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Myiasis Infections in Animals and Men

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INTRODUCTION

Myiasis is a condition caused by larval stages of different types of flies belonging to the order Diptera that attack tissues and organs of vertebrate animals, including man. The word myiasis is derived from the Greek word *myia* meaning= fly. On the other hand, this chapter is not an exhaustive review of flies causing myiasis, it refers to some of the most important myiasis, primarily in farm animals of economic interest (Hall and Wall 1995) and secondarily, in man (Francesconi and Lupi 2012; Hosni et al. 2019). In this context, myiasis-producing larvae are important because it produce economic losses in farm animals which are source of infestations in humans. This situation is aggravated by factors such as the growing human population, climatic change, and the lack of proper control measures of myiasis-producing larvae. Under these circumstances, the One Health approach offers a viable control alternative.

Etiological Agents

The major myiasis causing larvae belongs to the *Oestrus ovis*, *Hypoderma* spp., *Gasterophilus* spp., *Dermatobia hominis*, and *Cochliomyia hominivorax*.

Oestrus ovis Linnaeus

O. ovis (Fig. 1) is a species of fly widely distributed in the world. The larvae are obligate parasites of the nasal passages of sheep and goats (Yilma and Dorchies 1991; Hall and Wall 1995; Cepeda-Palacios et al., 1999; Murguia et al., 2000; Yacob et al., 2004) and occasionally affect other species such as man (Hall and Wall, 1995) and dog (Zanzani 2016). The female normally deposits active young (L_1) larvae from early summer or fall in nostrils of host (Fig. 2). Then larvae enter host sinuses, often to the base of the horn and attaching to the

Fig. 1: *Oestrus ovis* adult fly. (Photograph by Carlos R. Bautista-Garfias)

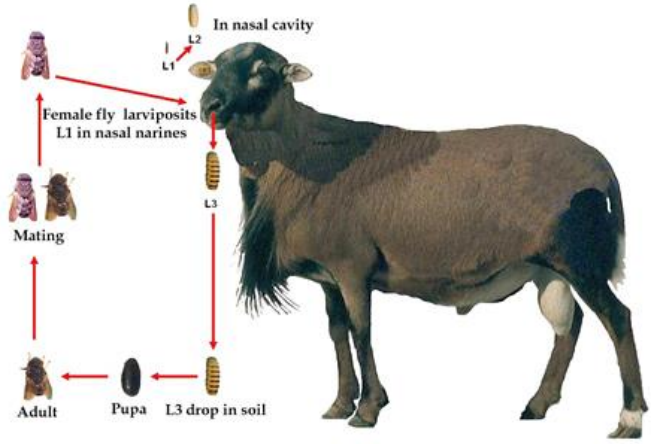

Fig. 2: Biological cycle of *Oestrus ovis*. (Photograph by Carlos R. Bautista -Garfias)

mucous membranes (Fig. 3). Larvae of different stages of development (L_1, L_2, and L_3) can be found here. The larvae reach their maximum development (L_3) in the following spring, with their larval period of 8 to 10 months (Fig. 4) (Hall and Wall 1995).

Generally, the pupal period lasts between three to six weeks, sometimes much longer in areas where low temperatures prevail. Adults can live up to 28 days. The complete development of the parasitic phase, in lambs born in the spring, can be from 25 to 35 days (Hall and Wall 1995).

In the presence of *O. ovis* fly, sheep and goats become very agitated, shaking their heads, thrusting their nostrils into the dust, snorting. In parasitized animals, there is a purulent discharge from the nostrils, vigorous shaking of the head and the animal become emaciated. The infestation by *O. ovis*

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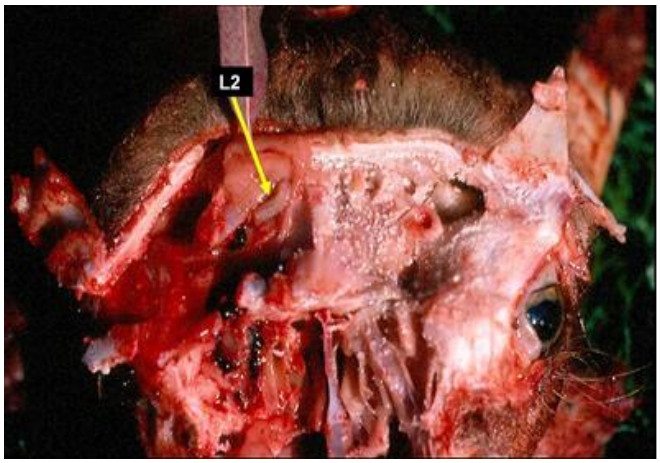

Fig. 3: *Oestrus ovis* L2 in frontal sinus of sheep (arrow). (Photograph by Carlos R. Bautista -Garfias)

Fig. 4: *Oestrus ovis* L_3 goes out sheep nostril. (Photograph by Carlos R. Bautista-Garfias)

larvae generally is not fatal; however, some animals can die within a week or less after the appearance of aggravated signs (secondary infections produced by bacteria) (Horak 1977).
Diagnosis is difficult since it can be confused with the signs caused by other diseases. However, based on the knowledge that sheep and goats mount an immune response against the larvae (Bautista-Garfias 1987; Bautista-Garfias 1996; Tabouret et al. 2003), serological tests can detect IgG circulating antibodies against the larvae (Bautista-Garfias et al. 1982; Bautista-Garfias et al. 1988; Otranto et al. 2004).
On the other hand, there is occasional occurrence of human cases of *O. ovis* infestation infecting the eyes (Beltrán et al. 2006; Singh and Singh 2015; Basmaciyan et al. 2018; Tabuenca-del barrio et al. 2018) and pharynx (Hazratian et al. 2017). With respect to the control, One Health approach has been proposed in order to effectively control sheep myiasis and to increase sheep production (Colwell and Wall 2018).

Hypoderma spp.

Hypodermosis is caused in cattle by the larvae belonging to the genus *Hypoderma*, widely distributed in the northern hemisphere (Hall and Wall 1995; Boulard 2002; Wei et al. 2004). *H. lineatum* (de Villers), the common larva of cattle, is found throughout the U.S., Canada, and northern Mexico. *H. bovis* (Linnaeus) is the larva of north-eastern cattle and is found in Canada and the north-eastern USA. *H. bovis* adults induce a kind of fear or dread in cattle that makes them run uncontrollably, potentially injuring themselves and causing decrease in milk production. Although the adult fly does not bite or sting, it can induce such fear. Adults resemble bees, which are often called "heel flies" (Fig. 5). *Hypoderma* adults are present for four to six weeks from early spring to early summer (Broce 1985). *H. bovis* eggs are attached individually on the flank or lower abdomen; those of *H. lineatum* are glued in rows of 3 to 10 on a single hair on the forelegs, chest, or lower body. They hatch in approximately four days and, after penetration of host´s skin, the larvae causes irritation and exudation. The total production of eggs by a single female fly has been estimated to range between 500 and 800, which dies a short time later, as it has no mouthparts and is unable to feed (Broce 1985).
The larva spends 9 to 10 months migrating as an internal parasite (L_1, L_2) before emerging as L_3 from (Fig. 5) the host to pupate and become a short-lived adult in the following summer (Fig. 6). The active larva L_1 spends much of its parasitic period in migrating through the intermuscular connective tissue to the subcutaneous tissue of the back (loin) (Fig. 7). However, there is an important wintering period in or around the spinal cord in *H. bovis*, or in the mucosa of the oesophagus in *H. lineatum* (Broce 1985). This migration often follows the course of nerves, avoiding blood vessels and muscles. When L_1 reaches the back (loin), it develops into L_2, cutting a one to three mm diameter hole in the skin to breathe through its rear breathing spiracles. At this stage, host reactions give rise to a fibrous cyst that forms around the larva. Shortly thereafter, L_2 transforms into L_3, which is much larger, approximately 25 mm long, brown in colour, and has armour-like features with spines (Fig. 6).
After 6 to 11 weeks, the larva emerges from the breathing hole in the skin of the back, falls to the ground and pupates after burrowing into a dark brown puparium (Fig. 8). The stage, of the development to the adult, lasts approximately 35 days, depending on the climatic conditions but it can be as short as two weeks under optimal weather conditions. The adult then emerges by pushing off the pupal cap, and then comes to the surface to prepare for flight (Broce 1985; Hall and Wall, 1995).
The adult, without effective mouthparts, is a reproductive and dispersal phase that dies approximately six days after emerging. Their success in the distribution of the species depends on prevailing weather conditions, which limit their activity and their ability to find a breeding partner and potential animal host (Hall and Wall 1995).

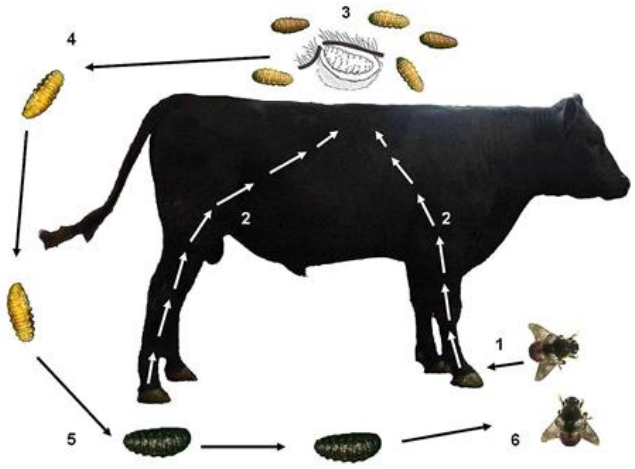

Fig. 5: Life cycle of *Hypoderma* spp. 1, gravid female glues her eggs to host hair. 2, The first instar larvae (L_1) migrate towards the back of the bovine where they pass to the second instar (L_2). 3, A fibrous cyst forms around the larvae; 4, The L2 transform into third instar larvae (L_3) that fall to the ground. 5, L3s transform into pupae. 6, Adults are born from the pupae, which then mate. (Photograph by Carlos R. Bautista-Garfias)

Fig. 6: *Hypoderma* spp. L_3. (Photograph by Carlos R. Bautista-Garfias)

Economic losses for the control and the production costs in USA as estimated by the USDA 1976 were close to 360 million US dollars. Much of this is due to costs of systemic insecticides in beef cattle and non-lactating dairy cattle. The largest losses due to *Hypoderma* larvae are those that are obvious on slaughterhouses such as devalued carcasses, loss of condition, and damage to hides (Broce 1985). As in the case of *O. ovis*, cattle mount immune responses against antigens from *Hypoderma* larvae (Baron and Colwell 1991a), thus serological diagnosis has been shown to be possible (Otranto et al., 2004) and even immunize cattle against *Hypoderma* (Baron and Colwell 1991b).

Hypoderma larvae, occasionally cause myiasis in tissues of human beings i.e. skin (Morgan et al. 1964; Logar et al. 2008), eyes (Lagacé-Wiens et al. 2008), groin and testicular region (Puente et al. 2010), muscles (Starr et al. 2009) and even in the lymph (Scott 1964).

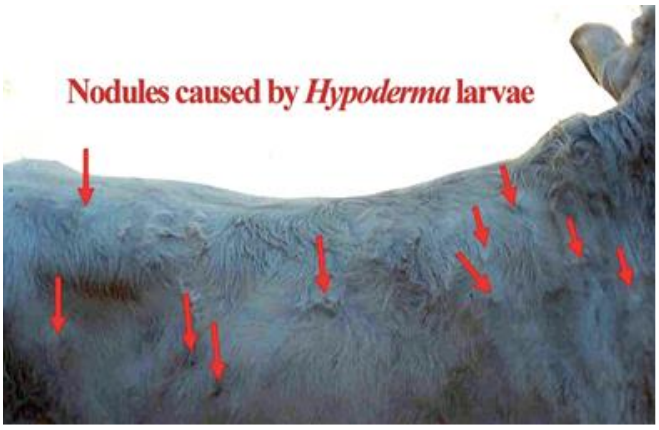

Fig. 7: Nodules produced by *Hypoderma* larvae on back of parasitized cattle (Photograph by Carlos R. Bautista-Garfias)

Fig. 8: *Hypoderma* spp. pupa. (Photograph by Carlos R. Bautista-Garfias)

Gasterophilus spp.

Gastrophilosis in horses, donkeys and mules is caused by the larvae of flies belonging to the genus *Gasterophilus* distributed worldwide depending on its association with the host. The most important species are *G. intestinalis* (De Geer), *G. nasalis* (Linnaeus) and *G. haemorrhoidalis* (Linnaeus) (Broce 1985; Principato 1989; Pandey et al. 1992; Hall and Wall 1995; Otranto et al. 2005).

Adults of all three species have atrophied, non-functional mouthparts and are therefore short-lived. Females begin to oviposit after mating. During this activity, the eggs are attached to the host's body hairs. The site of oviposition varies with the species, and all newly hatched larvae (L_1) penetrate the subcutaneous tissues of the mouth (lips, gums, and tongue) where they spend three weeks. After this time, larvae move to the stomach or small intestine mucosa and transform into second-stage larvae (L_2), which after several months become third-stage larvae (L_3) that detach on their own and go outside with the faeces. Pupation takes place in the upper layer of the soil under the manure. Subsequently, the adults emerge between a few weeks to two months later, depending on the climatic conditions (Fig. 9) (Otranto et al. 2005).

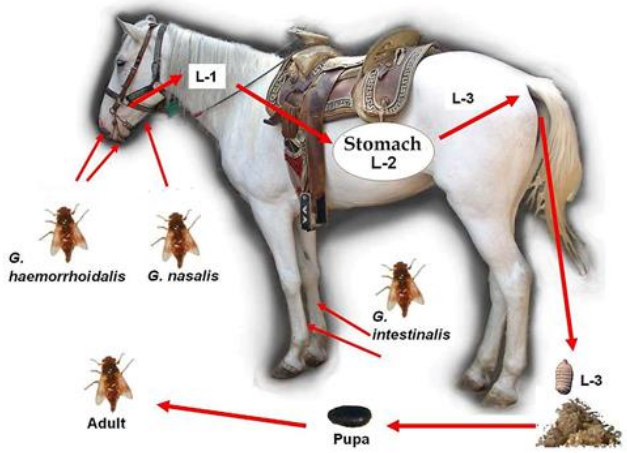

Fig. 9: Life cycle of *Gasterophilus* spp. (Photograph by Carlos R. Bautista Garfias)

Fig. 10: L_3 of *Gasterophilus* spp. (Photograph by Carlos R. Bautista Garfias)

G. intestinalis (the horse fly) females may lay up to 500 to 1,000 eggs. They oviposit as they fly, hovering near the host, occasionally darting toward it to lay an egg. The eggs generally are glued to the internal side of the front legs; however, they can be found in other sites. The general incubation period for horse fly eggs is approximately five days. After a short time in the mouth, they attach to the mucosa of the stomach and remain there approximately for 7 to 10 months, and then L_3 larvae pass out along with the faeces (Fig. 10). Adults are active in early summer (Broce 1985).
G. nasalis (the throat fly) glues its eggs to the hair of the host under the jaw. Each female is capable of producing 450 to 500 eggs and its oviposition activity is extremely troublesome for the affected horses. These eggs can hatch in four to five days. Hatched larvae move along the skin into the horse´s mouth and they penetrate the soft tissue. In approximately 20 days, larvae move toward the stomach to attach to the stomach or duodenum mucosa. Finally, L_3 larvae come out with the faeces. Much of the adult activity takes place in late spring or early summer (Broce 1985).
G. haemorrhoidalis (the nose fly) is a fast flier and females attach their blackish eggs to the hairs on the (upper and lower) lips of horses. Each female usually lays 160 eggs, which hatch in two days stimulated by humidity. The young larvae (L_1), after penetrating the tongue or lips, migrate to the stomach or duodenum. Then, L3 larvae reattach to the wall of the rectum close to the anus for two to three days (Otranto et al. 2005).
Both adults and larvae of *Gasterophilus* species cause damage (Broce 1985). Horse´s reactions to ovopositing females can be violent. L_1 larvae cause irritation when they burrow and move into oral tissue. Larvae adhered to the walls of the stomach and duodenum interfere the process of digestion, and may cause peritonitis (Lapointe et al., 2003). Animals parasitized by *Gasterophilus* larvae gain weight more slowly than non-parasitized horses (Principato 1989).
According to the available literature it is indicated that *Gasterophilus* spp. larvae parasitize almost all horses. *G. intestinalis* is the most prevalent species in USA and the infestation rate is almost 100% (Broce 1985). It is worth to note that studies carried out in central Italy suggest the tendency towards extinction of *G. inermis*, *G. pecorum*, and *G. haemorrhoidalis*, while the most prevalent species are *G. intestinalis* and *G. nasalis* (Otranto et al. 2005). Similarly, a study carried out on donkeys in Morocco showed that *G. intestinalis* and *G. nasalis* are the most prevalent species (Pandey et al. 1992).
The diagnosis of gastrophilosis can be carried out with serological tests in horses and donkeys (Escartín-Peña and Bautista-Garfias 1993). *Gasterophilus* myiasis cases in man are rare such as external ophtalmomyiasis (Medownick et al. 1985), oral myiasis (Townsend et al. 1978) and pulmonary myiasis (Ahmed and Miller 1969).

Dermatobia hominis

The neotropical fly, *Dermatobia (D.) hominis* is a cause of severe losses in the beef, dairy, and bovine leather industries from north-eastern Mexico to north-eastern Argentina (Fig. 11). The life cycle is very complex and requires a flying arthropod to transport its eggs to a mammalian vertebrate, which include cattle, dogs, cats, pigs and man (Sancho 1988; Pereira Da Silva et al. 1998; Brizuela et al., 2003; Maier and Honigsmann 2004; Saraiva et al. 2005). The adult fly is bottle blue in colour. Adults can't feed because of atrophied mouth parts (Sancho 1988).
The life cycle lasts between 100 to 120 days. Larval development is completed in 5 to 10 weeks, after which the mature larvae leaves the host and falls to the ground. After mating, the female lays her eggs on another insect (usually another fly or a mosquito) which transports them to a warm-blooded vertebrate host, after which the larva hatches and penetrates the skin of the new host.

Fig. 11: *Dermatobia hominis* distribution in America, from north-eastern México to north-eastern Argentina. On the left is shown a *D. hominis* L_3 (Figure designed by Carlos R. Bautista-Garfias).

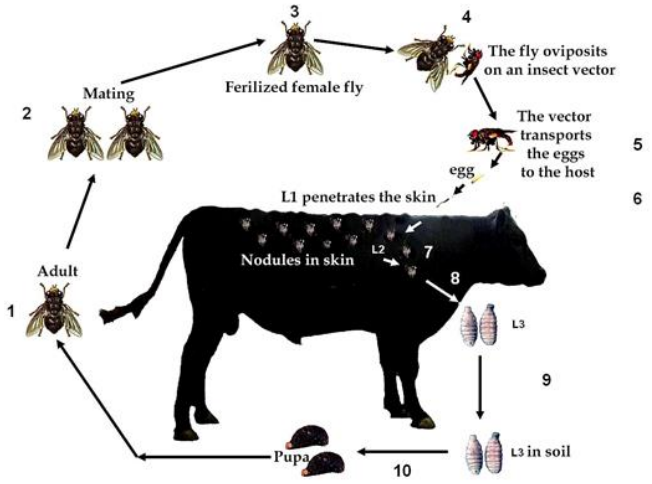

Fig. 12: *Dermatobia hominis* life cycle. 1, The adult fly hatches from the pupa;2, Mating between male and female. 3, The fertilized female captures. 4, An insect vector and oviposit on it. 5, The vector transports the eggs to the host and from each egg. 6, A larva 1(L_1) hatches that penetrates the skin to give rise to nodules where it transforms,7, into larva 2 (L_2) and matures,8, up to larva 3 (L_3) to later fall to the ground, 9, and transform into pupa, 10, from which an imago emerges to continue the cycle. (Photograph by Carlos R. Bautista-Garfias).

The eggs are glued onto other insect so that its flight efficiency is not adversely affected. Almost 50 insect species of carriers have been recorded (half are mosquitoes and one third are other fly species). Egg development requires 4-9 days and hatching is stimulated by increase in temperature, which occurs when the eggs are on a warm-blooded host. At this point, the larvae leave from the egg and enters to the host skin, which occurs between 5-10 minutes (Fig. 12) (Sancho 1988). The third instar larva is elongated and oval in shape, with belts of scattered spines and shows prominent mouth hooks (Fig. 13) (Sancho 1988).

The larvae are located on various parts of the body causing pain to the host. After larva is removed, and in the absence of a secondary infection, the condition resolves approximately in a week. In Brazil, more than 50% of the nodules caused by *Dermatobia* were located on the left side of the body. The preference of the bovine host to rest on its right side could be the reason for this asymmetric distribution (Sancho et al. 1996; Pereira Da Silva et al. 1998; Oliveira-Sequeira et al. 1996).

The mature larva emerges from the mammalian host after three months and pupates on the ground, and after a month, the adult fly emerges (Fig. 12). The L_3 larvae emerge from the host nodules and falls to the soil, then forming a hardened pupa in two to three days. The pupal stage lasts from 4 to 11 (Sancho 1988).

Reports of *D. hominis* myiasis in man are common (Toussaint-Caire et al. 2018; Martínez-Hernández et al. 2019). In America, the countries with the highest infection rates in travellers are Belize, Bolivia, and Brazil (Villalobos et al. 2016).

Cochliomyia hominivorax

Almost all warm-blooded animals, including man and occasionally birds, are hosts for the larvae (screwworms) of *Cochliomyia* (*C.*) *hominivorax*. Cattle, horses, sheep, pigs and dogs are frequently parasitized by this arthropod. If left untreated, screwworm-infested wounds can be fatal (Vargas-Terán et al. 2021).

Before starting the control program of release of sterile males (Davidson 1974) developed by entomologists of the Agricultural Research Service (ARS), Department of US Agriculture (USDA, the screwworm of cattle was widely distributed throughout the tropical and subtropical areas of the American Continent from the Southeast US to northeastern Chile. In 1982, the US was declared free of the screwworm and, then the parasite was controlled towards the south (in October 2000), and Costa Rica was declared free of the screwworm (Kouba 2004). The most successful technique for controlling screwworm was the use of the sterile insect technique (Vargas-Terán et al. 2021).

The adult fly of *C. hominivorax* is approximately two to three time larger than the common house fly and is metallic blue or blue green in colour. Female fly lays eggs on the skin around fresh or necrotic wounds. A wound of skin or mucous membranes is generally required to invade the host tissues. The eggs harch between 12 to 24 hours and the larvae feed

Fig. 13: *Dermatobia hominis* L_3 larvae (Photograph by Carlos R. Bautista Garfias)

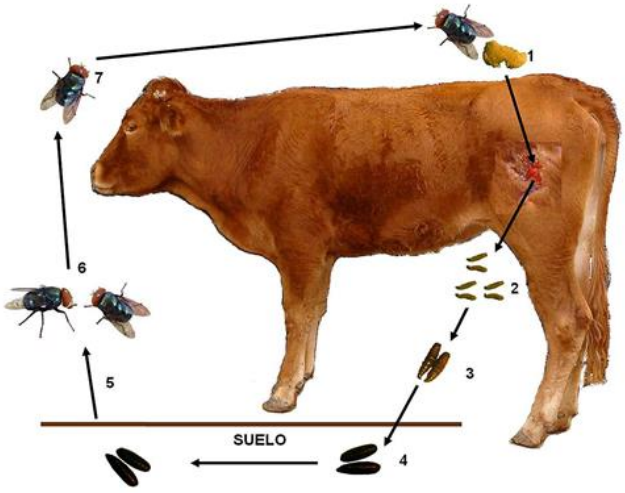

Fig. 14: *Cochliomyia hominivorax life cycle*: 1, The gravid female oviposit in a wound. 2, Larvae (L_1) hatch from the eggs that feed on the wound and then transform into L_2 first and L_3 later. 3, the mature larva (L_3) falls to the ground and buries itself. 4, L_3 pupates. 5, Pupae transform into adults. 6, the male and female mate. 7, The gravid female searches for a wound on a warm-blooded host to oviposit. (Photograph by Carlos R. Bautista-Garfias).

on the wound in a characteristic position (head down and spiracles towards the wound opening). The larvae continue to develop for the next 4 to 10 days, growing to a length of approximately 17 mm. After this time, they fall out of the wound and then transform to pupa in the soil. The pupal stage lasts from a week to three months approximately (Fig. 14) (Vargas-Terán et al. 2021).

Females characteristically mate only once and lay their first set of eggs 5 to 10 days after emergence. They may subsequently lay egg masses every three days during their lifetime. The life cycle during the summer is 24 days on average (Kouba 2004).

C. hominivorax is a true obligate parasite that requires living tissue to feed. It cannot grow on carrion, although an artificial medium for culture has been developed in the laboratory. During feeding, the larva forms characteristic pockets in the affected tissue. Several livestock management procedures such as castration, dehorning, and hot-iron branding, often create oviposition sites (wounds) that attract female fly. The untreated navels of newborn calves in infested areas are frequently attacked. Screwworm-infested wounds are increasingly attractive to gravid flies. Consequently, the syndrome is self-perpetuating in endemic areas and the usual result is death of the host. If *C. hominovorax* populations are not monitored, 20% or more of the animals on a farm may be affected. In the 1980s, ranchers in the USA volunteered to report cases of screwworm myiasis, and in many cases modified their management practices to reduce screwworm problems. In this sense, the breeding programs were altered to produce calves during the winter months (free of flies) and the herds were carefully monitored to facilitate prompt and timely treatment of wounds (Kouba 2004).

In complementary programs, known populations of hematophagous arthropods that attack cattle and similar animals were studied. In this respect, acaricide-impregnated plastic ear tags were widely used to suppress ear tick populations that were later invaded by screwworm (Vargas and Hall 1989; Vargas-Terán 1991; Vargas-Terán et al. 2005, Vargas-Terán 2015; Wyss 2000; Bowman 2006).

C. hominivorax larval infestation in humans generally is a wound myiasis, which can be very severe with penetration and destruction of the underlaying tissue. When the infestation occurs in the nose or ears, the fatality rate is high if untreated (Francesconi and Lupi 2012; Barros and Bricarello 2020; Notejane et al. 2021).

Conclusion

Myiasis in animals and human is caused by the larvae of various species of fly which needs to be controlled as it causes huge economic losses in the animals. The situation may be aggravated by various factors including growing human population, climatic change and lack of proper control measures. One health approach showed its efficacy when a rapid control of the New World screwworm (*C. hominivorax*) outbreak in Florida was achieved in 2016-2017. So, under these circumstances, one health approach offers a viable control alternative.

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