

CHAPTER 10

PROMOTING BIOSECURITY THROUGH INSECT MANAGEMENT AT ANIMAL FACILITIES

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1 Introduction

Insects and related terrestrial arthropods (including mites and ticks) are incredibly diverse groups of invertebrate animals found almost everywhere on Earth. Insects alone comprise approximately 75% of the total animal species on Earth (Samways, 2005). While not as species-diverse as insects, mites can be very abundant in some habitats. Fortunately, few insect and mite species directly harm animals. In contrast to insects and mites, all tick species have the potential to cause harm to animals because all ticks feed on animal blood. The insects, mites, and ticks that do harm animals can severely impact animal health and welfare, often resulting in considerable economic loss to domestic animal production.

2 Damage caused by insects

With few exceptions, the insects, mites, and ticks that harm animals feed on blood, skin, hair, feathers, or body exudates (e.g., tears, mucus) on the external body surface of their animal host and are therefore often collectively described as external parasites or ‘ectoparasites.’ These ectoparasites can negatively impact animal health and productivity in many ways, ranging from reduced feed consumption, growth, and economic output (e.g., in meat, milk, or eggs) to severe health consequences or even death of parasitized animals. Negative impacts include (1) physical damage to the animal host caused by insect feeding, (2) expression of unproductive animal behaviour in response to animal disturbance caused by the painful bites of some biting insects, and (3) transmission of viruses, parasites and other pathogens from infected animals to susceptible animals. Even when ectoparasites cause no obvious physical damage to their animal host, painful or irritating bites can negatively impact animal production due to increased host metabolic activity and behavioural responses that lower feed conversion efficiency or feed consumption of the animal host. Additionally, some insects and mites cause economic damage to animal producers as a result of nuisance to facility employees or neighbours.

2.1 Insects and animal disease

Of the negative impacts described above, the transmission of pathogens among animals is perhaps of greatest concern for many veterinarians and animal producers. In some cases, an arthropod is a necessary intermediary for the transfer of pathogens among animals, and disease transmission would not occur but for the presence and activity of the ectoparasite. These ectoparasites are called 'biological vectors' identifying their required role in transmission of the pathogen. In these cases, the arthropod is as much a host of the pathogen as is the vertebrate animal; the pathogen being adapted for life in both the arthropod and the vertebrate animal. Ectoparasites that feed on animal blood can acquire pathogens from an infected animal host, subsequently transferring these pathogens to susceptible animals during later feeding events. For example, biting midges in the genus *Culicoides* are biological vectors of several viruses that infect cattle, sheep, and horses. Within the biting midge, the virus must escape the digestive system, amplify, and spread to the insect salivary glands where the virus is then positioned to be introduced to a new host when the biting midge feeds again. The time required for the virus to amplify and reach the salivary glands is called the 'extrinsic incubation period' and a biting midge that feeds on a new host before the extrinsic incubation period is completed cannot pass on the virus. The extrinsic incubation period is typically dependent upon environmental temperature, with higher temperatures resulting in a shorter incubation period (Reisen, 2009). A higher environmental temperature typically also increases the insect development rate. These temperature effects are the reason that many insect transmitted diseases show a seasonal transmission pattern with greater disease incidence during warmer months of the year (e.g., see Gerry et al., 2001). A few biological vectors transmit pathogens to vertebrate animals through more unconventional associations. The lesser mealworm beetle (*Alphitobius diaperinus*) is a biological vector of chicken tapeworm, though this beetle does not bite or feed on chickens. Rather, these beetles acquire tapeworms when burrowing through poultry faeces contaminated with tapeworm from infected birds. The tapeworm then undergoes development

within the body of the beetle before being passed to a susceptible bird that eats the infected beetle. Often, targeted control of these biological vectors will lead to a reduction in disease incidence in the vertebrate animal population.

In some cases, insects are not required intermediate hosts for animal pathogens. Rather, pathogens may be acquired from the environment and distributed among susceptible animal hosts as the insect moves about the landscape. These ‘mechanical vectors’ may act to some extent as fomites, simply carrying the pathogen as a contaminant on external body surfaces and depositing pathogens wherever they go. Insects that develop in or feed on animal faeces are often mechanical vectors of animal pathogens shed in the animal faeces. Susceptible animals become infected with the pathogen when they consume feed or water contaminated with a pathogen as a result of insect contact, or susceptible animals may simply consume a contaminated insect. For example, house flies are proven mechanical vectors of pathogenic *Escherichia coli* bacteria to cattle presumably through these mechanisms (Ahmad et al., 2007). Recent evidence suggests that some insects that serve as mechanical vectors may be more than simple fomites. For example, flies that feed on animal faeces may harbour some pathogens within their digestive system, with pathogen amplification occurring within the insect digestive tract or even in the excreted insect faeces (Wasala et al., 2013; Nayduch & Burrus, 2017).

2.2 Insects and biosecurity

Biosecurity traditionally includes those preventive measures employed at animal facilities to limit the spread of pathogens among animals or to/from other animal facilities. Because insects, mites, and ticks can transmit numerous pathogens to wild and domestic animals, measures to prevent the spread of these pests among animal facilities is a critical part of an effective biosecurity programme. However, given the direct harm that ectoparasites can cause to animals, even in the absence of disease transmission, a more comprehensive understanding of biosecurity also includes

those measures intended to reduce pest numbers on animal facilities and prevent pest movement among animal facilities. It should be noted that most insects are winged as adults, resulting in a considerable challenge to preventing their movement and dispersal among nearby animal facilities. Instead, the focus of insect biosecurity should be on reducing the number of insects on animal facilities and limiting the contact of insects with infectious animals. In contrast, mites and ticks lack wings and dispersal among facilities generally occurs by movement of infested animals or by sharing machinery and supplies, though movement of facility employees among animal facilities can also pose a risk. Mite and tick biosecurity is thus best accomplished by quarantine and treatment of parasitized animals, exclusion of wild animals that may carry ectoparasites, and limiting the activities and movement of facility employees to reduce the accidental transport of ectoparasites to other susceptible animals.

2.3 Integrated pest management

Animal producers should implement the integrated pest management (IPM) concept to control insect pests and ectoparasites as part of a biosecurity programme. IPM is a coordinated strategy to reduce arthropod damage, including pathogen transmission, through application of a combination of techniques aimed at keeping pest abundance at levels below which damage is expected to occur. While it may be more difficult to determine a threshold of pest abundance when risk of disease transmission is involved, using an IPM strategy nevertheless provides a proactive focus on pest management ensuring that pests are held to low abundance levels thereby minimizing impacts on animal production. Lacking an IPM strategy, many animal producers respond to high pest numbers through application of pesticides for immediate reduction of the offending pest; but at these high pest numbers, disease transmission and economic damages have likely already occurred.

An IPM strategy focuses first on reducing opportunities for immature development of pest species. Reducing or manipulating the

available pest development habitat may alone provide the desired level of control. Where immature development habitat cannot be reduced or manipulated sufficiently, judicious use of pesticides on insect development sites may reduce pest production and keep numbers of damaging pests low. In some situations, application of pesticides for control of adult insects will be needed and may form part of an IPM strategy. When pest numbers reach damaging levels, or when pathogen transmission has been detected, immediate control of adult insects is warranted. In these situations, pesticides may be applied directly to the host animal or to animal facility structures to target insects resting on these structures. A searchable, online database of pesticides registered by the U.S. Environmental Protection Agency for control of arthropod pests of animals is maintained by veterinary entomologists in the United States as part of a U.S. Department of Agriculture (USDA) sponsored multistate research project, and is available at <https://www.veterinaryentomology.org/vetpestx> (Ferguson et al., 2015). However, if pesticides are often used for emergency pest control due to failure of proactive IPM measures, facility managers should re-evaluate their IPM program. Frequent application of pesticides is unsustainable, and pests will quickly develop resistance to the chemicals used. When applying pesticides, care must be given to maximise control of the damaging pest while minimising pesticide impact to useful insects, such as pollinators or any insect predators and parasitoids that naturally prey on the damaging pest.

An IPM strategy necessarily includes a mechanism for monitoring pest abundance, with increasing abundance triggering additional control measures aimed at keeping pest numbers from reaching damaging levels. Monitoring pest abundance is also important to note if control measures applied have been effective in decreasing pest populations. Effective pest monitoring methods will differ by pest species based upon the biology and behaviour of each pest species as well as differences in the location of immature development sites and adult resting sites. In general, a weekly count of the number of individual ectoparasites on a representative number of host animals is a useful way to monitor changing pest abundance for many ectoparasites, including ticks and some of the larger bit-

ing flies. Animals can also be observed for certain behaviour or an appearance that is indicative of pest activity or pest abundance. For example, cattle will stamp their legs, toss their heads, or bunch together in a group to avoid the painful bites of some biting flies, and an animal's 'mangy' appearance is an indicator of possible infestation by a mite species. Other pest species can be monitored using attractive traps (baited with a host or food odour) or by using traps that passively capture pests as they move about their environment. Appropriate methods for monitoring relevant pest species will be discussed in each animal commodity section below.

3 Insect pests of cattle

Since the 1980s, the production of milk worldwide has increased more than 50% to 769 million tons of milk produced in 2013 (FAOSTAT, 2017). The increase in milk production is attributed to growth of the industry in developing countries throughout south Asia where milk is often produced on smallholder or family farms. Major milk producing countries are India, the United States, China, Pakistan, and Brazil. Countries with the highest milk surpluses are New Zealand, the United States, Germany, France, Australia, and Ireland. In developed countries, dairy farms are growing larger and are increasingly mechanised. Cow nutrition is now often carefully controlled through supplemental feed to increase milk production per animal. In contrast to milk production, beef production and consumption worldwide is increasing slowly with beef consumption increasing primarily in developing countries (FAO, 2016a). Beef production is limited by declining rangeland availability in most countries due to encroachment of other land uses and degradation of available rangelands. Further increases in beef production are likely to result from increasing animal density on available lands, with animals provided supplemental feeds where forage is no longer sufficient (Bruinsma, 2003). Modern cattle feedlots, where cattle have no access to pasture and are fed entirely on supplemental feed, are an extreme example of beef cattle intensification.

As cattle operations continue to move towards a more intensive operational model with increasing cattle density and reduced pasture availability, insect and tick species that impact cattle in open pasture settings are being eclipsed in importance by pest species that develop in cattle manure and feed waste. These often accumulate in great quantities on intensive operations (Gerry, in press).

3.1 Permanent ectoparasites

Some ectoparasites spend their entire life on a single host ('permanent ectoparasites'), with the host providing the necessary habitat and food for each life stage of the ectoparasite. There are five species of lice and four species of mites common to cattle as permanent ectoparasites. The more damaging blood feeding lice are the long-nosed cattle louse (*Linognathus vituli*), short-nosed cattle louse (*Haematopinus eurysternus*), cattle tail louse (*H. quadripertusus*), and little blue louse (*Solenopotes capillatus*). A single species of chewing louse, the cattle biting louse (*Bovicola bovis*), feeds on skin rather than blood. Cattle mites feed on skin debris or lymph within the dermal tissues, and include the important scabies or 'mange' mites *Psoroptes ovis*, *Sarcoptes scabiei* and *Chorioptes bovis*, as well as the cattle follicle mite (*Demodex bovis*). Feeding by lice and mites can be quite irritating to the host, and may result in considerable physical damage due to dermatitis, tissue destruction, and hair loss. Lice and mites can also cause damage to hides, particularly as animals rub and scratch against objects in their environment to alleviate the itching caused by ectoparasite feeding. Heavy infestations of lice and/or mites can reduce weight gain and milk yield (Wright, 1985). Additionally, poor physical condition of heavily infested animals, often coupled with substantial hair loss, can result in death of young calves and older cattle when exposed to severe weather conditions or low nutritional levels.

Surveillance for both lice and mites is by routine observation of animal health, with obvious signs of mange or other hide damage indicative of louse or mite infestation.

Management of lice and mites is commonly achieved by treating all cattle within a herd with a topically-applied insecticide (lice) or acaricide (mites), and by limiting contact among infested and uninfested animals or herds. Any animals left untreated in the herd, even if they appear to be free of lice or mites, will almost certainly result in treated cattle soon being infested again with lice and mites. Injection of ivermectin or related parasiticides may also provide control of lice and mites. For lice, two insecticide treatments 10-14 days apart are needed, as lice in the egg stage are protected from the insecticide and may survive the first treatment (Campbell, 1985).

3.2 Ticks

There are many tick species that feed on cattle. Ticks can be categorised as ‘hard ticks’ (Family Ixodidae) due to the presence of a rigid plate on the back that makes them difficult to crush between the fingers (Fig.10.1), or ‘soft ticks’ (Family Argasidae) which lack this rigid dorsal plate.

Most hard ticks have three life stages (larva, nymph, adult) and feed on a different vertebrate host during each life stage (3-host ticks), living off the host in the surrounding habitat between feeding periods. Attachment to hosts for feeding often lasts for at least several days. Where cattle are kept on pasture, 3-host ticks can be abundant due to the presence of off-host refuge and alternate hosts in this habitat. These ticks are less abundant on more intensive cattle operations where cattle access to pasture is limited, with ticks essentially absent on dairy and feedlot facilities where cattle have no access to pasture (Gerry, in press). While these ticks can cause economic damage from blood loss, irritation by tick feeding, and even toxic paralysis, their more important impact is as vectors of several bacterial and protozoal diseases of cattle. A few hard ticks will feed on the same cattle



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Fig. 10.1: Hard ticks in several genera (including *Dermacentor*, shown) can impact livestock, especially as vectors of pathogens.

host during all life stages (1-host ticks). Cattle ticks (*Rhipicephalus* spp.) are a particularly important group of 1-host ticks that are biological vectors of the *Babesia* parasites that cause bovine babesiosis or ‘cattle fever’ (Pérez de León et al., 2012).

Soft ticks tend to be more common in arid environments and can have quite variable life histories, often including several nymph stages before reaching the adult stage. During each life stage, soft ticks will feed on a host for only a few minutes after which they typically leave the host to moult to the next life stage. One unusual soft tick, the spinose ear tick (*Otobius megnini*), will spend its immature life feeding within the ear canal of a single host animal (Fig. 10.2; cattle and non-cattle), before dropping to the ground to complete a non-feeding adult stage. Due to this unusual life history, the spinose ear tick can be abundant in both pasture-based and confined cattle facilities.



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Fig. 10.2: Spinose ear ticks (*Otobius megnini*) are soft ticks that feed and develop in the ear canal of several animals including cattle and swine. They are more commonly found on animals held in confinement.

Tick numbers on cattle can be reduced by application of acaricides to adult tick feeding sites on the animal or in some cases by immersion of

the entire animal into a dipping vat containing acaricide (Wright, 1985). Management of ticks in pasture settings is quite challenging, as many ticks will also feed on non-cattle hosts, and will thus avoid the treatment or will be reintroduced with trespassing wildlife arriving from outside the cattle pasture. To address this, several novel methods to treat non-cattle hosts for ticks have been introduced in recent years, including the USDA ‘4-Poster’ device for deer to self-treat with an acaricide while accessing food bait (Carroll et al., 2009).

3.3 Cattle grubs and screwworm flies

Cattle grubs (*Hypoderma bovis* and *H. lineatum*) and screwworm flies, both New World screwworm fly (*Cochliomyia hominivorax*) and Old World screwworm fly (*Chrysomya bezziana*), are inter-

mittent parasites of cattle that feed on internal body tissues of cattle only during their immature life stages. The adult flies of these species do not feed on the animal, but seek cattle on which they will lay their eggs. Cattle grubs are parasites only of cattle, while screwworm flies will attack many warm-blooded animals (including humans). Neither fly is a vector of cattle pathogens, but the damage caused by the feeding of these flies on internal tissues can be severe, resulting in considerable economic cost to producers. Feeding damage by immature screwworm flies (maggots) can be particularly devastating. This often leads to the death of the animal as feeding wounds become infected which attracts additional egg-laying by tissue-consuming flies (Alexander, 2006).

Where the adult cattle grub (called a heel fly) is active, cattle often exhibit behaviour called ‘gadding’ where they run madly with their tails raised in the air in an apparent effort to prevent these flies from depositing eggs on the cattle body. Parasitized cattle will show swellings along the back (‘warble’) where the cattle grub has cut a breathing hole in the animal hide to complete its immature development. In geographic regions where screwworm is present, cattle should be routinely observed for wounds within which immature flies may be developing.

Cattle grubs are readily treated using systemic insecticides applied to cattle in late summer to kill the developing immature flies as they migrate through the body of cattle. Management of screwworm flies is more difficult and relies on early treatment of screwworm infested wounds with insecticides and culling of severely infested animals to prevent fly development to the adult stage. New World screwworm fly has been eradicated throughout North and Central America by sustained releases of sterile male screwworm flies initiated by the USDA in 1958.

3.4 Flies that develop in cattle faecal pats

Pest flies that require fresh, undisturbed cattle faeces (faecal pats) to complete their immature development are the horn fly (*Haema-*

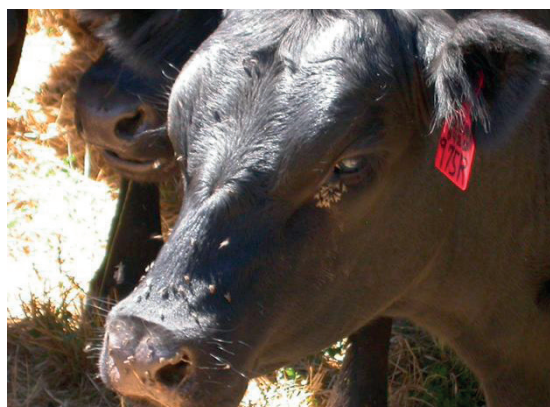


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Fig. 10.3: Horn flies (*Haematobia irritans*) feed on blood from cattle and occasionally horses. They spend most of their time on the host, and tend to orient themselves facing downward.

tobia irritans) and face fly (*Musca autumnalis*). During the adult stage, both fly species feed on cattle, but the horn fly feeds on blood (Fig. 10.3) while the face fly feeds primarily on exudates, particularly nasal and eye secretions (Fig. 10.4). Horn flies spend most of their adult life resting or feeding on cattle, taking many small blood meals each day (Cupp et al., 1998). Horn flies are easily disturbed by cattle activity, and readily move among nearby animals throughout the

day. Face flies feed only briefly on cattle before leaving the host animal to rest in the surrounding habitat. Face flies are recognized vectors of a bacterium (*Moraxella bovis*) causing bovine pinkeye, and of filarial nematodes (*Thelazia* spp.) that parasitize the cattle eye (Wall & Shearer, 1997). Horn flies are not recognized as vectors of a cattle disease, but their painful bites irritate cattle and can greatly impact production efficiency.

Both flies can be monitored by visual observation of fly numbers on cattle. Flies should be counted during mid-morning when horn flies are typically resting on the back and sides of cattle and face flies are actively feeding around the eyes and face. When daytime temperatures are high, horn flies can be difficult to accurately count as they retreat to the shaded lower regions of the cattle body to escape direct sun exposure (Lysyk, 2000). A weekly count of horn flies and face flies on 15 randomly selected animals in a herd is suitable for showing changes in fly abundance over time.



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Fig. 10.4: Face flies (*Musca autumnalis*) congregate near the eyes of cattle where they feed on exudate. Face flies are vectors of pathogens including bovine pinkeye and eyeworms of cattle and horses.

Management of these flies is best achieved by disturbance of freshly deposited cattle faecal pats. Where cattle are held in confinement at high density, faecal pats rarely remain intact as cattle disturb the pats as they move about their pen. For this reason, horn flies and face flies are usually not abundant on intensive cattle operations where cattle lack access to pasture. However, where cattle density is low or where cattle have at least

some access to pasture, these flies can be abundant unless facility workers manually or mechanically disturb the fresh faecal pats. Where disturbance of faecal pats is impractical, cattle can be given feed additives containing an insect growth regulator (IGR) that will pass through the animal digestive system and into the faeces to prevent immature fly development. However, some IGRs can also prevent development of dung beetles and other insects that assist with the breakdown of cattle faeces, so these products should be used judiciously. Where faecal pats cannot be disturbed or treated to prevent development of these flies, adult flies can be controlled using insecticides applied to cattle as insecticide-treated ear tags, or as topical pour-ons, sprays, oils, and dusts (Wright, 1985). Insecticide applications have been particularly useful in reducing adult horn flies as these flies only rarely leave their cattle host. However, over-use of insecticides for adult horn fly management has led to the inevitable development of horn fly resistance to some insecticides (Foil & Hogsette, 1994). There has recently been increased interest in using low toxicity botanical extracts and essential oils primarily as repellents applied to cattle to reduce biting by horn flies (Showler, 2017; Mullens et al., 2017a).

3.5 Flies that develop in fermenting organic matter

Fermenting organic matter including animal faeces, cattle bedding, and wet animal feed is often plentiful on most modern dairies and feedlots, with increasing animal density and mechanisation associated with greater quantities of these materials. Important pest flies that develop in fermenting organic materials are the stable fly (*Stomoxys calcitrans*) and the house fly (*Musca domestica*). The adult stable fly feeds on animal blood (Fig.10.5) while the adult house fly feeds on any number of carbohydrate or protein-rich foods available in the environment, including feeding on cattle faeces. Adult stable flies typically feed on cattle or other animals once per day. The bites are quite painful causing cattle to exhibit bite avoidance behaviour includ-

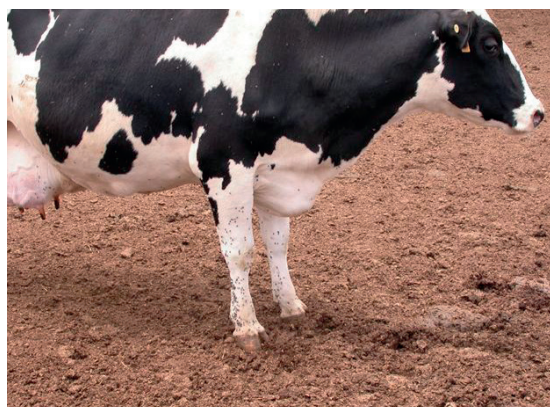
Fig. 10.5: Resting female stable fly (*Stomoxys calcitrans*) after taking a blood meal. Note the rigid proboscis.



ing leg stamping and tail switching to dislodge biting stable flies (Mullens et al., 2006). When biting pressure is high, cattle gather into groups ('bunching') to avoid these biting flies. This unproductive cattle behaviour can result in reduced weight gain and milk production for animals molested by stable flies (reviewed by Gerry et al., 2007). Somewhat surprisingly, the stable fly is not known to transmit important cattle diseases. In contrast, house flies do not feed on blood but are mechanical vectors of a number of viral and bacterial pathogens which they acquire from contact with animal faeces and subsequently distribute throughout the environment. Pathogen deposition by house flies onto human food crops is of particular concern (Talley et al., 2009).

Stable fly abundance and activity can be determined by counting flies on cattle, by using traps such as the Alsynite trap that target adult stable flies, or by observing animal behaviour in response to the painful biting of these flies (Gerry et al., 2007). If monitoring stable flies by counting flies on cattle, counts are performed by approaching the animal from one side and visually observing the number of stable flies on the outside of the front leg nearest to the observer and the inside of the opposite front leg (Lysyk, 1995) (Fig. 10.6). A count of 5 stable flies per leg is considered the thresh-

Fig. 10.6: On cattle, stable flies (*Stomoxys calcitrans*) prefer to feed on the lower legs. While feeding, they generally position themselves facing upward.



old for economic impact on cattle. Some cattle behaviour is associated with stable fly biting activity, and can be used as a means to monitor fly activity. When stable fly activity is high, cattle bunching may be noted and is certainly an indication that stable fly management is needed. At lower stable fly abundance, the number of cattle tail flicks within a 2-minute period can be used as a measure of fly activity, with an average of 10 tail flicks per animal considered the economic threshold (Mullens et al., 2006). It should be

noted that high numbers of horn flies will also affect cattle behaviour, including increasing tail flicks (Boland et al., 2008), making it difficult to distinguish which fly species are responsible for observed behaviour when both flies are abundant

on cattle. All cattle observations should be performed on a minimum of 15 randomly selected animals for statistical validity.

House fly activity can be determined by capturing flies using sticky traps or traps baited with food attractants, or by using ‘spot cards’, paper cards placed at fly resting sites on which flies deposit faecal and regurgitation spots. For a reliable monitoring programme, 5 traps or 12 spot cards are usually sufficient (Gerry et al., 2011). There has been recent interest in using computational technologies to improve fly monitoring, with development of software (Fly Spotter©) to automate counting fly spots on spot cards (Fig. 10.7) (Gerry et al., 2011). Monitoring systems that identify wingbeat frequency of flying insects passing through a sensor array are currently under development and may soon greatly simplify pest monitoring by identifying and counting several pest fly species simultaneously without the need to capture the insects (Chen et al., 2014).



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Fig. 10.7: House fly monitoring can be accomplished via placing white cards in likely fly resting areas. When flies land (shown) they regurgitate and/or defecate leaving ‘fly spots’. Spots can be hand counted or software such as FlySpotter© can be utilized to track relative populations over time.

Management of both the stable fly and house fly can be challenging on modern intensive cattle operations. Substantial quantities of cattle faeces collected from animal housing areas are often stored on-site and long-term storage of animal feed including hay, straw, grains, and fermenting feed additives including fruit and nut waste is also common. For both fly species, management is best achieved by applying sanitation measures to rapidly dry cattle faeces, to prevent wetting of stored dry cattle feeds, and to limit fly access to cattle feed that is intentionally fermented. Cattle pens should be regularly scraped or harrowed to break up and dry faecal accumulations within the pen. If faeces cannot be dried this way due to high animal density or pen characteristics, cattle faeces should instead be collected and piled to compost in a location where it will not be rewetted. Composting of cattle faeces can greatly reduce fly development as internal pile temperatures increase to exceed lethal temperatures for developing flies while simultaneously drying the outer portion of the compost pile to make it

unsuitable for egg-laying by female flies. Hay, grains, and other dry animal feeds should be stored in a manner to prevent wetting and subsequent fermentation of these materials. Flies will not develop on dry animal feed. Where fermentation of animal feed is desired or necessary, animal feed should be fermented within enclosed fermentation bags to prevent fly access. When sanitation measures fail and adult fly numbers reach damaging levels, insecticides used for immediate control of adult flies are best applied as sprays, fogs, or mists of a long-lasting or residual chemical such as a synthetic pyrethroid to facility structures near cattle where adult flies are noted to rest. However, insecticide application alone will not provide sustainable control of adult flies, and over-reliance on pesticides has resulted in the development of resistance to many available insecticides in both species (e.g., see Keiding, 1999).

3.6 Biting midges

Biting midges in the genus *Culicoides* are small, blood-feeding flies that are important vectors of several viruses that impact cattle, including bluetongue virus and the recently isolated Schmallenberg virus (Mellor et al., 2000; Rasmussen et al., 2012). These flies can be produced in substantial numbers in semi-aquatic habitats, moist leaf litter or even moist manure, depending on the species of biting midge. Developmental sites are difficult to identify for many species and are often widespread in the habitat surrounding animal facilities. *Culicoides* that bite cattle are usually active during crepuscular periods near both sunrise and sunset (Mellor et al., 2000), though activity may shift toward daylight periods in cooler weather. Risk of bluetongue virus transmission to cattle is primarily determined by *Culicoides* abundance and their cattle biting rate (Gerry et al., 2001; Mayo et al., 2016).

Culicoides activity is commonly measured using traps baited with UV light or carbon dioxide, though there are a number of limitations associated with these traps, including the inability of light traps to capture diurnally active midges and the poor efficiency of carbon dioxide traps for capturing a number of important midge

vectors of bluetongue virus (reviewed by Mullens et al., 2015). Collection of biting midges by aspiration directly from animals would provide better surveillance outcomes, but is certainly more difficult and is rarely done (e.g., see Gerry et al., 2009; Cohnstaedt et al., 2012).

Even when *Culicoides* development sites are known, manipulation of these developmental sites is often impractical, making management of biting midges challenging. Application of insecticides or insect repellents directly to animals may provide some level of protection from biting midges (Mullens et al., 2010; Griffioen et al., 2011) and might be particularly useful when transporting small numbers of animals through quarantine zones, but insecticide applications to cattle herds may not be successful in reducing virus transmission to treated herds overall (Mullens et al., 2001). Stabling of animals indoors can reduce biting by some *Culicoides* that are reluctant to enter structures (Meiswinkel et al., 2000).

3.7 Biosecurity for cattle pests

Biosecurity measures for cattle pests should focus on (1) sanitation measures to reduce fly development in cattle faeces and stored cattle feed, (2) limiting movement of cattle among herds and particularly among cattle facilities to reduce transfer of lice, mites, and ticks, (3) restricting deer and related wildlife access to cattle facilities to limit tick introductions, and 4) routine observation of cattle to monitor for pest introductions and increasing pest abundance to drive management efforts. The main biosecurity concerns will differ by geographic region, habitat, and the level of intensification of the cattle operation. In pasture-based cattle systems, management efforts should focus on ticks, cattle grub, horn fly, and face fly, while in more intensive confined dairy and feedlot systems management efforts should focus on house fly and stable fly, with biosecurity efforts applied to other pests when noted on cattle.

4 Insect pests of sheep

In the United States, sheep production has declined rapidly in the last 50 years as the use of synthetic fibres has replaced the need for wool (Jones, 2004). While meat production has replaced wool production as the primary emphasis for the sheep industry, the industry continues to decline in the United States and other countries due to increased regulatory pressures, reduced access to grazing lands, and increased costs for raising sheep (Shiflett, 2017). However, sheep production in Australia and New Zealand has adjusted to the shrinking wool industry, and export of sheep meat from these countries is increasing. Top producers of sheep meat today are China, Australia, New Zealand, the United Kingdom, and Turkey (FAOSTAT, 2017). Sheep are particularly suited for the conversion of many different types of forage vegetation into wool and meat, and for this reason are rarely held in intensive confined animal production systems.

4.1 Permanent ectoparasites

There are four species of lice found on sheep. Blood-feeding sheep lice are the sucking body louse (*Linognathus setosus*), the sucking foot louse (*L. pedalis*), and the African blue louse (*L. africanus*). A single species of chewing louse, the sheep biting louse (*Bovicola ovis*), feeds on skin rather than blood. The sheep biting louse can be very irritating, causing sheep to pull at their fleece and rub against objects to alleviate the itching. These actions can result in considerable fleece damage as large areas of fleece can be completely rubbed off. Lice are transferred among animals by direct contact.

Sheep mites include *Psoroptes ovis* which causes a condition called 'sheep scab', the scabies mite (*Sarcoptes scabiei*), the sheep leg mite (*Chorioptes ovis*), and the Australian itch mite (*Psorergates ovis*). Of these mites, *Psoroptes ovis* is of most concern as this mite causes intense itching so that sheep scratch their bodies against objects in their environment, often to the point of causing physical

damage to their fleece and hide. *Psoroptes ovis* has been eradicated from the United States, Australia, New Zealand, Scandinavia, and Canada (Spickler, 2009).

The sheep ked (*Melophagus ovinus*) is a wingless, blood-feeding fly that spends its entire life in the fleece of sheep. Female sheep ked develop larvae one at a time within their body, periodically depositing a fully developed larva onto the fleece. Populations of sheep ked therefore build up more slowly than for most ectoparasites. Like lice and mites, sheep ked are transferred among sheep by direct contact between animals. Sheep ked cause damage from their irritating bites which can result in the formation of nodules or 'cockles' on the skin, which reduces the value of sheep skin.

Permanent ectoparasites are monitored by direct observation of animals, with poor fleece or skin conditions indicative of ectoparasite presence. Management of lice and mites on sheep is similar to their management on cattle (see above). Sheep ked can be eradicated by shearing of sheep before lambing in spring, followed by application of insecticides to all animals in the herd. To prevent reinfestation of the herd, new animals should be quarantined, inspected and treated with insecticide prior to introduction to the herd.

4.2 Ticks

Ticks described in the cattle section above will also feed on sheep, and management is similar for ticks on both animals.

4.3 Sheep bot fly

The sheep bot fly (*Oestrus ovis*) is a worldwide pest of sheep and goats. Adult flies deposit first instar larvae in the nostrils of sheep where the larvae (maggots) consume the nasal mucosa. Feeding by sheep bot maggots can be irritating to the sheep and can increase the opportunity for bacterial infection of the nostrils. The mere presence of adult flies can also irritate sheep, and they will attempt

to avoid the flies by running in short bursts and by snorting, behaviour which affects sheep grazing and reduces animal weight gains. There are no management recommendations for this fly, though individual animals can be treated with ivermectin or other antihelminthics if infestation is deemed to be problematic for the animal.

4.4 Wool maggots

Wool maggots are the generic name for the larvae of any fly species that lay their eggs on sheep fleece that is soiled with urine, faeces, or blood due to wounding. Most of these flies belong to the blow fly family (Calliphoridae) and are typically carrion-feeding flies. Wool maggots consume bacteria associated with the soiled fleece and may also readily feed on infected skin wounds or lesions. Where an infestation becomes severe, sheep mortality may occur.

Preventive measures include shearing pregnant ewes to prevent soiling of fleece during lambing, and scheduling lambing for early spring before flies are abundant. Fleece that is soiled by urine or faeces should be clipped to reduce the opportunity for fly strike (egg laying by flies). Animals infested with wool maggots can be spot treated with insecticide at the site of infestation to eliminate maggots.

4.5 Biting midges

Sheep are a suitable host for many *Culicoides* species that will attack cattle. Sheep are particularly at risk of *Culicoides* transmitted bluetongue virus, which can often result in death of infected sheep.

Surveillance and management for biting midges is described in the cattle section above.

4.6 Biosecurity for sheep pests

Biosecurity measures for sheep pests includes limiting movement of sheep among herds to reduce transfer of lice, mites, sheep ked, and ticks, and monitoring sheep for the presence of other pests with increasing pest abundance driving management efforts. The main biosecurity concerns will differ by geographic region and by habitat, with viruses transmitted by biting midges perhaps of greatest concern for sheep health in most countries.

5 Insect pests of swine

Pork is the most consumed animal protein worldwide and accounts for 35% of the world's meat intake (FAO, 2016b). China is the world's leading pork producer, which over 50 million metric tons produced in 2016; this is followed by the European Union (> 23 million MT) and the United States (> 11 million MT). Over 780 million pigs were stocked for consumption in 2016, 68 million in the United States alone (USDA, 2017). Most swine are housed indoors, with modern confinement facilities in Europe and the U.S. housing a high density of swine within environmentally controlled facilities (Plain & Lawrence, 2003). However, pasture-based swine production has increased recently in response to animal welfare interests (e.g., Edwards, 2005; Honeyman et al., 2006).

5.1 Permanent ectoparasites

The hog louse (*Haematopinus suis*) is a large (ca. 6 mm) blood-feeding louse specific to pigs. Eggs are glued to hair near the skin and typically require 2-3 weeks to hatch (Williams, 1985). Lice are typically found on pigs in the area around the tail and upper inside of the legs. Blood-feeding causes irritation, which can indirectly lead to hair loss and skin damage as animals rub against objects to alleviate itching. Hog lice are also recognized as important vectors of the swine pox virus, though this virus can also be transmitted

by direct contact among pigs. Lice do not survive more than a few days off host and are more noticeable during the winter months.

Like many other animals, swine may get sarcoptic mange caused by the mite *Sarcoptes scabiei*. In pigs, mange usually appears first around the head but can occur anywhere. Damage to swine due to the irritating bites of lice and mites and the management of these pests is similar to that described for lice and mites of cattle.

5.2 Ticks and fleas

Like cattle or sheep, swine with access to pasture may become hosts for many of the 3-host ticks commonly encountered in the pasture environment. Also like cattle and sheep, swine can host the spinose ear tick (*Otobius megnini*), a soft tick that may be found feeding in the ear canal of pigs. Soft ticks in the genus *Ornithodoros* are known to vector African swine fever virus (Kleiboeker & Scoles, 2001), an often fatal viral disease among pigs. While African swine fever virus is not currently in the U.S. or Europe, an outbreak of this virus on the eastern edge of Europe that started in 2013 is threatening to expand into Eastern Europe, perhaps distributed by infected wild boars (FAO, 2017). In the past, African swine fever virus was also transmitted to pigs by soft ticks endemic in the Caribbean and in Brazil. Should this virus spread to the main pig raising regions of Europe or North America, soft ticks in both regions are capable of transmitting the virus.

Swine may also become infested with several species of fleas, including the cat flea (*Ctenocephalides felis*), the dog flea (*C. canis*), and the human flea (*Pulex irritans*). Adult fleas take blood meals from the host. Larvae develop and feed on organic material near vertebrate hosts. Adult fleas are dark brown and may be spotted periodically feeding on pig bodies; larvae are too small to easily find in the environment. Flea bites are quite irritating to swine who will scratch continuously in response to the bites.

Fleas that attack swine will also attack their handlers as well. Observation of fleas or flea bites on handlers is often the first indication of a flea problem in a swine facility. Fleas are controlled by removal of animal bedding and application of insecticides to the floor, lower walls, and other structures in the swine facility before replacement of bedding. Insecticides may be applied directly to pigs as well for immediate control of fleas on the animals.

5.3 Flies and mosquitoes

House flies (*Musca domestica*) and stable flies (*Stomoxys calcitrans*) can develop in and around swine facilities where manure and other organic material accumulate and are left relatively undisturbed. To address animal welfare concerns, swine producers often add enrichment devices to swine pens. Enrichment devices can range from balls to teeter-totter type structures with devices fixed to the ground. Faeces can accumulate beneath and around such devices creating additional challenges for sanitation of swine pens. House flies are mechanical vectors of *Salmonella* and classical swine fever virus, and there is evidence that they may also be involved in the transmission of porcine reproductive and respiratory virus (PRRSV) in swine facilities (Otake et al., 2003).

Monitoring of flies is described in the cattle section above. Fly control in swine facilities is achieved primarily through sanitation measures aimed at interrupting fly development in swine faeces and bedding. All bedding and accumulated faeces should be removed and pens cleaned each week, or twice per week if weekly cleanouts are insufficient to achieve the desired level of control. Immediate control of adult flies can be achieved by using long-lasting insecticides applied by sprayer to facility walls and structures.

Mosquitoes are typically produced in waste water lagoons or other bodies of standing water, though some pestiferous mosquito species can develop in small, temporary water sources such as pails or other objects that can fill with rainwater. At least one mosquito species (*Aedes vexans*) has been shown to vector PRRSV (Otake

et al., 2002). Mosquitoes are controlled by eliminating aquatic development sites or by treatment of sites with insecticides, oils, or bacteria that kill some strains of mosquitoes.

5.4 Biosecurity for swine pests

Limiting the movement of animals and humans among groups of swine will help to prevent the direct spread of permanent ectoparasites. Proper manure management can limit house fly and stable fly development. Developmental sites for fleas or soft ticks near animals should be eliminated or treated. Tick prevention will be more difficult if swine are on pasture. Measures for pastured swine would reflect biosecurity for pastured cattle (above).

6 Insect pests of horses

Worldwide horses and other equines are kept for recreation, sport, and as work animals. Indirect economic impact of the equine industry is over \$100 billion in both the United States and in Europe, with horse riding in Europe reported to be increasing by 5% each year (FEI Sports Forum, 2013). While horses are still used in some parts of the world as work animals for farming or herding, in many countries they are predominantly used for recreation and competitive sport. Horse meat is consumed in some countries, but is generally unavailable or even taboo, especially in many English-speaking countries where horses are considered more as pets than food animals. Horses are perhaps the most exported animal worldwide, for example accounting for 57% of all U.S. live livestock exports (including cattle, poultry, swine, sheep, and goats; USDA, 2015). The United State is the world leader in horse population followed by Mexico, China, Brazil, and Argentina (FAOSTAT, 2017). There is also an exceptionally active international equine sporting industry with worldwide horse movement to attend international competitions. Horse travel has increased the risk of movement of horse pathogens from endemic areas to non-endemic areas.

6.1 Permanent ectoparasites

Horses host two lice species; the horse biting louse (*Bovicola equi*) and the horse sucking louse (*Haematopinus asini*). Eggs of the horse biting louse are laid on fine hairs of the neck and flank of animals, but can spread to the entire body. Adult biting lice are 1-2 mm in length. Horse sucking lice prefer coarse hair and are found on the mane, base of the tail, and above hooves. Adult sucking lice are 2-3 mm in length. Lice can be spread by direct contact or by contaminated equipment or blankets. Lice infestations tend to be heaviest in winter months when longer coats offer better habitat. Horses can be infested with various species of scabies or mange mites and will exhibit similar scratching behaviour as cattle (see above).

Management of lice and mites on horses is similar to that described for cattle.

6.2 Ticks

Many of the ticks that negatively impact cattle will also infest horses. Ticks can transmit a suite of protozoan, viral, and bacterial pathogens to horses, including those that cause anaplasmosis, piroplasmosis, Lyme disease, tularemia, and Q-fever (Granström, 1997).

Management of ticks on horses is similar to that described for cattle.

6.3 Bot flies

The main species of bot fly that can affect horses are the common horse bot fly (*Gasterophilus intestinalis*), the throat bot fly (*G. nasalis*), and the nose bot fly (*G. haemorrhoidalis*). Eggs are laid onto the fur of horses and are ingested during grooming. First instar larvae attach to the mucosa of the mouth or gastrointestinal tract where they feed on tissue. This process takes several months,

and when larvae reach the 3rd instar they detach and are excreted. Bots will then pupate in soil or dried manure. Damage to the host occurs when the gastrointestinal lining becomes inflamed or 1st instar larvae burrow into the mouth lining. As for cattle, the presence of adult flies attempting to lay eggs can panic horses leading to horse self-injury.

6.4 Flies and mosquitoes

Horses are affected by many of the same fly species that impact cattle, including the stable fly, horn fly, face fly and house fly. While horse faeces is typically less productive for flies relative to cattle faeces, both stable fly and house fly can be produced in large numbers when horse faeces and urine is mixed with straw bedding for stabled horses. Horn flies and stable flies will bite horses and stable flies in particular have painful bites. Horn flies prefer bovine hosts, but will feed on horses and cause irritation to animals despite not reaching high populations on them (Fig. 10.8). Face flies feed on eye secretions and annoy animals. They are also vectors of eye worms (*Thelazia* spp.) House flies do not directly affect horses, but may be a nuisance to animals, workers, and neighbours. House flies are also vectors of numerous pathogens and parasites of animal health importance, including roundworms of horses (*Habronema microstoma*).

Fig. 10.8: Horn flies blood-feeding on a horse. While cattle are the preferred host, horses in proximity to cattle may be also be attacked.



Mosquitoes develop in aquatic environments in and around horse facilities. Mosquitoes are vectors of several important viruses of horses, including eastern equine encephalitis (EEEV), western equine encephalitis (WEEV), West Nile virus (WNV), St. Louis encephalitis (SLEV), and Venezuelan equine encephalitis (VEEV). These viruses can cause significant disease in horses, with mortality as high as 90% for EEEV (Knapp, 1985). A vaccine is available to protect horses against WNV, and should be considered for horses in geographic regions where this virus is actively transmitted.

Other flies that negatively affect horses and develop in aquatic or semi-aquatic habitats include black flies (Family: Simuliidae), biting midges (*Culicoides* spp.), and horse flies (Family: Tabanidae). The adults of both black flies and biting midges are small (≤ 15 mm) but in large numbers they can severely depress animals due to their painful and irritating bites. Biting by these flies can also result in pronounced itching and tissue irritation as a result of host allergic reaction to salivary compounds injected into the bite wound by these flies (Knapp, 1985). Biting midges are also of concern as vectors of African horse sickness virus (AHSV), a severe disease of horses which is currently limited to sub-Saharan Africa but has the potential to spread to other geographic regions. Horse flies are large (10-30 mm) blood-feeding flies that will readily attack horses. Horse flies have painful bites that can cause horses to display defensive behavior including panicked running which may cause horse self-injury. Horse flies are vectors of equine infectious anaemia and trypanosomes (Knapp, 1985).

Monitoring for flies and management of flies and mosquitoes is described in the cattle and swine sections above.

6.5 Biosecurity for horse facilities

Horse facilities present a unique challenge in terms of biosecurity because of their inherent purpose. Rather than being kept for livestock or as work animals, most horses are kept for recreation, meaning that limiting contact among animals or between humans and animals is not feasible. It may be much more important, therefore, to monitor for insect pests on animals more closely, especially those that could spread to uninfested animals by direct contact (e.g., lice and mites) and to keep horse stalls clean to prevent insect breeding. Guidelines outlined for pastured cattle (above) also apply to horses kept on pasture.

7 Insect pests of poultry

Poultry is one of the most important sources of protein found around the world (Vaarst et al., 2015). Commercial poultry raised for food include chickens or related birds that lay eggs and birds raised for meat. Worldwide, poultry meat production is increasing with worldwide consumption expected to increase 19% by 2025 (Conway, 2016a). An estimated 110 million metric tons of poultry meat were produced worldwide in 2016 with the United States as the world leader followed by China, Brazil, and the European Union. China is the leading producer of eggs at 30 million metric tons in 2015, followed by the United States (5.8 million MT), India (4.4 million MT) and Mexico (2.6 million MT) (Conway, 2016b). A variety of insect and arthropod pests and ectoparasites can negatively impact commercial birds. Egg-laying chickens (layers) are generally raised for longer periods of time than chickens for meat (broilers), which can influence the type and severity of insect pests. Additionally, poultry housing can influence the prevalence and severity of poultry pests (reviewed in Mullens & Muriillo, 2017). As animal welfare concerns influence poultry housing (e.g., cage-free eggs) arthropod pest complexes will be affected.

7.1 Permanent ectoparasites

There are several species of lice and mites that infest chickens and other poultry as permanent ectoparasites. Common species include, the chicken body louse (*Menacanthus stramineus*), the shaft louse (*Menopon gallinae*), the northern fowl mite (*Ornithonyssus sylviarum*) and the scaly leg mite (*Knemidocoptes mutans*) (McCrea et al., 2005). Lice are generally host-specific, able to feed on a single host species or very closely related host species. In contrast, poultry mites can often feed on a range of avian hosts (Baker et al., 1956). With a rapid life cycle and high reproductive rate, both lice and mites can reach high numbers on layers, which have a productive life of 1-3 years. However, broilers rarely have high infestations of lice or on-host dwelling mites due to their limited lifespan (6-14 weeks).

Louse nymphs and adults feed on feathers and sometimes blood of poultry, causing irritation to birds (Fig.10.9). Eggs are laid singly or in clumps in bird feathers, and the location of the life stages will vary by louse species. Lice can only survive for short periods of time off-host. For example, chicken body louse adults can survive off-host for only up to 2-3 days in favourable conditions (Chen & Mullens, 2008).



▲
Fig.10.9: Chicken body lice (*Menacanthus stramineus*) on a chicken (dark brown near the base of the feather). Several species of chewing lice infest poultry. Most are feather-feeding, but *Menacanthus* spp. also sometimes feed on blood.

The northern fowl mite is the most common mite that lives on poultry (Fig. 10.10). It is primarily found in the vent region of birds due to a favourable microclimate in this location. Eggs are laid in these feathers, and protonymphs and adult mites blood feed in this area. Mite blood feeding results in irritation to birds and can result in decreased egg production. These mites are not important vectors of disease. Adult northern fowl mites can survive nearly a month off-host when temperatures are cooler (<33 °C) and relative humidity is high (85%) (Chen & Mullens, 2008). The northern fowl mite can feed on a range of poultry and wild bird hosts making it difficult to prevent introduction of these mites into a new poultry flock (Knee & Proctor, 2007). The scaly leg mite looks similar to scabies and lives in the skin under foot and leg scales where they can cause irritation, inflammation, and in severe cases, foot deformation or lameness.

Monitoring for lice or mites that live on-host will rely on direct inspection of animals periodically. Lice may be found all over the body, but mites will be primarily in the vent area (Axtell & Arends, 1990). The presence of mites on eggs is also an indicator of high mite populations and has been used as a threshold for treatment, though ideally treatment would occur before mite populations reach such levels (Mullens et al., 2000).

Control of permanent ectoparasites has traditionally relied on insecticidal sprays applied directly

▼
Fig. 10.10: Northern fowl mites generally live in the vent region of chickens. Mite protonymphs and adults travel from the feathers to the skin surface to blood-feed.



to the birds (Axtell & Arends, 1990). These chemicals must be sprayed at high pressures to penetrate the feather layer to reach where the ectoparasites live. Chemical resistance, increasing organic production, and the shift from caged to cage-free birds has limited the use and effectiveness of insecticides in recent years (Mullens & Murillo, 2017; Mullens et al., 2017b). Alternatives to traditional insecticides include the use of inorganic dusts such as kaolin clay or diatomaceous earth in dustboxes (Martin & Mullens, 2012) or the application of sulphur dust directly to birds or by dustboxes or bags (Martin & Mullens, 2012; Murillo & Mullens, 2016).

7.2 Nest parasites

Some ectoparasites require poultry blood for development and reproduction, but spend most of their time living off their poultry host in the nest area ('temporary ectoparasites'). Common temporary ectoparasites of poultry include the bed bug (*Cimex lectularius*), poultry red mite (*Dermanyssus gallinae*), sticktight flea (*Echidnophaga gallinacea*), and several soft ticks (*Argas* spp.). These temporary ectoparasites can be problematic for both layers and broilers as long as suitable off-host harbourage is available.

Fig. 10.11: Adult sticktight fleas (*Echidnophaga gallinacea*) attach to the host to blood-feed. They prefer to attach to combs, wattles, and areas around the eyes (shown).

The eggs of bed bugs, poultry red mites, and soft ticks are laid in protected cracks and crevices near poultry, such as in nest boxes. Other life stages of these ectoparasites also live within cracks and crevices and other harbourage locations near birds, emerging at night to blood feed on nearby birds. Bed bugs can take 1-4 months

to develop from egg to adult depending on environmental conditions, and they survive for weeks to months without feeding. Bed bugs cause irritation by feeding but have not been found to vector poultry disease (Krinsky, 2009). Poultry red mites can develop from egg to adult in as little as 10 days (Maurer & Baumgärtner, 1992). Red mites have been implicated as vectors of numerous poultry pathogens including bacteria and



viruses (Moro et al., 2005). Soft ticks can transmit spirochetes and cause tick paralysis (Proctor & Owens, 2000).

Sticktight flea adults blood feed by attaching to hosts on the head or face area for extended periods of time (Fig. 10.11) (Axtell, 1985). Sticktight flea adults lay eggs without detaching from birds. Eggs fall to the litter, where immatures develop on organic material and adult flea faeces. Sticktight fleas have not been implicated in disease transmission.

Monitoring for off-host dwelling ectoparasites should target likely harbourage near animals. Nest boxes should be examined periodically for various life stages of ectoparasites, including eggs, or signs of ectoparasites such as blood-faecal spots (Fig. 10.12). Traps made from corrugated cardboard create harbourage for ectoparasites and can be used for monitoring presence and relative abundance. The combs of birds should be examined directly for the presence of sticktight fleas.

While it can be difficult to locate the often numerous harbourage sites of these temporary ectoparasites, application of insecticide or acaricide sprays to these harbourages near birds can provide control. Sprays must be thorough for effective control. Dusts or silica gels or entomopathogenic fungi can likewise be applied directly to cracks and crevices, though environmental conditions may affect their efficacy.

7.3 Insects that develop in poultry faeces and litter

Insects that develop in poultry faeces and poultry litter include the lesser mealworm (*Alphitobius diaperinus*) and several species of flies, notably the house fly and the little house fly (*Fannia canicularis*). Lesser mealworm immatures require months to develop, then burrow into soft wood or poultry housing insulation to pupate

Fig. 10.12: Bed bugs (eggs, immatures, and adults) in a wooden nest box on a commercial poultry facility. The dark spots are caused by bed bug defecation of digested blood and can be indicative of an infestation.



(Axtell, 1985). Besides causing structural damage, beetles are also reservoirs and vectors of numerous poultry diseases. They can also be nuisance pests of humans if large numbers of these beetles are removed from poultry houses with manure cleanout, leaving the adult beetles to disperse into the surrounding area. House flies and little house flies develop in nutrient-rich moist environments that include poultry litter, manure, and spilled feed.

House flies can develop from egg to adult in as little as 7-10 days. Little house flies, in contrast, require 20-30 days to develop from egg to adult (Axtell, 1985). Adult flies can mechanically transfer pathogens, though flies are primarily nuisance pests of humans.

Various traps can be used to monitor for immature and adult beetles (Axtell & Arends, 1990). Tube traps can be constructed out of short (ca. 15 cm) pieces of PVC pipe filled with corrugated cardboard. These traps should be placed along the poultry house perimeter and checked weekly to track relative beetle abundance. Fly monitoring and control as described for cattle (above) apply here. In poultry housing, moist manure or litter should be inspected directly for the presence of developing beetles and fly larvae, which may then be targeted for control.

Control of these pests is best achieved by sanitation efforts applied to poultry manure and litter. Moist areas, such as under leaking water lines, may be hot spots of development. Every effort should be made to dry manure quickly, which will make it unsuitable for fly development. In addition, insecticides or insect growth regulators (prevent insects from maturing to adults) may be applied to manure or other immature development habitat where these pests are noted. Control of adult flies includes insecticidal spray to resting areas, granular fly baits, or fly traps, though this should be secondary to reducing immature development sites.

7.4 Biosecurity for poultry pests

Biosecurity can impact how insect pests get into poultry flocks, how insects and disease are spread among flocks, and the dispersal of insect pests from commercial poultry facilities to nearby properties. Permanent and temporary pests can be limited or prevented entirely with good biosecurity because they are so dependent on poultry hosts for survival. Excluding wild birds and their nests and excluding or limiting rodent activity can limit introduction and spread of mites and lice. Humans may act as incidental carriers of poultry ectoparasites and move them from infested to uninfested flocks. Cleaning boots and equipment in between flocks can limit the spread of insects. Limiting movement between poultry houses will also reduce the risk of spreading ectoparasites.

Lice and northern fowl mites do not infest humans, but poultry red mites may feed on people causing irritation. The bed bug species that feeds on humans can also infest poultry flocks, though the importance of humans to introducing bed bugs to poultry facilities is unknown.

Insects that develop in poultry manure are not as dependent on the presence of poultry, and the way in which manure is stored or managed is much more important for their survival during the time between flocks. Manure and litter can be composted or treated with insect growth regulators or insecticides to limit the spread of nuisance pests and potential vectors. Flies in particular may be able to transmit pathogens to or from poultry facilities. House flies and little house flies can potentially mechanically transmit exotic Newcastle disease, and the vector potential for avian influenza is currently unknown.

8 Conclusion

Biosecurity measures employed to protect animal health must include control of insects, mites, and ticks that negatively impact animals by direct feeding damage or as vectors of animal pathogens. Control of these pests should follow the general principles and practices of an integrated pest management (IPM) programme, including pest monitoring and focusing on proactive measures to limit pest production.

Insect biosecurity is best achieved by (1) reducing fly abundance through appropriate sanitation practices to limit fly development habitat, (2) quarantining and treating animals infested with lice or mites to prevent direct transfer of these pests to other animals, (3) separating farm animals from wild animals that may carry and transfer lice, mites, and ticks, (4) monitoring pest abundance and activity regularly to identify new pest introductions and to determine whether pests are nearing damaging levels, and (5) training facility employees to avoid accidental transfer of ectoparasites from infested facilities to non-infested facilities.

The pests that need to be monitored and managed will depend upon the production animal, the operational characteristics of the facility (e.g., pasture-based or confinement), the geographic region where animals are located, the season, and the presence or absence of pathogens within the region. As discussed in the sections above, pests of importance often differ among the different species of vertebrate hosts, so monitoring efforts should focus on relevant pests for each animal commodity.

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