VETERINARY ECTOPARASITOLOGY

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Summary

Veterinary ectoparasites (insects, mites and ticks) have a significant impact on the health, well being and productivity of their vertebrate animal hosts. These impacts can be either direct, through tissue damage and blood loss or indirect, through their role as vectors of viral, bacterial, protozoa and helminth pathogens. A second category of indirect effects are those that result from the alteration of host behaviour induced by arthropod attack and blood-feeding activity. The insect ectoparasites include flies (Diptera), lice (Phthiraptera), fleas (Siphonaptera) and bugs (Hemiptera). Arachnid ectoparasites include soft and hard ticks as well as the mites. Lifecycle information along with a description of the impact and approaches for control are provided for each group. A summary of diseases and disease agents vectored by arthropod parasites is also included.

1. Introduction

Two major groups of arthropods are parasites of birds and mammals that are important to humans; influencing the well being and productivity or acting as vectors for viral, bacterial, protozoan or metazoan (helminth) disease agents. These same groups of arthropods impact wildlife species often inducing significant stress and altering behaviours related to feeding, and movement. Two arachnid sub-orders, the ticks and mites, in addition to four orders of insects form a group commonly referred to as ectoparasites. Most mites known to biologists are free-living, predacious or plant-feeders, but there is a small sub-group that are parasites of animals. In contrast, all ticks are parasites, feeding primarily on blood of their hosts and acting as vectors for numerous serious pathogens. Among the insects there are members of four orders that are considered ectoparasites. These include all members of the Phthiraptera (chewing and sucking lice) and the Siphonaptera (fleas). Some members of the Hemiptera (true bugs) are important blood feeders as well as being vectors for protozoan diseases. Among the Diptera the vast majority of species are free-living; however, there are several taxa whose larval stages (maggots) feed on the living tissues of hosts. There are a diverse group of dipterans whose adult stages are blood-feeders and which are vectors of significant veterinary diseases. Rare occurrences of animal parasites are noted in other Orders; e.g. *Platypsyllus castoris* the beaver beetle (Coleoptera) found on the North American beaver (*Castor canadensis*) and several examples in the Lepidoptera where blood feeding or feeding on lachrymal secretions are known.

Veterinary ectoparasites may be classified according to several criteria; the body site they occupy, the rigour of the host association and the duration of the host association. Ectoparasites thus may be internal, burrowing into host tissues or living in body cavities (e.g. myiasis producing fly larvae), or external, living on the host skin for various periods where they either feed on blood obtained through piercing/sucking mouthparts or they live on skin debris, hair, sebaceous secretions or plasma.

The rigour of host association falls into two primary categories. Facultative associations occur only under specific conditions and the parasite can survive and develop in the absence of hosts, as free-living organisms, utilizing other food sources. These ectoparasitic associations often arise accidentally, but nonetheless can have severe consequences for the affected hosts (e.g. some traumatic myiasis). Facultative ectoparasite associations most often do not have a high degree of host specificity. The second category of host association is an obligatory association in which hosts are an absolute requirement for the parasite and no alternative lifestyle is possible. The host provides key elements required by the parasite and the associations are often highly specific with the parasite capable of developing only in one host species (e.g. hypodermosis).

The duration of association between the parasite and host can vary considerably, even in those associations that are obligate. There are numerous examples in which the parasites are in continuous contact with the host (e.g. blood feeding lice). In these cases all lifecycle stages are dependent on their association with the host and they cannot usually survive for any length of time away from the host. In some cases only specific lifecycle stages are in continuous association with the host, although the parasite has an absolute requirement for the host (e.g. myiasis causing flies). In contrast, a majority of veterinary ectoparasites are intermittently associated with the host with a proportion of the lifecycle stages being free-living (e.g. some ticks, flea larvae). In these instances oviposition is generally away from the host and larval stages develop without dependence on the host. Blood feeding adults such as mosquitoes, tabanids, black flies and some muscoid flies have a very short interaction with the host yet have serious impact on the well being and productivity through both direct effects of the feeding activity and indirectly as vectors of a variety of pathogens.

Ectoparasites with an intermittent host association have very little dependence on the host for provision of a suitable environment for larval development. These life stages depend on a completely different set of environmental variables than the adults. The larval stages of these ectoarasites are much more susceptible to temperature and humidity variations. Larvae of some species depend on an environment provided through host activities (e.g. dung) or activities that comprise standard animal husbandry/management procedures (soiled bedding, spilled feed). These include a diverse group of flies such as stable flies, house flies, face flies and some species of ceratopogonids. Free living larval stages of other ectoparasites are dependent on environments that are highly dispersed and widely spaced (e.g. larval stages of mosquitoes, tabanids, midges and black flies require aquatic environments of diverse types).

2. Impact of Ectoparasites

Ectoparasites impact hosts in two primary ways; directly through removal of blood, damage to tissues as well as through stimulation of inflammatory and immune responses that are energetically expensive for the host. The second effect on the host is a set of indirect effects which are the result of ectoparasites acting as vectors for pathogens. Interaction between the effects of ectoparasitic infection and those of endoparasites such as protozoa or helminthes can result in impacts that are greater than either group alone. The degree of damage caused by ectoparasites varies from the imperceptible impact of a small blood-feeding louse infestation to deaths that result from a massive invasion of screwworm larvae. In the case of domestic livestock, where productivity is important, the impact is defined by the concepts of “economic threshold” (parasite population level at which measures should be taken to prevent parasite population reaching injurious levels) and “economic injury level” (reduction in yield equals the cost of control). In the case of companion animals these concepts have no relevance and often “one is too many”; a concept that derives from practical considerations shaped by the possibility of pathogen transmission to owners (i.e. zoonoses) as well as owner perceptions (i.e. psychological factors). Ectoparasites are also of importance for companion animals, being responsible for vectoring severe arthropod borne diseases (ABDs). Indeed, blood-sucking arthropod pests act as vectors of viral, bacterial or protozoal infections such as tick-borne fever, babesiosis, ehrlichiosis and filariosis, louping ill, Lyme disease, tick-borne encephalitis, leishmaniasis, rickettsiosis, Q fever and typhus. The latter six are infections that may cause disease in both animals and humans (zoonoses).

Direct effects of arthropod infestation of companion animals, primarily associated with feeding activities, include anaemia, hypothermia, immuno-suppression and invasion of wounds by secondary pathogens (e.g. bacteria). Therefore, through pain and suffering of their hosts, parasitic arthropods pose a major threat to the health and welfare of both companion and domestic animals and are indirectly important components in maintaining public health.

The primary approach for management of ectoparasites is the application of insecticides/acaricides to the animals, to their housing or to the environment in which the animals live. However, effective, sustainable management of arthropods requires more thoughtful and planned integrated approaches that combine several techniques in a coordinated fashion. The integrated approach will reduce use of synthetic insecticides/acaricides, reduced environmental contamination and non-target effects as well as reduce the development of insecticide/acaricide resistance by the target arthropods. Most of the economically important arthropods which have faced the onslaught of synthetic chemical control products have eventually developed resistance to those products. Resistance has often been the driving factor for the animal health industry to develop new classes of active ingredient, but with the staggering costs for development and registration, coupled with relatively small markets, the appearance of new classes has slowed or been focussed on the companion animal sector. Management of resistance now largely involves planned alternation of insecticide/acaricide classes or the use of products with combinations of classes. The logic behind these approaches is that the evolution of resistant genotypes against two distinct chemicals in sequence or in combination will be unlikely to occur.

Because of the intimate relationship between many arthropod ectoparasites and their host animals there is often an opportunity to manage the infestations through manipulation of host responses, in particular the immune response. There have been many theoretical discussions of the utility of immunization as a management strategy for a variety of arthropods ranging from blood feeding flies, to myiasis, ticks and mites, there has been only one notable success. A vaccine has been produced and marketed for the protection of cattle against the tropical tick *Boophilus microplus* and it continues to be refined. Other attempts to develop vaccines against other targets have yet to yield marketable products.

3. Insects

Four insect Orders have species that are ectoparasitic on mammals and birds. Adult members of these Orders have the typical structural features with a hard chitinous exoskeleton, three main body regions (head, thorax and abdomen), six legs (attached to the thorax) and usually two pairs of wings (also attached at the thorax). The head is usually characterized by the presence of the mouthparts, as well as a pair of compound eyes and a pair of antennae which comprise two important sensory elements. Legs, attached at the thorax, are multi-segmented (six main subdivisions) with a set of terminal tarsi that have various structures (tarsal claws) that aid in gripping the surface as well as having a wide variety of sensory structures that aid in host selection/acceptance. Sensory structures on the tarsi regulate feeding as well as recognition of mates. Wings are membranous with a variable number of thickened veins that are key features in identification of many insects. The abdomen contains the main portions of the post-oral alimentary canal, including midgut, hindgut and associated cecae. The main osmo-regulatory organs, known as Malpigian tubules, float freely in the body cavity and connect with the gut at the midgut-hindgut junction. All of the reproductive organs are located in the abdomen and open to the exterior through terminal genital openings.

Following mating insects produce eggs in which embryonic development occurs.

Larval stages exit the eggs and begin searching for suitable food sources. Larvae grow and develop through periodic shedding of the exoskeleton (a process known as ecdysis or molting). The larval stage between each molt is referred to as an *instar*. The number of instars required to reach maturity ranges from three to six in most insects.

Two major modes of development are known in insects; one, characteristic of groups early in insect evolution, in which the change in features between larvae and adults is gradual (i.e. the larvae and adults appear superficially similar) and is known as *incomplete metamorphosis*. This group of insects is also referred to as *hemimetabolous*. The developmental stages in this mode of development are egg, nymph (of which there may be several) and adult. Larvae and adults usually occupy similar niches and utilize similar food sources.

The second developmental mode is known as *complete metamorphosis* in which there are dramatic structural differences between larval stages and the adult. This group of insects is also referred to as *holometabolous*. In this mode of development the last larval stage forms a pupa within which the structural changes the lead to the adult form occur. The lifecycle stages in this mode are egg, larva (of which there maybe several), pupa and adult. Larvae and adults usually occupy distinctly different ecological niches and utilize completely different foods.

Ectoparasites are known from four insect Orders: Diptera (flies), Siphonaptera (fleas), Phthiratpera (lice) and Hemiptera (true bugs). Occasional ectoparasi.tic species are found in other orders, including Coleoptera (beetles) and Leptidoptera (butterflies and moths), but they will not be discussed

3.1 Flies (Diptera)

Flies are either direct ectoparasites with a strong host association or are micro-predators having only brief association with the host. In the latter group the short association with the host is focused on blood feeding activities. Flies exhibit complete metamorphosis, but there are instances where females will develop either one or all of the larval instars within their body, depositing first instars or mature third instars, and thus are referred to as ovoviviparous.

Adults typically have two wings (the other two wings are reduced to small structures called halteres which function as stabilizing devices in flight), have well developed mouthparts variously modified depending on the food source. Flies have four distinct lifecycle stages; egg, larva, pupa and adult. Larval and adults stages occupy distinct ecological niches with the larval stage often in an aquatic or very moist environment (e.g. liquid manure or living animal tissues). Adult stages are highly mobile and utilize a variety of food sources from nectar to dung.

Flies are classified into three sub-orders; the Nematocera which includes the mosquitoes, the biting midges, sand flies and the black flies; the Tabanomorpha which includes the horse and deer flies and the Brachycera with includes the muscid flies (house flies, stable flies, horn/buffalo flies), blow flies, flesh flies and bots flies. These three groups are distinguished by characteristic larval and adult morphological features and habits as well has distinct larval habitats. These features combine making the impact and management of each group a distinct challenge.

Adult Nematocera tend to be small delicate insects with narrow wings and long, many segmented antennae. Their larval stages are aquatic, there are often more than three instars and the pupae are motile. Tabanmorph adults are large, robust flies with stout wings, short stout antennae, tend to have very large eyes and they are excellent fliers. Larvae are aquatic, there are usually more than three instars and the pupae are not motile. Adult Brachycera are medium to large bodied flies with characteristic three segmented antennae and stout wings. Larvae are semi-aquatic living a variety of semi-liquid media, there are three instars and the pupa develops within the last larval skin.

As ectoparasite flies are grouped into those whose larval stage are parasitic in the living tissues of vertebrate hosts, causing myiasis, those whose adult stages are blood feeders and those who have indirect impacts through a variety of activities that affect with wither animals or humans.

3.1.1 Myiasis

Myiasis is the infestation of live vertebrate tissues by fly larvae that feed on the tissue, either living or dead, bodily fluids or food ingested by the host. The requirement for association with the host can be obligate, facultative or accidental; the association can be short duration (days) or long duration (ranging from weeks to nine months). In obligatory associations the larvae require the live host tissues for successful completion of their development. Facultative associations usually arise from infestation of living tisue by carrion dwelling larvae that do not have an absolute requirement for living host tissues.

Myiasis is often classified according to the tissue invaded by the larvae; i.e. cutaneous, gastro-intestinal, naso-pharyngeal, ophthalmic, etc. Invasion of the skin following individual larval penetration often leads to a boil-like lesion referred to as furuncular myiasis. Creation of an irregular skin lesion or wound by the larvae is known as traumatic myiasis. Lesion from traumatic myiasis can be large with a great deal of tissue damage accompanied by substantial serous exudates and physiological upset. Host death resulting from traumatic myiasis is not unusual and can occur in as early as 4 – 5 days post-infestation.

Myiasis can also be classified according to the rigour of host association, thus in obligatory relationships the larvae require close association with the host tissues throughout their development and will not successfully develop in carrion; in facultative myiasis the larvae are often accidental parasites of living host tissues as they will develop as well in carrion. Accidental myiasis occurs when eggs or larvae of a variety of flies, including house flies, cheese skippers, are accidentally ingested and reported found in the faeces. It is unclear whether these stages will survive transit of the mammalian digestive tract.

Three families of higher Diptera (suborder.Brachycera) have species that cause myiasis: Calliphoridae, Sarcophagidae and Oestridae. The former two families have small numbers of genera in which some species cause myiasis while larvae of all representatives of the latter are obligate parasites.

All myiasis producing flies have a similar lifecycle characterized by six distinct stages; egg, three larval stages, the puparium and the adult. Eggs are deposited by female flies on or near the host; the first instars hatch and begin their development within the host tissues. Second and third instars continue development in the tissues, but upon reaching maturity will depart in search of a relatively dry environment in which to pupariate. The hard, usually dark, puparium is formed from the rigidified skin of the last larval stage. Within this protective layer larvae metamorphose into the adult stage.

Myiasis is detected by careful examination of the skin surface for detection of the lesions characteristic of fly strike. In early stages this can be difficult, but becomes less difficult as the infestation persists and the lesions increase in size.

Cryptic infestations associated with infestations by bot fly larvae (e.g. cattle grubs, horse stomach bots and sheep nose bots) can usually be diagnosed by detection of specific antibodies in serum.

Myiasis has severe impact on survival, productivity and well being of affected animals. Infestations with species such as *Cochliomyia hominovora*, *Lucilia* spp and *Wohlfartia magnifica* result in morbidity and often mortality of the affected animals. Productivity is reduced in surviving animals.

Infestations with bot flies such as *Hypoderma* spp and *Oestrus* sp. only rarely result in death but induce dramatic reductions in productivity (reduced weight gain and milk yield) and affect the quality of products obtained from affected animals (e.g. damaged hides, loss of meat quality). The infestations also result in general immuno-suippression with accompanying increased susceptibility to other pathogens. Subtle negative influences on behavior result in alterations to breeding patterns and pasture utilization.

Currently available endectocides are highly effective for control of myiasis. These macrocyclic lactone based products kill migrating larvae and can be applied by spray or a 'pour-on' technique, by individual oral dosing or by mixing in the feed. Their widespread use in nematode control programs plays a major role in controlling warble flies.

The sterile insect technique (SIT) has been used successfully in management and eradication of myiasis producing flies. This approach combines the use of insecticide treatments with the mass release of sterilized male flies. The insecticide application reduces the fly population so that when sterile males are release they dramatically outnumber wild males and thereby increase the odds that wild females will mate with sterile males and thus produce no viable eggs.

The most significant and successful use of SIT has been the USDA screwworm eradication program which has successfully eliminated this fly from North and Central America and now maintains a barrier at the Panama Canal. Development of high throughput mass rearing procedures allow for production of millions of sterile male *Cochliomia hominovorax* each week.

A similar SIT program was successful in eradicating cattle grubs from a region of south-western Alberta, Canada and north-western Montana, US. The extent and broad utility of the program were limited by the lack of a suitable mass rearing procedure.
Important myiasis producing species:

Calliphoridae
Obligate
Cochliomyia hominovorax – New World screwworm
Chrysomya bezziana – Old World screwworm
Facultative
Lucilia sericata - sheep blow fly
Sarcophagidae
Wohlfartia magnifica
Oestridae
Hypoderma spp – cattle, deer and goat grubs, warble flies
Oestrus ovis – sheep and goat nose bots
Gasterophilus spp. – horse stomach bots
Dermatobia hominis – tropical or human bot fly

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