Integrated management of blood-feeding arthropods in veterinary teaching facilities – Part 3: proposal for a coherent and affordable control plan

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Summary

As reviewed in Part 1 of this publication series, numerous haematophagous arthropods have negative direct effects and are involved in the transmission of pathogens to either animals and/or humans in Western Europe. Their control is therefore essential to prevent vector-borne infections. Different control methods, either general or arthropod-specific, were presented in Part 2 of this publication series. Part 3 focuses on integrated management of arthropods and proposes a coherent and affordable plan for facilities housing sick animals in a veterinary faculty, i.e. small animals and large animals, with an educational farm. Control of arthropods should be part of a biosecurity plan, the effectiveness of which requires awareness raising and education of the different actors, i.e. staff, students and animal owners. The originality of the review lies in its specificity to a veterinary faculty and animal housing facilities, from a One Health point of view. As far as it could be ascertained, this is the first review focusing on arthropod control in this specific at-risk environment.

Keywords

Companion animal – Horse – Integrated arthropod management – Livestock – Parasitic haematophagous arthropod – Veterinary hospital.

Introduction

As reviewed in Part 1, numerous haematophagous arthropod species are involved in the transmission of animal, human and zoonotic pathogens in North-western Europe (1). Through several drivers such as climate change and globalisation, the occurrence of vector-borne infections is raising a great deal of concern in Western Europe (2, 3). The geographical distribution of vectors such as mosquitoes or ticks is constantly expanding. This is the case for *Aedes albopictus* (the Asian tiger mosquito), which can transmit, among others, Zika and chikungunya viruses, *Phlebotomus* sandflies, the main vectors of leishmaniosis, and the tick *Hyalomma marginatum*, one of the main vectors of Crimean–Congo haemorrhagic fever (4, 5, 6). It is therefore essential to improve preparedness for such emerging vector-borne infections through the implementation of appropriate preventive and control measures to reduce the risk of transmission. The main arthropod control methods – either general or arthropod-specific – were presented in Part 2 of this publication series. As mentioned previously, the intensive use of chemical insecticides in the control of adults and immature stages of insects has increased the resistance to chemical pesticides among targeted species; this is particularly well known for mosquitoes, as observed in malaria control programmes (7, 8). Furthermore, the intensive use of chemical pesticides has negative consequences on the environment, especially on beneficial insects (9). The environment is one of the three pillars of the One Health concept (with human and animal health), which considers host (animal and/or human), arthropod (potential vector) and environment and the relationships between them. Increased insecticide resistance, along with its negative effects on human health and the environment, raises the need for effective non-chemical and environmental control strategies (10, 11). The concept of integrated vector management (IVM) is very appropriate to answer such challenges as it includes the three pillars of the One Health approach.

This paper, Part 3 of the series, will address the topic of IVM and propose an affordable and practical 'arthropod (vector) control plan' based on the principles of IVM and considering the One Health concept, at the scale of a veterinary faculty. Targeted facilities consist of clinics housing small and large animals, a closed pig farm, and an educational farm housing cattle and small ruminants, as well as animals at pasture. Moreover, the control of arthropods is an essential component of biosecurity plans in veterinary faculties (12).

Management of blood-sucking arthropods in veterinary teaching facilities according to the principles of integrated vector management

Integrated vector management is defined as a 'rational decision-making process to optimise the use of resources for vector control' (13). It combines several tools such as source reduction, biological control, chemical control, monitoring, detection of pathogens and emergence of resistance, and public education (14, 15, 16). This approach aims at improving efficacy, cost-effectiveness, ecological soundness and sustainability of disease vector control. It ensures the rational use of available resources by addressing several infections, integrating both non-chemical and chemical arthropod control methods and other disease control methods (14).

The concept of IVM was initially developed in agriculture subsequent to the intensive use of chemical insecticides, and was named integrated pest management (17). Such an approach requires a good knowledge of both the 'enemies', i.e. arthropods and infections, and the 'victims', i.e. mammalian hosts. One of the advantages of IVM is that it can address several infections concurrently; indeed, several arthropods transmit several pathogens. For example, *Ixodes ricinus* is a well-known biological vector of three pathogen groups: bacteria (several genospecies of *Borrelia burgdorferi* sensu lato), protozoa (*Babesia divergens*) and viruses (e.g. tick-borne encephalitis [TBE]) (18). Moreover, some control tools are effective against several arthropods, e.g. a physical control method such as regular-size window screening prevents the entry of both mosquitoes and flies, among others (19). Integrated vector management has two important characteristics: a) it combines several control methods against adults and immature stages – indeed, none of these control options is 100% effective, and b) it reduces the emergence velocity and the probability (or rate) of emergence of resistance to chemical pesticides in targeted arthropods (14). As mentioned above, the concept of IVM totally falls into the One Health approach, as it involves direct and indirect actions on hosts (e.g. by treating infested/infected animals and/or protecting them from future infestations/infections through the application of repellents), the environment (e.g. through ecologically friendly landscape management) and arthropods (e.g. use of larvicides). All these approaches reduce the human health impact of arthropods and the control measures against them. The implementation of IVM does not rely solely on pesticides applied on hosts or in the environment, because resistance to pesticides is increasingly reported (10).

Proposal for an integrated arthropod management-based vector management plan in veterinary teaching facilities

General recommendations

Control measures applicable to all facilities

Physical control of flying haematophagous arthropods is essential: doors must be kept closed as much as possible, especially in animal housing facilities. The existence of an anteroom (delimited by a double-door system) also helps to reduce the entry of arthropods (Figs 1 and 2).

Fig. 1

Anteroom to access a large animal isolation unit

Two automatic shutters delimit an anteroom for large animals seen upon entering the isolation unit. Such an anteroom is an additional barrier against winged haematophagous arthropods, potential vectors of infection (location: University of Liège, large animal isolation unit, Liège, Belgium, January 2017).

Fig. 2

Anteroom to access a small animal isolation unit

A double-door system delimits an anteroom, which is an additional protection against the entrance of potential vectors of infections from outside the unit (and their exit) (location: University of Liège, small animal isolation unit, Liège, Belgium, January 2017).

Potential mosquito breeding sites should be minimised by overturning or covering any object where water could accumulate, filling holes (with earth, stones or sand) and regular cleansing of gutters, along with their repair when damaged (20).

Sanitation and hygiene are essential to reduce fly infestation. Figure 3 illustrates a situation that must be avoided. Any non-essential organic matter, e.g. spilled feed or faeces/soiled litter, should be cleaned as quickly as possible. Trash cans should be emptied at least once a week and kept closed at all times.

Fig. 3

Poor management of a container for biologically contaminated waste

Poor waste management is a strong attractant for some groups of haematophagous arthropods, especially if containers for biologically contaminated waste are concerned. In this figure, larvae have already developed on the container. The outsides of waste containers should be kept as clean as possible to avoid such situations.

Lice- and flea-infested animals should be housed apart from other animals and their movements among facilities strictly minimised; infested cats should be carried in a transportation box. Attending people should wear appropriate equipment to protect working clothes and avoid transferring parasites from one animal to another. Each animal should have its own grooming equipment and bedding. Adequate biosecurity measures should be implemented upon animal discharge, i.e. cage cleansing and appropriate treatment of grooming equipment.

Given the potential risk of spreading infection through fomites (21), cleaning and disinfection of animal transport devices, such as transportation boxes for small animals (cats, pocket pets, etc.), livestock transporters and horse trailers, should not be neglected. Indeed, several studies have identified contaminated livestock transport vehicles as sources of pathogens such as classical swine fever virus (22) and *Salmonella* spp. (23). According to the Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004, laying down specific hygiene rules for on [*sic*] the hygiene of foodstuffs, all vehicles transporting animals must be cleaned and disinfected each and every time animals are unloaded at slaughterhouses, farms and collection points (24). The construction of a washing station for trailers is strongly encouraged in each veterinary teaching institution.

For livestock, insect control in transport vehicles is also important to avoid the introduction of new arthropod species (25); it is now recommended by European Regulations related to the control of bluetongue, for example Commission Regulation (EC) No. 1266/2007 (26).

Information, training and education

In order to be efficient, IVM should be available in the standardised form of clear and structured procedures. As vector control is one component of veterinary biosecurity, all measures/tools should be included in the Biosecurity Standard Operating Procedures (SOPs), as applied to the Faculty of Veterinary Medicine, University of Liège, Belgium, for example (27).

Training workers and technicians in all facilities is also one of the keys to success of an arthropod control plan. These persons will be in the frontline, as they take care of animals every day. It is therefore crucial for them to have the appropriate knowledge to identify any problematic situation that requires the adaptation of IVM to a new situation or species. Continuing education is also essential, for example to keep staff aware of potential emerging arthropod species and infections.

In a veterinary faculty, an effective arthropod plan cannot work without the effective involvement of students. This includes provision of adequate education in the importance of arthropods as potential vectors, endemic and threatening exotic vector-borne infections, appropriate control measures and IVM.

As the control of arthropods is everyone's business, it is also crucial to regularly inform animal owners and, more broadly, the general population. For example, periodic (seasonal) campaigns on the prevention of tick bites are important to raise awareness of infestation risks of companion animals.

Monitoring, record keeping and traceability

Record keeping and traceability are important components of IVM, and may include several pillars. The recording of any chemical treatment provided to an animal or to the environment is highly recommended. As daily checking for the presence of arthropods is strongly advised (e.g. the presence of ticks or fleas on dogs and cats, fly counts on pastured cattle), observations of arthropods should be recorded carefully and included in the monitoring system, in combination with trapping results, as described in Part 2 (19).

Large animal facilities (ruminants, horses and pigs)

Tables I and II summarise the control and preventive arthropod-specific measures adapted to large animal facilities, i.e. veterinary hospitals, pig farms and educational farms housing ruminants.

Table I

Winged haematophagous arthropods: control measures and tools in large animal facilities

Measures	Mosquitoes	Biting midges	Tabanids (horse flies)	Flies*	Black flies	Sandflies	References
Physical tools and measures							
Keep doors closed at all times	x	x	x	x	x	x	
Double-doorway system	x	x	x	x		x	28
Window screens/nets – regular mesh size (≥ 1.5 mm) (regular maintenance)	x		x	x			28, 29, 30
Window screens/nets – mesh size < 1 mm (regular maintenance)		x			x	x	28, 29
Trapping							
– CO_2-baited light trap	x						31, 32, 33
– OVI light traps		x					34
– Sticky papers or traps				x		x	28
– Ultraviolet fly traps				x			28
– Electric fly killers				x			28
– H-trap			x				35
Pasture: shelter providing dark conditions					x		36
Chemical tools							
Synthetic contact organic products							
– Organophosphorus compounds	x						37
– Carbamates	x						38

– Pyrethroids	x	x	x	x	x	x	37, 39, 40, 41, 42, 43, 44
– Diethyltoluamide (also called DEET)			x				45
Insecticides on adult sick animals (treated ear tags, topical pour-on, sprays)	x	x	x	x	x		46, 47, 48
Insecticides in the environment (e.g. room sprays etc.)	x			x	x		28, 38, 47
Environmental measures							
Avoid all factors favouring the presence and accumulation of standing water	x						49
Control moisture		x	x	x			50, 51
Reduce/eliminate emergent and unwanted vegetation	x					x	20, 49
Pasture: make water fluctuate by 30–40 cm every six days in large reservoirs of drinking water	x						20, 49
Experimental and educational farm: keep silage well covered				x			52
Strict hygiene (eliminate substrates such as faeces, silage and organic residues) and sanitation		x		x			47, 53
Avoid accumulation of organic debris (frequent inspection and removal)		x	x	x		x	47, 50, 53, 54, 55
Disturb organic debris once a week (e.g. spilled feed, bedding, rotten vegetation, leaves)				x			56
Remove detritus from nearby bodies of water					x		57
Pasture – watering ponds							
– Regular treatment with biological larvicide or introduction of insect-eating fishes is encouraged	x						58
– Drainage/paving of the surrounding area (water-filled hoof prints act as breeding sites) and regular cleaning	x					x	28, 59
Tyre storage (experimental and educational farm)							
Tyres used to cover silage bunkers							
– When not in use, stored under a roof or covered, on racks with the possibility of inspecting them separately – Holes pierced in tyres (to avoid accumulation of water) – Prompt recycling if not used anymore	x						60
Weekly inspection, and dumping out of any accumulated water	x						61

Trash cans							
– Weekly disposal and cleaning (especially if containing biologically contaminated waste such as blood etc.)	x			x		x	40, 51
– Keep trash cans covered (lids) (especially if containing biologically contaminated waste such as blood etc.)	x			x		x	40, 51
Drainage system							
– Rain gutters – periodic inspection and cleansing (leaves/debris)	x						60, 62
– Rain gutters – repair leaks and use a suitable gradient	x						60, 62
– Drains – keep drainage ditches free of excessive vegetation and debris	x						61
– Drains – screen small drains and keep free of water and debris	x						61
Manure/faeces							
– Store manure in a remote site, if possible, where it will not be rewetted		x		x			40, 47, 53, 56
– Daily removal				x			63
– Scrape/harrow walls and floor regularly to break up any dry faecal accumulations in boxes/stalls				x			47
– Disturb manure once a week to prevent eggs hatching				x			56, 62
– Pasture (low cattle density): disturb freshly deposited cattle faecal pads				x			64

* these flies include stable flies and horn flies
CO_2: carbon dioxide
OVI: Onderstepoort Veterinary Institute

Table II

Ticks, fleas and lice: control measures in all facilities

Measures	Ticks	Lice	Fleas	References
Physical control				
Separate/limit contacts (physical separation) between infested and non-infested animals		x	x	65, 66
Avoid sharing equipment (grooming material, blankets, etc.)		x	x	65
Small animals: avoid tick habitat when walking dogs outside the clinic (edges of lawns and proximity of brushes)	x			67
Limit movements of animals among facilities (to reduce transfer of ticks and other ectoparasites)	x	x	x	66
Small animals: regular checking of animals – daily tick checks and removal	x			67
Small animals: daily mechanical cleaning of cages and bedding areas – keeping housing well swept and floors washed			x	68
Shearing/clipping if necessary (severe infestation)		x	x	65
Chemical control – repellents/environment				
Application of chemical treatment on animals (repellents)	x	x	x	41, 69
Herd management: ivermectin or related pesticides; for lice, repeat the treatment after 10–14 days – treat all animals	x	x		44
Small animals: environment chemical treatment with insecticides	x	x	x	70
Environmental control				
Landscape management				
– Reduce ticks around buildings (most ticks are located within 3 m of the lawn perimeter, along woodland edges, stone walls and ornamental plantings)	x			71
– Regularly trim tree branches and shrubs around the lawn edge (to allow more sunlight in)	x			71
– Regularly mow and remove cover vegetation around buildings, especially in dog walking areas	x			71
– Remove leaf litter, clear tall grasses and brush at the edge of pastures and around stone walls (and wood piles)	x			71
– Fencing (to exclude large wild hosts)	x			71
– Management of rodent potential habitat (control vegetation around outdoor-stored items, seal stone walls and small openings)	x			71
– Pasture: 1-m buffer area of wood chips/tree bark or gravel between pasture and woods (to restrict tick migration into pastures)	x			71
Control of rodents to minimise contacts with arthropods	x		x	71

The chemical control of adult flies in such facilities is only recommended a) when populations reach damaging levels, b) during epidemics of an emerging infection (e.g. bluetongue), c) in the case of introduction of an exotic arthropod (e.g. *Aedes albopictus*) or d) when there is a risk to human health (e.g. Crimean–Congo haemorrhagic fever or TBE). Nevertheless, chemical control cannot replace adequate hygiene measures.

Onderstepoort Veterinary Institute (OVI) traps may be used for the monitoring of biting midges in strategic locations, for example around large animal isolation premises and pastures (72).

In areas where they are present (rural and semi-rural environments), natural predators, such as swallows or swifts and bats, contribute to the reduction of adult flying insects (73). As generalist predators, bats can consume up to 1,000 mosquitoes and other kinds of insects in only one hour (74). Barn swallows consume large numbers of flies, which can plague livestock (75). They feed on selected aerial insects of intermediate size that occur at relatively high density and have poor flight performance (76). A single barn swallow can consume 60 insects per hour (77). Nevertheless, birds and bats may play the role of vectors of pathogens such as *Salmonella* spp., *Campylobacter* spp. and *Clostridium difficile* (78, 79, 80, 81). They should be prevented from accessing facilities and limited to the area around them, through placement of artificial nests in dedicated areas not at risk, for example.

Large animal isolation facilities

In addition to boarding windows, double screening on the air extraction system provides an additional barrier in large animal isolation facilities, using: a) a screen with regular mesh size (first barrier between animals and outdoors) (Figs 4 and 5) and b) small-size mesh screen to prevent the exit of smaller insects, placed 'downstream' from the first screen level (to limit fouling). Regular maintenance and cleansing of screens/filters are essential to limit fouling because this reduces ventilation efficacy. They should be regularly inspected for any damage, and cleaned once a month. Indeed, rapid fouling has a negative impact on ventilation.

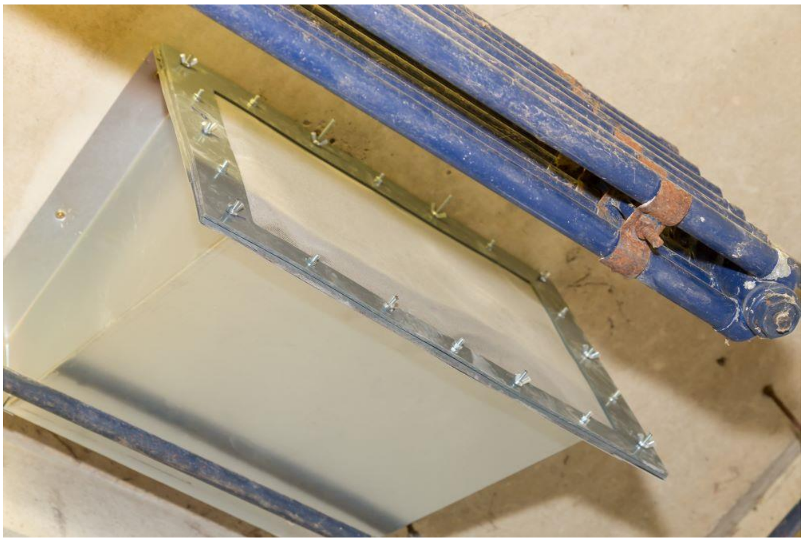

Fig. 4

Screen on the air blasting system in a large animal isolation unit

Screening the openings of air blast systems helps to reduce the entrance of winged haematophagous arthropods, potential vectors of infection, from outdoors (location: University of Liège, large animal isolation unit, Liège, Belgium, January 2017).

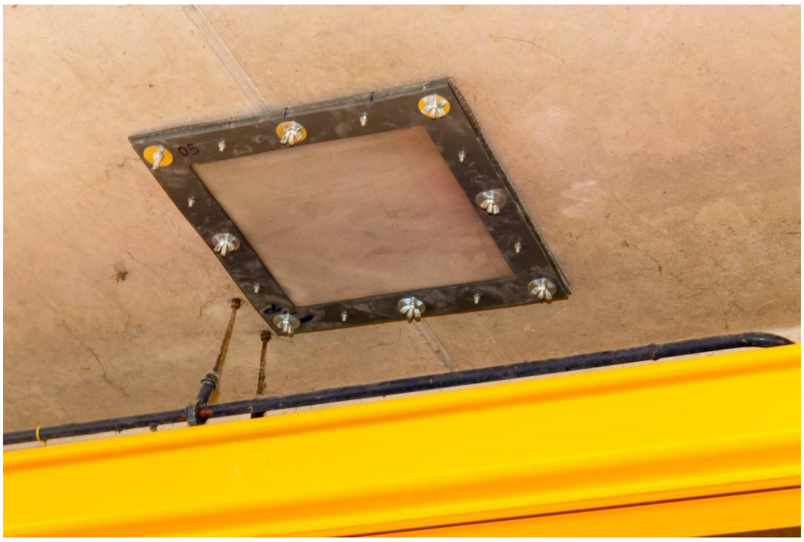

Fig. 5

Screen on the air exhaust system in a large animal isolation unit

First level of screening on the air exhaust system that helps to prevent the exit of mosquitoes and flies (as it is of regular mesh size) from the isolation unit to the outside of the unit. It is a barrier to their escape if they are potentially contaminated. A second level of screening, with smaller mesh size, is placed ‘downstream’ to block smaller arthropods such as *Culicoides* biting midges (location: University of Liège, large animal isolation unit, Liège, Belgium, January 2017).

Farms housing ruminants

Several management methods suggested in Table II to control permanent ectoparasites and ticks are of particular interest for a farm, i.e. landscape management and herd management. To improve tick control, landscape management and restricted access of wild animals to pastures could be combined. New animals should be quarantined, inspected and treated with insecticide prior to their introduction to the herd. Furthermore, it is strongly advised to monitor the effectiveness of treatment.

It is important to avoid, or limit as much as possible, potential mosquito breeding sites in pastures, by draining or paving the area around watering points, draining standing water and reducing or eliminating vegetation close to water (59). Water storage tanks should be made mosquito-proof, e.g. by fixing a sieve on the cover, as such devices help reduce mosquito populations (82). Flushing out the water in watering tanks or troughs every week is strongly recommended if drainage outside the area is good (60).

Old tyres generally used to cover silage bunkers should be stored appropriately when not in use, e.g. under a roof or covered, in order to avoid the accumulation of rainwater. Furthermore, holes can be pierced in the tyres to avoid accumulation of standing water. They should be promptly recycled if not used anymore. One can investigate the alternatives to the use of tyres to cover silage bunkers.

Vegetation around buildings should be controlled in order to avoid providing a suitable environment for rodents and breeding sites for some groups of haematophagous arthropods. Figure 6 illustrates overgrown vegetation next to farm buildings; such a situation should be avoided.

Fig. 6

Overgrown vegetation around farm buildings

Such situations should be avoided, because vegetation offers rodents hiding places and generates decaying organic material that can provide breeding sites for some groups of haematophagous arthropods.

Stabling animals indoors does not reduce attacks by biting midges, because breeding sites have been reported indoors as well (83). Insecticides or repellents directly applied on animals provide some level of protection, but were not very successful when used during the European bluetongue epidemics (84).

Regarding black flies, an emergency action plan could be elaborated, in collaboration with the neighbouring municipality, to be prepared for and prevent any massive attack, because some pastures are located less than 100 m from a river.

Small animal facilities

Control of haematophagous arthropods is easier to implement in small animal facilities, because it is possible to seal the environment more effectively. Control and preventive measures against arthropods of concern specific to small animal facilities are detailed in Tables II and III.

Table III

Winged haematophagous arthropods: control measures and tools in small animal facilities

Measures	Mosquitoes	Sandflies	References
Physical measures and tools			
Keep doors closed at all times	x	x	
Window screens/nets – regular mesh size (≥ 1.5 mm) (regular maintenance)	x		28, 29, 30
Window screens/nets – mesh size < 1 mm (regular maintenance)		x	28, 29
Trapping			
– CO_2-baited light trap	x		31, 32, 33
– Light traps		x	28
– Bait traps		x	28
– Sticky traps		x	28
– Flight traps, ultraviolet electrocutor trap		x	28
Chemical tools			
Synthetic contact organic products			
– Organophosphorus compounds	x		37
– Carbamates	x		38
– Pyrethroids	x	x	39, 40, 43
Insecticides on animals (impregnated collars, spot-on)		x	85
Insecticides in the environment (e.g. room sprays etc.)	x	x	45, 86

Environmental control of breeding sites and larval habitats			
Avoid all factors favouring the presence and accumulation of standing water	x		20
Reduce/eliminate emergent and unwanted vegetation	x	x	20, 49
Trash cans			
– Weekly disposal and cleaning	x	x	36, 40
– Keep trash cans covered with adapted lids	x	x	36, 40
Drainage system			
– Rain gutters – periodic inspection and cleansing (leaves/debris)	x		62
– Rain gutters – repair leaks and use a suitable gradient	x		62
– Drains – keep drainage ditches free of excessive vegetation and debris	x		61
– Drains – screen small drains and keep free of water and debris	x		61
Strict hygiene (eliminate substrates such as faeces and organic residues) and sanitation		x	30, 55, 87
Avoid accumulation of organic debris (frequent inspection and removal)		x	30, 55, 87
Fill cracks and crevices in walls, ceilings and floors (adult resting sites)		x	28, 43
Clear and roll, tamp or pave outdoor areas		x	28, 43
Destroy rodent habitat (reservoir hosts)		x	87
Keep dogs indoors at dusk and dawn during the risk season if leishmaniosis becomes established in the region		x	30

CO_2: carbon dioxide

All animals should be inspected for the presence of ticks and fleas (or lice, although less common in small animals) upon admission to the hospital and on a daily basis; indeed, grooming activity is reduced, and even abolished, in sick animals. If found, ticks should be promptly removed with appropriate devices such as fine-tipped tweezers that allow one to grasp the tick as close to the skin surface as possible and twist, without squeezing the tick's body or letting mouth parts remain in the wound (88). If infestation by fleas or lice is detected, specific control measures should be promptly implemented (Table II).

Conclusions

This review proposes an affordable and coherent IVM-based plan to control haematophagous arthropods in the animal facilities of a veterinary faculty. It includes recommendations applicable to the control of several species, but also arthropod-specific measures, which aim at reducing the risk of several pathogens. The suggestions consider physical control methods for adult insects but also source reduction, while limiting the use of chemical insecticides against immature stages and imagos. Indeed, the use of chemical insecticides and/or repellents should be considered carefully in order to minimise the emergence of resistance and limit the impacts on local biodiversity and non-targeted species, on the health of treated animals (e.g. by using insecticides with no side effects on treated animals) and on human health (e.g. avoiding insecticide residues in livestock and ensuring the safety of persons handling insecticides). Hygiene and sanitation are essential for fly control, while avoiding any standing water is one of the key factors in mosquito source reduction. The propagation of non-flying haematophagous arthropods should be contained as much as possible through separation and treatment of infested animals, along with the use of dedicated equipment. In order to be efficient, such a plan requires the involvement of every person in the veterinary faculty, i.e. staff, students and animal owners. This is implemented first through (continuing) education, along with providing information to animal owners, which is deliverable through various channels such as seasonal campaigns, e.g. raising awareness of the risks associated with ticks (89) or the control of mosquitoes (90). Such an approach is essential to increase global resilience and reduce the risk of transmission.

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