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Biological Control of the Horn Fly, *Haematobia irritans* L., in Hawai'i (Diptera: Muscidae)

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ABSTRACT. The effort to control the horn fly, *Haematobia irritans* (L.), is one of the longest (1898 to 1982) and most extensive attempts at biological control in Hawai'i. By the late 1950s, 45 species of parasites, predators, and competitors (dung beetles) had been introduced, 20 of which became established. Horn fly control was considered satisfactory by some ranchers at lower elevations and drier sites, but unsatisfactory at higher and wetter locations. In a new program from 1973 to 1982, 9 additional species of South African dung beetles were introduced by way of Australia. All but 1 species were found established in 1989. The distribution and relative abundance of agents found in a 1985 survey is presented.

Haematobia irritans (L.) is a small muscid fly, native to the Mediterranean area, that is about half as large as the common house fly. It pierces the skin of cattle and, occasionally, horses, sheep, humans, and other animals to suck blood (Herms 1950). When flies are numerous, their painful bites interfere with feeding and resting of cattle, resulting in weight loss and reduced milk production. The flies are found commonly on the shoulders, but sometimes are observed around the base of the horns in a dark band, giving the fly its common name. Female flies dart down to deposit eggs on fresh cattle dung, usually when the dung pads are only minutes old and still warm. Eggs hatch in a day or two, and larvae develop in the dung pads.

Introduced into Hawai'i with cattle sometime before 1897, the horn fly soon became a significant livestock problem. Horn flies rapidly spread to all Hawaiian islands and can now be found from sea level to 2,000 m. The first effort at biological control of the horn fly was the introduction and release of a predatory histerid beetle, a *Hister* sp. from Puerto Rico in 1898. This was followed by the release of 12 more species of natural enemies, mostly parasitic hymenopterans, by 1910 (Swezey 1911).

Subsequent introductions concentrated on predatory histerids and dung beetles (Table 1). Perhaps the most significant introductions were initiated in the late 1950s by Cliff Davis, Chief Entomologist of the Hawai'i Department of Agriculture, who was assisted by Noel Krauss, Exploratory Entomologist (pers. comm.). While searching for natural enemies of various insect pests and weeds in Hawai'i, Krauss collected dung beetles such as *Onthophagus gazella* (Frabricius) and *Liatongus militaris* (Castelnaa) in Africa, and *Oniticelolus cinctus* (Fabricius) and *Onthophagus sagittarius* (Fabricius) in Sri Lanka. Krauss also collected the predator, *Hister nomas* (Erickson), in Africa. All of these insects were shipped to Hawai'i by air freight and were released on the island of O'ahu in 1957 and 1958. Histerid beetles hunt for fly maggots in the cowpats, and both adults and larvae feed on immature horn flies. Dung beetles, on the other hand, feed on dung and bury it for rearing their larvae. When numerous, the beetles break up the cowpads and hasten their drying process, thus preventing fly larvae from completing their development (Bornemissza 1960, 1970, 1976).

RECENT INTRODUCTION

The present program gained a new impetus in the mid-1960s, when the CSIRO Division of Entomology (henceforth referred to as CSIRO) in Australia decided to initiate its own program for controlling dung-breeding flies. Australia's objectives were to control 2 dipteran pests, the blood-sucking buffalo fly of cattle, *Haematobia irritans exigua* (De Meijere), and the human-pestering bush fly, *Musca vetustissima*, and to speed up recycling of dung pads. Due to a lack of bovine dung-feeding arthropods in Australia, dung pads remained undecomposed for years and smothered grasses desirable for forage (Bornemissza 1960). In November 1965, Dr. George Bornemissza visited Hawai'i to review the status of our earlier effort. Based on Bornemissza's request, Hawai'i supplied CSIRO with shipments of 9 species of dung beetles and histerids between 1967 and 1968, most of which were eventually released in Australia. By 1970, CSIRO assigned Bornemissza to work in South Africa, where he studied dung beetles for 9 years and shipped the most promising species to Australia. Many were later released and became established in Australia (Bornemissza 1979). Between 1973 and 1982, in exchange for material which Australia had received from Hawai'i in the 1960s, CSIRO supplied Hawai'i with 9 African species of new dung beetles and a new gene pool strain of a previously released and established dung beetle, *O. gazella* (Table 2). Since all of the beetles had previously cleared quarantine in Australia, these insects were released in the field in Hawai'i without additional testing. Eight of the new species are known to be established (Table 2). All releases of beetles from Australia were made only on the island of Hawai'i by the senior author.

RESULTS

The only previous survey to determine the abundance of insects associated with dung pads in Hawai'i an pasture was by Harris *et al.* (1982), who sampled insects in cattle droppings in 2 open pastures on O'ahu. They found 16 species of predators, only 5 of which were deliberate introductions, including the 2 species of histerids, 1 of the 4 hydrophilids, and 2 of the 9 species of staphylinids. The others probably arrived with cattle dung in the holds of ships, since most are cosmopolitan, appearing wherever cattle have been introduced.

The scarabs were by far the most abundant biocontrol insects found in the dung pads. Of the 7 species recovered, 6 were deliberate introductions by the Hawaii Department of Agriculture, viz. *Copris incertus* (Say), *Onthophagus incensus* (Say), *O. gazella*, *O. cinctus*, *L. militaris*, and *Aphodius fimetarius* L. Early attempts to recover *A. fimetarius*, which was introduced from Europe in 1909, failed, but after 1960, it was commonly found in Hawai'i. The seventh species, the cosmopolitan *Aphodius lividus* (Olivier), probably arrived via ships carrying cattle.

In 1985, Dr. Truman Fincher of the USDA Agricultural Research Service in College Station, Texas, visited Hawai'i to review our program by surveying dung inhabiting insects on the islands of Hawai'i, Maui, O'ahu, and Kaua'i. His unpublished reports (Fincher 1985) and observations by him and the senior author have been used to prepare Table 3, which shows the abundance and distribution of the most common dung associated insects at that time. The result of this survey disclosed that the newly established dung beetles have expanded the effective range of dung burial since Bornemissza's 1966 study. At that time, *O. gazella* and *L. militaris* were the only widespread species at lower elevations up to 500 m on the dry side of the island. Above this band, the Mexican *Canthon humectus* (Say), *O. incensus*, and *C. incertus* were more prominent than the former two. In 1985, 7 of the newly introduced species were found to be established, with *Onthophagus nigriventris* (d'Orbigny) as the predominant beetle among *Onitic alexis* and

Table 1. Natural enemies of horn fly released in Hawai'i and established by 1967 (Legner 1978, Funasaki *et al.* 1988, and unpubl. Hawaii Department of Agriculture Records).

Species	Origin	Year(s) Released	Island of Release
Parasitic Hymenoptera			
Cynipidae			
Eucoila impatiens	Germany	1910	?
Pteromalidae[1]			
Muscidifurax raptor	South Africa	1913	?
Pachycrepoideus vindemiae (= *dubius*)	Philippines	1914	?
Spalangia cameroni	Africa	1914–20	
Spalangia endius (= *philippensis*)	Philippines	1914	?
Beetles			
Scarabaeidae (Dung Beetles)			
Canthon humectus	Mexico	1923,1952	Hawai'i
Copris incertus var. *prociduus*	Mexico	1922	Hawai'i
Oniticellus cinctus	Sri Lanka	1957	Hawai'i
Oniticellus (=*Liatongus*) *militaris*	Zimbabwe	1957	Hawai'i
Onthophagus gazella (=*catta*)	Zimbabwe	1957	Hawai'i
O. incensus	Mexico	1923	
O. sagittarius	Sri Lanka	1957	O'ahu
Predators: Birds			
Ardeidae			
Bubulcus ibis	Florida	1951, 1959	?
Predators: Insects			
Histeridae			
Hister bimaculatus	Germany	1909	Hawai'i
H. cocnosus	Puerto Rico	1952	O'ahu
H. nomas	Zimbabwe	1957	Hawai'i
H. (Pachylister) lutarius	Sri Lanka	1958	O'ahu
Pachylister caffer	Zimbabwe	1957	Hawai'i
Hydrophilidae			
Sphaeridium scarabaeoides	Germany	1909	?

[1] Hawai'i Department of Agriculture records indicate these 4 parasites were purposely introduced for house fly control, and while all are established in Hawai'i, none have been recorded attacking the horn fly (Funasaki *et al.* 1988).

Table 2. Natural enemies of horn flies released in Hawai'i since 1967. All species are dung beetles supplied by the Division of Entomology CSIRO from established colonies in Australia.

Species	Date	No. Released2	Reference	Established
Euoniticellus africanus (Harold)	1974	500	Nakao & Funasaki (1976)	Yes
E. intermedius	1974	500	Nakao & Funasaki (1976)	Yes
(Reiche)	1982	565	Lai & Funasaki (1985)	
Onitis alexis Klug	1973	300	Nakao et al. (1975)	Yes
	1976	158	Nakao & Funasaki (1979)	Yes
O. vanderkelleni Lansberge	1976	490	Nakao & Funasaki (1979)	Yes
Onthophagus binodis Thunberg	1973	500	Nakao et al. (1975)	Yes
O. foliaceus Lansberge	1975	100	Nakao & Funasaki (1979)	Yes
O. gazella (F.) (= *catta* F.)3	1973	500	Nakao et al. (1975)	Yes
O. nigriventris d'Orbigny	1975	100	Nakao & Funasaki (1979)	Yes
Sisyphus spinipes Thunberg	1973	300	Nakao et al. (1975)	?

2 All CSIRO releases were made by the Senior Author on the island of Hawai'i only. However, the Hawai'i Department of Agriculture's collection indicates that 3 specimens of *Onthophagus nigriventris* were found on the island of Maui (35 miles away) in 1984.

3 Successful releases in 1957 on island of O'ahu were recovered in 1959 (Davis 1960) and subsequently redistributed to all islands. The 1973 batch was a reintroduction of a strain believed to be better adapted to cooler, wetter sites.

Table 3. Natural enemies of horn flies and their relative abundance recovered in a 1985 survey on four Hawaiian islands. Parasitic Hymenoptera were not included in this survey.

Species	Year(s) of Introduction	Abundance Hawai'i	Maui	O'ahu	Kaua'i
Scarabaeidae (Dung Beetles)					
Aphodius fimetarius	1909	+++	++	+++	?
A. lividus	Cosmopolitan	+++	++	+++	+
Canthon humectus	1923	++	–	–	–
Copris incertus (=*incertus*)	1922	++	+	++	+
Euoniticellus africanus	1974	++	–	–	–
Oniticellus (=*Liatongus*) *militaris*	1957	+++	++	+++	+
Oniticellus cinctus	1958	–	–	++	–
Onitis alexis	1976	++	–	–	–
O. vanderkelleni	1976	+	–	–	–
Onthophagus binodis	1973	++	–	–	–
O. gazella (=*catta*)	1957, 1973	+	++++	++++	++++
O. incensus	1923	+	–	+++	–
O. nigriventris	1975	++++	+	–	–
O. sagittarius	1958	–	–	+++	–
Histeridae					
Hister (=*Pachylister*) *caffer*	1957	+	+++	+++	+++
H. nomas	1957	+	+	++	–
H. bimaculatus[4]	1909	–	–	–	–
H. coenosus[4]	1952	–	–	–	–
H. (=*Pachylister*) *lutarius*[4]	1958	–	–	–	–
Hydrophilidae					
Sphaeridium scarabaeoides	1909	+++	+++	++	++
Staphylinidae					
Oxytelus sp.	1920	+	+	+++	

– = Not recovered; + = One or two specimens recovered; ++ = Common at a few locations; +++ = Very common at most locations; ++++ = Most abundant species in the complex

[4] Previously recorded as established (Table 1), but not recovered in these surveys.

Onthophagus binodis (Thunberg), especially in the higher elevations, where *O. gazella* was never abundant. In general, the dung pad fauna on the island of Hawai'i was greatly enriched by the latest CSIRO introductions. On the islands of Maui, O'ahu, and Kaua'i, where members of the CSIRO complex of beetles have not been released, *O. gazella* was the only widespread species among *L. militaris* and *C. incertus*. In addition, *O. sagittarius* and *O. cinctus* were also found on O'ahu.

On a visit to Hawai'i in June 1989, Bornemissza, accompanied by the senior author, surveyed several sites between 1,200–1,500 m elevation. Again, *O. nigriventris* was the most abundant species, followed by *O. binodis* and *Onitis vanderkelleni* (Lansberge). *Euoniticellus africanus* (Harold) was also commonly found together with *O. alexis*, and *Euoniticellus intermedius* (Reiche) was first recorded as being established.

It is interesting that although a large number of hymenopterous parasites were introduced for horn fly control or control of related species of muscoid flies (Legner 1978), the Hawai'i Department of Agriculture has no record of any of the parasitoids being recovered from horn flies, although they have been reported attacking related fly species in Hawai'i (Funasaki *et al.* 1988, Toyama & Ikeda 1976). However, the authors know of no surveys to specifically search for these parasites under various pasture conditions.

Perhaps the most publicized introduction of the horn fly program was the cattle egret (*Bubulcus ibis* L.) which was introduced from Florida (Davis 1960) between 1959 and 1961. By 1968, well established rookeries were found on the 3 islands of Hawai'i, Kaua'i, and O'ahu, and the egret population appeared to have increased considerably. This large, white bird is now common on all our major islands and has become so abundant that the birds have become a safety hazard at Hilo airport, where some flights have been aborted because of the egrets (Anonymous 1982). It is doubtful that this bird feeds significantly on horn flies, since a recent survey of the bird's crop contents indicated that grasshoppers and cockroaches are its main food (Q. Tomich, pers. comm.).

DISCUSSION

By the mid 1960s, the original biological control program was credited with successfully controlling horn flies at lower elevations and drier sites on the island of Hawai'i, where the senior author was the resident entomologist. This was confirmed by Bornemissza in a 1955 study that used cages to exclude dung beetles and large predators from fresh dung pads following oviposition. The study showed that 97 percent fewer horn flies emerged from dung pads in open pastures, where the burying and shredding action by dung beetles destroyed the pads before the horn fly larvae could complete their development. However, at higher elevations with more rainfall, the control was less effective. This was the main reason for the decision to obtain additional beetles from CSIRO. Those shipped to Hawai'i on Bornemissza's recommendation between 1974 and 1982 were specifically chosen because it was thought they were better adapted to higher elevations and wetter conditions (Bornemissza 1979).

During the 1980s, the senior author noted that several Big Island ranchers generally felt that the horn fly was no longer a menace, especially at elevations up to 1200 m, but that ranchers on Maui and O'ahu still found it to be a serious problem (Harris *et al.* 1982). In a 1985 visit to Hawai'i , Fincher noticed that the new species of CSIRO scarabs were established only on the Big Island (Table 3) and had not reached Maui, O'ahu, or Kaua'i. He therefore recommended that these species of beetles be introduced on the neighboring islands.

Fincher's proposal never materialized, partly due to a sudden lack of interest in the horn fly program by local ranchers, who were using a chemical called ivermectin to control horn flies. Ivomec, the trade name for the chemical ivermectin (manufacturer Merck

& Co.), is a systemic compound that is injected into cattle to control a wide variety of external and internal pests. In 1990, discussions with ranchers on Hawai'i and Maui indicated that most were using ivermectin and obtaining satisfactory control of horn flies.

However, the widespread use of ivermectin raises some questions. Shortly after application, ivermectin has been shown to appear in the dung, where it can adversely affect many species of dung-associated insects, including scarabs (Ridsdill-Smith 1988, Fincher 1992). To date, only 2 of the species of dung beetles established in Hawai'i have been tested, but both show susceptibility to ivermectin. What the long-term effect of low dosages of this drug in dung may have on the reproductive success or the overall population of our dung beetles remains to be seen.

CONCLUSION

The horn fly control program was one of the longest and most extensive biological control projects for a single insect pest in Hawai'i . It resulted in the establishment of a complex of 25 agents, representing 6 families of insects, using the same ecological resource, cattle dung. The program appears to have been successful in some parts of the island of Hawai'i , and probably would have also shown similar success on neighboring islands, if vigorous redistribution of the new African beetles had been attempted. However, the use of ivermectin treatment overshadowed the success of this program, and newer ranchers often are unaware of the Hawai'i Department of Agriculture's horn fly biological control program. Significantly, the overall long-term impact that ivermectin treatments may have on this large group of beneficial insects is unknown. Will there still be a well established complex of dung beetles in Hawai'i should horn flies become resistant to the drug ivermectin? Hopefully, the CSIRO beetles will be redistributed to the neighbor islands, and comprehensive studies will also be conducted on the overall dung beetle complex, including adverse effects ivermectin may be having on beneficial insects.

DISCLAIMER

This article reports the results of dung beetle surveys only. Mention of a commercial product does not constitute an endorsement or a recommendation by either the Hawai'i Department of Agriculture or the USDA.

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