insecticide, posting fly strips in barns or on posts in deep pits.

Moving Tape Fly Count

Figure 6

Date	House/ Location	No. of Flies	Initials of Counter	Date	House / Location	No. of Flies	Initials of Counter

LARVAL MONITORING

Larval house flies are monitored daily by the pest management specialist. Coffee-ground-like areas should be visually inspected for larvae. The number of larvae present should be determined by the number of hot spots (coffee-ground-like areas) in the house. Treatment decisions regarding larvae should be based on the percentage of the manure infested.

CONTROL

MANURE MANAGEMENT

Fly control is primarily a manure management strategy. Dry manure reduces the suitability for flies to breed and provides a desirable habitat for natural fly predators. The keys to controlling this environment include moisture management, sanitation, and manure removal.

Fresh manure contains 75 to 80 percent moisture and flies can breed in manure containing 50 to 85 percent moisture. Therefore, controlling manure moisture levels is the single most important factor in fly population reduction. The following are examples of strategies used for fly control:

1) Shovel and pile manure in pits multiple times each week.
2) Hang fans in deep pits to aid in manure drying.
3) Pit crews inspect for water presence.
4) Eliminate all sources of water in pit (i.e., exterior seepage, leaks from overhead water lines, condensation).
5) When possible, utilize outside air to accelerate the drying process.
6) Jug traps can be deployed around the perimeter of the facility in zone three to intercept house fly adults that may be leaving or migrating towards the poultry operation.

ADULT FLY CONTROL

Adult flies can be killed with baits, residual sprays, and insecticidal fogging. If fogging is used:

1) Fogging needs to be done early in the morning before sunrise so as to treat the flies before they leave the house.
2) All ventilation in the house should be turned off.
3) Roll up the curtains.
4) Go to the far end of the house and walk out.
5) The fog should be aimed at the flies.
6) Once fogging is finished wait as long as possible before lowering curtains and resuming power ventilation. A minimum of ten minutes should be allowed before turning the ventilation back on.

LARVAL CONTROL

In most areas, approved feed-through controls, residual sprays, and parasitic wasps can all be employed.

DARKLING BEETLES

Adult darkling beetles (*Alphitobius diaperinus*) are also called litter beetles or black bugs. while their larval stage is commonly referred to as the lesser mealworm. With the development of the modern cosmopolitan poultry industry, darkling beetles have become one of the most widespread, consistent insect pests in all types of bird-related industries, especially so within chicken layer and broiler facilities.

Adult darkling beetles are highly active, both through running and, at night, through flight. They are predominantly nocturnal so they prefer a dark daytime hiding place. They will congregate in areas where there are warm, moist conditions. They are sensitive to freezing and high temperatures, dehydrating rapidly when their environment does not contain adequate moisture.

They will also avoid excessively wet areas, especially those in which anaerobic microbial activity is high, such as areas where fermentation of wet feed or soupy manure is present.

Beetles of all life stages tend to clump together in close contact in areas where food, water and environmental conditions are best for their survival. Adult darkling beetles will eat feed, litter, manure solids, and even portions of dead and dying birds; they will burrow through manure consuming anything of nutritional value. They will also move out of the chicken area of these buildings into the insulation, feeding on any remotely edible portion of the poultry operation and destroying wood and any type of organic material in the process. They have no significant natural enemies and can carry a large variety of viruses, bacteria, fungi, and parasites that pose threats to humans and poultry, without observable negative effects on the beetles themselves. The larvae in particular harbor Newcastle disease virus, Pox virus, and Infectious Bursal Disease (IBD) virus, to name a few. Adults have been identified as harborers of many varieties of E. coli and Salmonella. Darkling beetles present an alternate pathway and a reservoir in the infection cycle of these bacterial pathogens in poultry; they contribute to carryover of these diseases and parasites into the next flock by acting as a reservoir during clean-out or during periods between flocks. These little insects are also intermediate hosts for tapeworms (both *Choetaenia* and *Raillietina* sp.), resulting in reinfection of the flock when chickens eat the beetles or when the beetles defecate near chicken feed. Indeed, birds find these insects especially attractive since the beetles are small and active. Turkeys and chickens often prefer feeding on darkling beetles instead of on poultry feed. This creates a situation in which the birds consume the beetles with their disease pathogens and do not consume adequate feed, resulting in lower weight gain and higher incidence of poultry intestinal problems.

Despite all this, it must be noted that through their active consumption of edible organic matter and their burrowing, darkling beetles do contribute to recycling of poultry wastes and to removal of some of the material that would otherwise be excellent habitat for a variety of flies. Low to moderate darkling beetle populations, therefore, can have a very positive effect on controlling fly populations in high-rise, deep pit, caged layer houses, where the manure and litter are allowed to build-up.

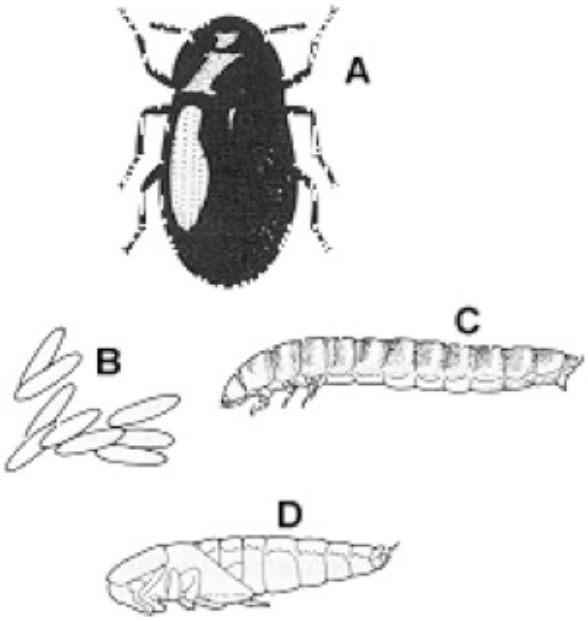
LIFE CYCLE

Darkling beetles require food, water and a warm place in which to complete their life cycle. Since darkling beetles are cannibalistic at all stages, they will actually lower their own populations through predation when conditions are too dry or food is in short supply. Unfortunately, conditions that might favour beetle cannibalism often also stimulate their migration, resulting in their becoming pests in insulation or in other buildings near the poultry buildings.

During their lifetime, adult female darkling beetles have the potential to lay over 2,000 eggs. The female beetles are very effective in laying their eggs in the best location for larval development, such as around feed and water lines. Darkling beetles remain in the egg stage for 4-7 days. In the subsequent larval stage, the beetle is commonly known as the lesser mealworm, and remains there for roughly 7 weeks. Larval mealworms have variable numbers of stages or instars, usually from 6 to 11, depending upon the temperature and other environmental conditions. During the meal worm stage, larvae are roughly ½ inch (1.3 cm) in length, and yellowish-brown in color. They are nearly as active as the adults, being totally directed towards feeding and survival. They tend to clump under feed and water lines or around dead or dying bird carcasses. They decidedly favor dark areas, feeding 24 hours a day.

The beetles then live for 7-11 days as pupae before developing into adults. Adult beetles are roughly 1/4 in (0.6 cm) in length and dark brown or black in color. The overall length of time required to move from egg to adult is dependent on environmental conditions, and adult life span is up to 2 years. For a visual depiction of the darkling beetle life cycle, see Figure 7.

Figure 7



Lesser mealworm.
A, Darkling beetle. B, Eggs.
C, Lesser mealworm. D, Pupa.

INSPECTION/MONITORING

The first step in the monitoring process is determining the population levels existing in the complex. To do so, a physical, in-person tour of a cross section of the farms in the complex must be made. Within each house, inspection will be conducted under drinker lines, under feed lines, around interior walls, around exterior walls, and within feed rooms. A threshold of approximately 50 beetles is suggested.

Beetle traps are also an effective means of monitoring. Traps can be placed and subsequently collected throughout the poultry growth cycle.

CONTROL

Successful treatment should kill >95% of the adult population. In order to accomplish this, litter treatment and removal may be required prior to treatment application. Additionally, more than one application between grow-outs, and even treatment during the grow-out, may prove necessary.

A pesticide sensitivity study should be completed prior to starting the treatment program. To accomplish this, a history of pesticide usage for beetle control by the farmers in the complex needs to be compiled. Additionally, a detailed description of the pesticide rates used for each pesticide must be prepared, and a list of the methods of application put together. A calendar, reflecting the frequency of past pesticide applications, should be completed, and a representative population sample of adult darkling beetles must be collected to determine the sensitivity/resistance of the beetles to the different classes of pesticides.

If required, field testing of different pesticides based on the results of the above sensitivity tests should be undertaken. These field tests will yield the following data, all of which should be presented to the people in charge of the pest management program so they may decide which pesticide will be used:

1) Percent control achieved by each pesticide in the test.

2) Residual efficacy of each pesticide tested.

3) Application techniques for best usage of the pesticide.

4) Equipment needed to apply the pesticide.

In situations where multiple treatments are possible, treatments should take place right after depopulation, right after crusting, as close as possible to bird placement, and during the grow out. If resources or time prevent multiple treatments, a single treatment should be made as close to bird placement as possible.

CONCLUSIONS

By focusing on the various zones, knowing common pests, and looking out into the broader world for potential issues, the efficacy of a vector management program can be maximized.