

## A Review of Biological Control Introductions in Hawaii: 1890 to 1985

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### ABSTRACT

Classical biological control has been practiced in Hawaii for almost a hundred years due to the influx of many new immigrant pest species into the Islands. Six hundred seventy-nine species of organisms were purposely introduced and released in Hawaii during 1890 to 1985 for the biological control of insects, weeds, and other pest species; 243 (35.8%) have become established. Two hundred ten (86.4%) of the 243 established species have been recorded to prey on or attack about 200 pest species. Of the 210, 64.6% (157 of 243 species) attack the intended target pests only, while 21.8% (53 of 243 species) attack both target and non-target pest species. The remaining 33 (13.6%) of the 243 established species have been reported to prey on or attack pest, native and/or beneficial species. Of the 33, 8.2% (20 of 243 species) have been reported from native species, 7.0% (17 of 243 species) from beneficial organisms. No purposely introduced species, approved for release in the past 21 years, has been recorded to attack any native or other desirable species.

### INTRODUCTION

Hawaii's government has been practicing classical biological control, i.e., the suppression of pest populations by introduction and liberation of natural enemies, for almost a hundred years. While attempts to control pests through the introduction of animals into Hawaii have been made by private citizens as early as 1865, it was not until 25 years later, in 1890, that the concepts and procedures of biological control were actually sanctioned by the reigning Hawaiian government.

Prior to the establishment of procedures for biological control work, the myna bird, *Acridotheres tristis tristis* (L.), and the mongoose, *Herpestes auro punctatus auro punctatus* Hodgson, were introduced and released in Hawaii.

The myna was brought to Hawaii from India in 1865 by Dr. William Hillebrand, a physician-naturalist and author of the Flora of the Hawaiian Islands, to feed on armyworms that were infesting pastures (Berger 1981). It spread and multiplied at a rapid rate and for many years has

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been common throughout the State. It has been accused of being a major factor in the extinction of many native Hawaiian birds although Caum (1933) and Berger (1981) believed that the myna had little or nothing to do with the extinction of native birds. The myna, has also been implicated as playing a large role in the dissemination of the noxious weed, *Lantana camara* L., by feeding on the berries and spreading the undigested seeds via droppings in lowland areas (Pemberton 1964).

The mongoose, native to India, was imported from Jamaica, British West Indies, by Hamakua plantation owners in 1883 and 1885 and liberated in sugarcane fields on the islands of Hawaii, Maui, Molokai and Oahu (Baldwin et al. 1952; Doty 1945; Kramer 1971; Tomich 1986). The mongoose became established on these four islands and, in addition to preying on rats, it unfortunately preyed on other fauna, including ground nesting birds (Berger 1981; Kramer 1971; Tomich 1986).

Today, the mongoose (more so than the myna) is often mentioned as a classic example of "biological control gone astray" because of lack of planning and poor evaluation prior to its introduction. However, it must be realized that prior to 1890, planning and evaluation before the introduction of any organism were nonexistent simply because they were not required. There were no laws or regulations restricting or prohibiting the importation of any plant or animal from other geographical areas into Hawaii. It was only since 1890 that biological control procedures were established through authorization by the reigning government of Hawaii. More recently, others have also indicated that some biological control introductions have been responsible for causing the extinction of some of our native biota, especially native moths (Gagne and Howarth 1982; Howarth 1985).

The purpose of this paper is to examine whether or not organisms purposely introduced for biological control are attacking hosts or prey other than the pest species for which they were brought in to control.

## HISTORICAL BACKGROUND OF BIOLOGICAL CONTROL IN HAWAII

During the late 1800's, as contacts with foreign countries were opened and efforts were directed toward developing Hawaii's lands for diversified crops, many new species of plants were introduced without restraint and many species of immigrant insect pests gained entry into Hawaii. In 1890, the Hawaiian Kingdom under the reign of King David Kalakaua, enacted "Laws of the Hawaiian Islands" to prevent immigrant insect pests from entering Hawaii, and to control those already established. Subsequently, in 1893, the year that the Hawaiian monarchy under the two-year reign of Queen Lydia Liliuokalani was overthrown, Albert Koebele was appointed entomologist of the provisional government of the Republic of Hawaii and was given the responsibility of biologically controlling the many species of immigrant insect pests in Hawaii at that time. Koebele was already well known for his part in the biological control

of the cottoncushion scale, *Icerya purchasi* Maskell, in California and Hawaii.

The Territorial Government (Hawaii became a U.S. Territory in 1898) was apparently encouraged by the successful control of various species of scale insects, aphids, mealybugs, armyworms and other immigrant insect pests by predatory and parasitic species of insects introduced by Koebele. The territorial legislature enacted a law (now Chapter 141, Hawaii Revised Statutes) in 1903 which organized the Board of Commissioners of Agriculture and Forestry and provided for buildings and materials to obtain, propagate, study, and distribute beneficial species of insects to control pest species of insects and weeds. The law also provided for a quarantine system to prevent entry of new immigrant pests.

In 1904, the Experiment Station of the Hawaiian Sugar Planters' Association (HSPA) established an Entomology Department to biologically control sugarcane pests, especially the sugarcane delphacid, *Perkinsiella saccharicida* Kirkaldy, which was threatening the survival of the sugarcane industry at that time (Swezey 1936). During 1904 until about 1942, HSPA played an important role in the introduction and liberation of many biological control organisms. Since then, HSPA's biological control activities have been reduced due to successful control of most of the important sugarcane pests by natural enemies.

Other institutions also have participated in the introduction and release of natural enemies of immigrant pest species. Parasitic and predatory species of insects were imported and liberated during 1935-1936 by the U.S. Bureau of Entomology and Plant Quarantine's Fruit Fly Laboratory (now United States Department of Agriculture's Tropical Fruit and Vegetable Research Laboratory), for biological control of fruit flies. Natural enemies of pineapple insects were introduced and released during 1930-1938 and in 1946 by the Experiment Station of the Pineapple Producers Cooperative Association (later changed to Pineapple Research Institute of Hawaii but defunct since 1971) (Fullaway 1952; Swezey 1939). A cooperative program to search for, import, study, propagate and release natural enemies of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), melon fly, *Dacus cucurbitae* Coquillet, and oriental fruit fly, *Dacus dorsalis* Hendel, in Hawaii was conducted during 1947-1951. Participating agencies were the USDA Tropical Fruit and Vegetable Research Laboratory, Territorial Board of Commissioners of Agriculture and Forestry [now Hawaii Department of Agriculture (HDOA)], Pineapple Research Institute of Hawaii, HSPA's Experiment Station, Hawaii Agricultural Experiment Station of the University of Hawaii's College of Tropical Agriculture ("and Human Resources" was later added), and the California Agricultural Experiment Station, University of California (Clausen et al. 1965). Natural enemies of the forest day mosquito, *Aedes albopictus* (Skuse), were introduced and liberated by the Hawaii Department of Health during 1950-1954 (Steffan 1968).

When Hawaii became a state in 1959, a reorganization plan was initiated by the Legislature which resulted in the transfer in 1961 of

forestry and fish and game activities from HDOA to the Hawaii Department of Land and Natural Resources. Rules, policies and procedures governing biological control activities remained under the province of HDOA.

According to the records, more biological control projects against immigrant species of insect pests have been conducted in Hawaii than anywhere else in the world (DeBach 1964). This is understandable since Hawaii, by virtue of its strategic location near the middle of the Pacific Ocean, has been invaded by many species of immigrant insects and related arthropods from the west (southeast Asia and other countries in the western Pacific) and from the east (American continents).

Pemberton (1964) indicated that there were well over 2,000 species of adventive (= immigrant) insects in Hawaii. Beardsley (1979) calculated that during 1962 to 1976, 287 species of immigrant insects and other terrestrial arthropods gained entry into Hawaii and became established. Based on the trend of about 17 species of immigrant insects and related arthropods becoming established each year from 1977 to 1985, it is estimated that today over 2,500 immigrant species of arthropods have become permanent additions to Hawaii's fauna. However, not all of them are pests; many are inconsequential species while some are predators and parasites (= parasitoids) of other insects and related arthropods. In the past decade, 17% of the immigrant species of insects and other organisms which entered Hawaii and became established were predators and parasites (HDOA Ann. Rpt. FY 1986).

In spite of the annual influx of new immigrant species of insects and other related arthropods, many more would have become established in Hawaii without the activities of both State and Federal quarantine programs.

## DEFINITIONS AND METHODOLOGY

Some of the terms used in this paper need to be defined. *Native* species refer to those which are indigenous or endemic to Hawaii. *Immigrant* species are those which gained entry into Hawaii on their own accord, most likely either as hitchhikers on aircraft or ships, or through commerce on plants and animals and their products. *Purposely introduced* species are those which were intentionally brought into Hawaii and liberated by authorized agencies for biological control projects. The terms "alien", "foreign", "exotic", or simply "introduced" are sometimes used in published literature in reference to non-native species of arthropods. These words do not distinguish whether a species was purposely introduced or an immigrant and, therefore, often cause confusion and misinterpretation. For example, there are purposely introduced as well as immigrant species of predatory and parasitic insects present in Hawaii. Since the purposely introduced species of predatory and parasitic insects were studied and deemed beneficial prior to being released, most of those which became established have restricted their attack to pest species.

However, many of the immigrant species of predatory and parasitic insects are relatively indiscriminate predators and parasites, some are hyperparasites.

Sometimes, especially in earlier biological control introduction programs, predatory or parasitic species have been purposely introduced and liberated to aid in the control of a complex of pest species, such as to control "armyworms and cutworms", "seed beetles", "aphids", "mealybugs", etc. If the purposely introduced species restricted its attack to its target pest complex, it was considered to be *specific* in this paper. On the other hand, if a predatory or parasitic species was purposely introduced and released to control a single target pest species, e.g., the green scale, *Coccus viridis* (Green), and subsequently it was recorded also to attack another species of scale, such as the black scale, *Saissetia oleae* (Olivier), then it was considered to be *non-specific*. As more observations are made and reported, some purposely introduced species which are now considered to be specific may eventually be found to be non-specific.

The data presented are derived mostly from the Proceedings of the Hawaiian Entomological Society and from volumes of the Insects of Hawaii series. The scientific names of some of the purposely introduced species, as well as some of their hosts and prey, have been changed due to subsequent published synonymy and revisions in generic concepts. Only the currently accepted scientific names are used in this paper.

## PURPOSELY INTRODUCED BIOLOGICAL CONTROL ORGANISMS

During the 96-year span from 1890 to 1985, a total of 679 species of biological control organisms was released in Hawaii. Although most of these species have been predatory and parasitic insects which attack arthropod and mollusk pests, and phytophagous insects of terrestrial weeds, some other organisms also have been involved. Freshwater fishes were released to feed on mosquito larvae. The barn owl and cattle egret were liberated to prey on rats and livestock pests, respectively. Predatory snails were released primarily to prey on the giant African snail, and predatory mites were disseminated to feed on mite pests. Scarabaeid beetles were liberated to feed on cattle dung. Pathogens of weed and insect pests, and insectivorous bats and amphibians were also released for biological control purposes. Of the 679 released species, 243 (35.8%) became established (Table 1). The ratio of releases to establishments is 2.8 to 1.

For clarity of presentation and ease of discussion, a tabulation of established species of purposely introduced biological control organisms and their hosts and prey is given in 9 separate tables.

Tables 2 and 3 pertain to predatory insects and mites; Tables 4, 5 and 6 deal with parasitic species; Tables 7 and 8 list terrestrial weed-attacking organisms; Table 9 enumerates dung feeding scarabaeid beetles; and Table 10 covers mollusks and vertebrates. The tabulation is based only on

**TABLE 1.** Liberation and Establishment of Biological Control Introductions in Hawaii: 1890 - 1985.

Type of Organisms	Number of Species Released	Number of Species Established	Percent Establishment
Predatory Insects & Mites	256	62	24.2
Parasitic Insects	283	115	40.6
Insect Pathogens	7*	2	28.6
Phytophagous Insects	71	43	60.6
Plant Pathogen	1	1	100.0
Dung Beetles	29	10	34.5
Predatory Snails	17	3	17.6
Bats	2	0	0.0
Birds	3	2	66.6
Fishes**	3	2	66.6
Toads	3*	1	33.3
Frogs	4*	2	50.0
	679	243	35.8

\*Estimate.

\*\*Not including four species of *Tilapia* which were imported and liberated in ponds and reservoirs during the 1950's primarily to be used as live bait for tuna fishing. Upon establishment, they also have been found to be useful for sport fishing, as food fishes, as forage for freshwater game fishes and for the control of aquatic weeds in irrigation ditches, reservoirs and drainage canals (Kanayama 1967).

available recorded information. It is conceivable that there may be inadvertent omissions.

### Predatory Insects and Mites

Biological control began in Hawaii in 1890 with the introduction and liberation of a predatory insect, the vedalia beetle, *Rodolia cardinalis* (Mulsant), to prey on the cottonyshield scale, *Icerya purchasi* Maskell. Soon after establishment of the vedalia beetle, the cottonyshield scale was brought under complete control and this status has persisted to the present time (Pemberton 1964; Zimmerman 1948).

During 1890 to 1985, 250 species of predatory insects and six species of predatory mites were purposely introduced and disseminated in Hawaii. Of these, 60 species of predatory insects and two species of predatory mites became established.

Of the 62 species of predatory insects and mites, 32 have been reported to prey only on their intended target pest species and 25 have been recorded to prey on their intended target species and/or other immigrant pest species which were present in Hawaii at the time of their liberation or which became established subsequent to their liberation (Table 2). Of the five remaining species, *Cryptolaemus montrouzieri* Mulsant preys on its target pest species, 13 other immigrant pest species, one native species, and one purposely introduced species; *Montandoniola moraguesi* Puton preys on its target pest species and a purposely introduced species; *Diomus ?pumilio* Weise preys on its target pest species and a native species; *Tytthus*

*mundulus* (Breddin) preys on its target pest species, two immigrant pest species and a native species; and *Hyperaspis fimbriolata* Melsheimer preys only on a native species (Table 3).

### Parasitic Insects

Two hundred eighty-three species of parasitic insects were purposely introduced and released in Hawaii for biological control, mostly of economically important pest species of insects. Of these, 115 (110 Hymenoptera and 5 Diptera) species became established.

Seventy-six of the 115 species are considered to be specific as they have not been reported to attack any other species of insects or related arthropods other than their intended target species (Table 4). Twenty-two species are not specific but they have been recorded to attack, beside their target pest species, only other pest species (Table 5).

Seventeen species have been implicated as utilizing a total of 39 immigrant, 13 purposely introduced, 27 native, and two uncategorized species as hosts in addition to their target pest species (Table 6). It is noteworthy that, of these 17 species, only six have been recorded to attack native species of Lepidoptera.

Zimmerman (1978) stated, "Many of the introduced parasites attack many species of moths, and they have not confined their attacks to the few pest species which they were introduced to control." He cited the ichneumonids, *Pristomerus hawaiiensis* Perkins and *Trathala flavo-orbitalis* (Cameron) as examples of non-specific parasites which attacked many species of moths. However, the ichneumonids are immigrants, not purposely introduced species. Gagne and Howarth (1982) also implied that biological control introductions have been one of the reasons, or the sole reason, for the demise of 16 of 27 native species of Pyraloidea and Macrolepidoptera. However, at least four of the 16 species presumed to be extinct, *Hedylepta meyricki* (Swezey), *H. continuatalis* (Wallengren), *Scotorythra nesiotis* (Perkins), and *Manduca blackburni* (Butler), have been collected during the 1970's and 1980's. A perusal of Hawaiian literature also revealed that one species of predator and seven species of parasites which have been recorded to attack the 16 native moths were immigrants. In addition, two predators of the moths were native species. Of the parasites of the moths, only the tachinid, *Lespesia archippivora* (Riley), was a purposely introduced species, but it has been recorded as a parasite of only one of the 16 listed species of moths. The fact that nearly all of the records of parasites which have been reared from the listed native Lepidoptera are of species which are immigrants appears to contradict the implication that biological control introductions have been a major factor in the extinction of these native moth species.

### Pathogens of Insects

Although several species of insect pathogens were imported, cultured and studied in the laboratory, apparently only about seven species were released in the field. Of these, only two species of fungi have been

reported to be established. The scale fungus, *Sphaerostilbe coccophila* Tulasne, purposely introduced from Florida in 1899, was found attacking the purple scale, *Lepidosaphes beckii* (Newman), on citrus at Mountain View, Hawaii (Kotinsky 1906; Tanada 1956). Another fungus, believed to be the white halo fungus, *Verticillium lecanii* (Zimmerman), was reported to be effective in controlling the green scale, *Coccus viridis* (Green), on coffee at Kona, Hawaii during wet seasons (Beardsley 1952; Illingworth 1929). *V. lecanii* was also found attacking several other species of coccids in Hawaii (Beardsley 1952; Tanada 1956, 1957). *V. lecanii* is believed to have been purposely introduced from Florida in the early 1900's for biological control of "scale insects" (Illingworth 1929).

Since both *S. coccophylla* and *V. lecanii* have confined their attack only to species of scale insects, they are considered to be host-specific (Table 4).

### Phytophagous Insects and Plant Pathogen

The importation and release of phytophagous insects to control weeds were initiated in Hawaii in 1902, against the lowland pasture pest, *Lantana camara* L. During a span of over 50 years, 27 species of lantana-feeding insects were released, 15 of which were successfully established. The weed is no longer considered a serious pasture pest largely due to the persistent activities of these 15 phytophagous species (Pemberton 1964).

A total of 71 species of phytophagous insects and one species of fungus was purposely introduced and liberated in Hawaii during 1890 to 1985 to aid in the control of 21 species of weeds. Of these, 43 species of phytophagous insects and the species of fungus became established. Thirty-two species (including the fungus) are considered host-specific in that, since their release, they have attacked only their target weeds (Table 7). Six species of phytophagous insects have been reported to attack other species of weeds in addition to their target weeds (except for *Chrysolina hyperici* (Forster), which has not been reported to feed or breed on its target weed, *Hypericum perforatum* L., but only on *H. degeneri* Fosb., a closely related weed species). The remaining six species of phytophagous insects have been recorded to feed or breed, in addition to their target weeds, on a total of two native plant species, nine beneficial plant species and three weed species. However, these 12 non-specific species (Table 8) have not been reported to cause any significant damage to the non-target plants.

### Scarabaeid Dung Beetles

The introduction and liberation of scarabaeid beetles for suppression of livestock fly pests, particularly the blood-sucking horn fly, *Haematobia irritans* L., differs from all other attempts at biological control. The primary target of these beetles is not the livestock pests but the breeding medium of these pests. The beetles utilize fresh cattle excrement as food and, together with their active movement within the droppings, they remove and hasten decomposition of the dung. This in turn lessens the amount of suitable fly breeding medium in open pastures.



**TABLE 2.** Purposely Introduced Species of Predatory Insects & Mites Which Prey on Target Pest Species and/or Other Pest Species in Hawaii.

<u>Predator</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
1. <i>Ampulex compressa</i> (F.) Hymenoptera: Ampulicidae	1940	<i>Periplaneta americana</i> (L.) Orthoptera: Blattidae	<i>Periplaneta australasiae</i> (F.) Orthoptera: Blattidae
2. <i>Azya orbigera</i> Mulsant Coleoptera: Coccinellidae	1908	<i>Coccus viridis</i> (Green) Homoptera: Coccidae	<i>Ferrisia virgata</i> (Cockerell) Homoptera: Pseudococcidae
3. <i>Calosoma blaptoides tehuacanum</i> (Lapouge) Coleoptera: Carabidae	1923	<i>Agrotis ipsilon</i> (Hufnagel) <i>Peridroma saucia</i> (Hubner) <i>Pseudaletia unipuncta</i> (Haworth) Lepidoptera: Noctuidae	
4. <i>Chilocorus circumdatus</i> (Schonherr) Coleoptera: Coccinellidae	1895	<i>Coccus viridis</i> (Green) Homoptera: Coccidae  <i>Lepidosaphes beckii</i> (Newman) <i>Pinnaspis buxi</i> (Bouche) Homoptera: Diaspididae	
5. <i>Chilocorus nigrinus</i> (F.) <sup>a</sup> Coleoptera: Coccinellidae	1958		<i>Asterolecanium bambusae</i> (Boisduval) Homoptera: Asterolecaniidae
6. <i>Coccinella 7-punctata brucki</i> Mulsant <sup>b</sup> Coleoptera: Coccinellidae	1958	<i>Aphis gossypii</i> Glover Homoptera: Aphididae	

**TABLE 2.** Purposely Introduced Species of Predatory Insects & Mites Which Prey on Target Pest Species and/or Other Pest Species in Hawaii. (Continued)

<u>Predator</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
7. <i>Coelophora inaequalis</i> (F.) Coleoptera: Coccinellidae	1894	<i>Melanaphis sacchari</i> (Zehntner) Homoptera: Aphididae	<i>Aphis craccivora</i> Koch <i>Aphis gossypii</i> Glover <i>Aphis nerii</i> Boyer de Fonscolombe <i>Hyadaphis erysimi</i> (Kaltenbach) <i>Myzus persicae</i> (Sulzer) <i>Neophyllaphis araucariae</i> Takahashi Homoptera: Aphididae  <i>Psylla uncatoides</i> (Ferris & Klyver) Homoptera: Psyllidae  <i>Rhopalosiphum maidis</i> (Fitch) <i>Toxoptera aurantii</i> (Fonscolombe) <i>Toxoptera citricida</i> (Kirkaldy) Homoptera: Aphididae
8. <i>Coelophora pupillata</i> (Swartz) Coleoptera: Coccinellidae	1895	<i>Aphis nerii</i> Boyer de Fonscolombe <i>Toxoptera citricida</i> (Kirkaldy) <i>Reticulaphis distylii fici</i> (Takahashi) Homoptera: Aphididae	<i>Heteropsylla cubana</i> Crawford Homoptera: Psyllidae  <i>Paraleyrodes naranjæ</i> Dozier Homoptera: Aleyrodidae  <i>Selenothrips rubrocinctus</i> (Giard) Thysanoptera: Thripidae

9. <i>Curinus coeruleus</i> Mulsant Coleoptera: Coccinellidae	1922	<i>Nipaeococcus nipae</i> (Maskell) Homoptera: Pseudococcidae	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae
			<i>Aphis nerii</i> Boyer de Fonscolombe Homoptera: Aphididae
			<i>Chrysomphalus aonidium</i> (L.) Homoptera: Diaspididae
			<i>Heteropsylla cubana</i> Crawford Homoptera: Psyllidae
10. <i>Cyrtorhinus fulvus</i> Knight Hemiptera: Miridae	1938	<i>Tarophagus proserpina</i> (Kirkaldy) Homoptera: Delphacidae	
11. <i>Cyrtorhinus lividipennis</i> Reuter Hemiptera: Miridae	1939	<i>Peregrinus maidis</i> (Ashmead) Homoptera: Delphacidae	
12. <i>Dactylosternum hydrophiloides</i> McLeay Coleoptera: Hydrophilidae	1925	<i>Rhabdoscelus obscurus</i> (Boisduval) Coleoptera: Curculionidae	
13. <i>Delphastus pusillus</i> (LeConte) Coleoptera: Coccinellidae	1980	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae	<i>Aleurothrixus floccosus</i> (Maskell) <i>Orchamoplatus mammaeferus</i> (Quaintance & Baker) <i>Trialeurodes vaporariorum</i> (Westwood) Homoptera: Aleyrodidae
14. <i>Diomus notescens</i> (Blackburn) Coleoptera: Coccinellidae	1894	<i>Toxoptera citricida</i> (Kirkaldy) Homoptera: Aphididae	<i>Nipaeococcus vastator</i> (Maskell) <i>Planococcus citri</i> (Risso) Homoptera: Pseudococcidae
15. <i>Dolichurus stantoni</i> (Ashmead) Hymenoptera: Ampulicidae	1917	<i>Allacta similis</i> (Saussure) <i>Melanozosteria soror</i> (Brunner) Orthoptera: Blattidae	
16. <i>Fulvius brevicornis</i> (Reuter) Hemiptera: Miridae	1925	<i>Rhabdoscelus obscurus</i> (Boisduval) Coleoptera: Curculionidae	

**TABLE 2.** Purposely Introduced Species of Predatory Insects & Mites Which Prey on Target Pest Species and/or Other Pest Species in Hawaii. (Continued)

<u>Predator</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
17. <i>Harmonia conformis</i> (Boisduval) Coleoptera: Coccinellidae	1973 <sup>c</sup>	<i>Psylla uncatoides</i> (Ferris & Klyver) Homoptera: Psyllidae	
18. <i>Hippodamia convergens</i> Guerin Coleoptera: Coccinellidae	1896	<i>Macrosiphum avenae</i> (F.) <i>Nasonovia lactucae</i> (L.) Homoptera: Aphididae	
19. <i>Hister bimaculatus</i> (L.) Coleoptera: Histeridae	1909	<i>Haematobia irritans</i> (L.) Diptera: Muscidae	<i>Musca domestica</i> L. Diptera: Muscidae
20. <i>Hister coenosus</i> Erichson Coleoptera: Histeridae	1952	<i>Haematobia irritans</i> (L.) Diptera: Muscidae	
21. <i>Hister nomas</i> Erichson Coleoptera: Histeridae	1957	<i>Haematobia irritans</i> (L.) Diptera: Muscidae	
22. <i>Hyperaspis jocosu</i> (Mulsant) Coleoptera: Coccinellidae	1908	<i>Orthezia insignis</i> Browne Homoptera: Ortheziidae	
23. <i>Hyperaspis silvestrii</i> Weise Coleoptera: Coccinellidae	1922	<i>Nipaeococcus nipae</i> (Maskell) Homoptera: Pseudococcidae	<i>Nipaeococcus vastator</i> (Maskell) Homoptera: Pseudococcidae
24. <i>Larra luzonensis</i> Rohwer Hymenoptera: Sphecidae	1921	<i>Gryllotalpa africana</i> Palisot de Beauvois Orthoptera: Gryllotalpidae	
25. <i>Leucopis nigriluna</i> McAlpine Diptera: Chamaemyiidae	1972	<i>Pineus pini</i> (Macquart) Homoptera: Adelgidae	
26. <i>Leucopis obscura</i> Haliday Diptera: Chamaemyiidae	1976	<i>Pineus pini</i> (Macquart) Homoptera: Adelgidae	

27. <i>Lindorus lophanthæ</i> (Blaisdell) Coleoptera: Coccinellidae	1894	<i>Aulacaspis rosarum</i> Borchsenius <i>Aspidiotus destructor</i> Signoret <i>Lepidosaphes beckii</i> (Newman) <i>Pseudaulacaspis cockerelli</i> (Cooley) Homoptera: Diaspididae	<i>Nipaecoccus vastator</i> (Maskell) Homoptera: Pseudococcidae  <i>Saissetia oleæ</i> (Olivier) Homoptera: Coccidae
28. <i>Motes subtessallatus</i> (Smith) Hymenoptera: Sphecidae	1922	<i>Teleogryllus oceanicus</i> (Le Guillou) Orthoptera: Gryllidae	
29. <i>Labodiplosis pseudococci</i> Felt Diptera: Cecidomyiidae	1930	<i>Dysmicoccus brevipes</i> (Cockerell) Homoptera: Pseudococcidae	<i>Nipaecoccus vastator</i> (Maskell) <i>Planococcus citri</i> (Risso) <i>Saccharicoccus sacchari</i> (Cockerell) Homoptera: Pseudococcidae
30. <i>Nephaspis annicola</i> Wingo Coleoptera: Coccinellidae	1979	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae	<i>Aleurothrix floccosus</i> (Maskell) <i>Orchamoplatus mammaeferus</i> (Quaintance & Baker) <i>Paraleyrodes naranjæ</i> Dozier Homoptera: Aleyrodidae
31. <i>Nephaspis bicolor</i> Gordon Coleoptera: Coccinellidae	1979	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae	
32. <i>Nephus bilucernarius</i> Mulsant Coleoptera: Coccinellidae	1930	<i>Dysmicoccus brevipes</i> (Cockerell) Homoptera: Pseudococcidae	<i>Nipaecoccus vastator</i> (Maskell) Homoptera: Pseudococcidae
33. <i>Nesomicromus navigatorum</i> (Brauer) Neuroptera: Hemerobiidae	1919	<i>Cerataphis lataniae</i> (Boisduval) <i>Melanaphis sacchari</i> (Zehntner) <i>Rhopalosiphum maidis</i> (Fitch) Homoptera: Aphididae	

**TABLE 2.** Purposely Introduced Species of Predatory Insects & Mites Which Prey on Target Pest Species and/or Other Pest Species in Hawaii. (Continued)

<u>Predator</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
34. <i>Olla abdominalis</i> (Say) Coleoptera: Coccinellidae	1908	<i>Saissetia oleae</i> (Olivier) Homoptera: Coccidae	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae  <i>Ferrisia virgata</i> (Cockerell) Homoptera: Pseudococcidae  <i>Heteropsylla cubana</i> Crawford Homoptera: Psyllidae  <i>Melanaphis sacchari</i> (Zehntner) Homoptera: Aphididae  <i>Psylla uncatoides</i> (Ferris & Klyver) Homoptera: Psyllidae
35. <i>Orcus chalybeus</i> (Boisduval) Coleoptera: Coccinellidae	1894	<i>Coccus viridis</i> (Green) <i>Saissetia oleae</i> (Olivier) Homoptera: Coccidae  <i>Parlatoria ziziphi</i> (Lucas) Homoptera: Diaspididae	<i>Aleurothrixus floccosus</i> (Maskell) <i>Orchamoplatus mammaeferus</i> (Quaintance & Baker) Homoptera: Aleyrodidae  <i>Macrosiphum rosae</i> (L.) Homoptera: Aphididae  <i>Spodoptera mauritia</i> (Boisduval) <sup>d</sup> Lepidoptera: Noctuidae
36. <i>Orius insidiosus</i> (Say) Hemiptera: Anthocoridae	1951	<i>Heliothis zea</i> Boddie <sup>d</sup> Lepidoptera: Noctuidae	

37. <i>Pachylister caffer</i> Erichson Coleoptera: Histeridae	1957	<i>Haematobia irritans</i> L. Diptera: Muscidae	
38. <i>Pachylister lutarius</i> Erichson Coleoptera: Histeridae	1958	<i>Haematobia irritans</i> (L.) Diptera: Muscidae	<i>Musca domestica</i> L. Diptera: Muscidae
39. <i>Phytoseiulus persimilis</i> A. & H. <sup>e</sup> Parasitiformes: Phytoseiidae	1975	<i>Tetranychus cinnabarinus</i> (Boisduval) Acariformes: Tetranychidae	
40. <i>Pseudoscymnus anomalus</i> Chapin Coleoptera: Coccinellidae	1970	<i>Aspidiotus destructor</i> Signoret Homoptera: Diaspididae	
41. <i>Rhizobius forestieri</i> (Mulsant) Coleoptera: Coccinellidae	1894	<i>Dysmicoccus brevipes</i> (Cockerell) <i>Nipaeococcus nipae</i> (Maskell) <i>Nipaeococcus vastator</i> (Maskell) <i>Planococcus citri</i> (Risso) Homoptera: Pseudococcidae	<i>Saissetia oleae</i> (Olivier) Homoptera: Coccidae  <i>Spodoptera mauritia</i> (Boisduval) <sup>d</sup> Lepidoptera: Noctuidae  <i>Toxoptera citricida</i> (Kirkaldy) Homoptera: Aphididae
42. <i>Rodolia cardinalis</i> Mulsant Coleoptera: Coccinellidae	1890	<i>Icerya purchasi</i> Maskell Homoptera: Margarodidae	<i>Pulvinaria mammeae</i> Maskell Homoptera: Coccidae
43. <i>Scymnodes lividigaster</i> (Mulsant) Coleoptera: Coccinellidae	1894	<i>Aphis gossypii</i> Glover <i>Toxoptera aurantii</i> (Fonscolombe) <i>Toxoptera citricida</i> (Kirkaldy) Homoptera: Aphididae	<i>Nipaeococcus vastator</i> (Maskell) Homoptera: Pseudococcidae
44. <i>Scymnus roepkei</i> (Fluiter) Coleoptera: Coccinellidae	1895	<i>Ferrisia virgata</i> (Cockerell) <i>Nipaeococcus vastator</i> (Maskell) <i>Planococcus citri</i> (Risso) Homoptera: Pseudococcidae	<i>Spodoptera mauritia</i> (Boisduval) <sup>d</sup> Lepidoptera: Noctuidae
45. <i>Scymnus uncinatus</i> Sicard Coleoptera: Coccinellidae	1922	<i>Dysmicoccus brevipes</i> (Cockerell) Homoptera: Pseudococcidae	<i>Nipaeococcus vastator</i> (Maskell) Homoptera: Pseudococcidae

**TABLE 2.** Purposely Introduced Species of Predatory Insects & Mites Which Prey on Target Pest Species and/or Other Pest Species in Hawaii. (Continued)

<u>Predator</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
46. <i>Sepedomerus macropus</i> (Walker) Diptera: Sciomyzidae	1958	<i>Galba viridis</i> (Quoy & Gaimard) Basommatophora: Lymnaeidae	
47. <i>Sepedon aenescens</i> (Wiedemann) Diptera: Sciomyzidae	1966	<i>Galba viridis</i> (Quoy & Gaimard) Basommatophora: Lymnaeidae	
48. <i>Serangium maculigerum</i> Blackburn' Coleoptera: Coccinellidae	1894		<i>Aleurocanthus spiniferus</i> (Quaintance) <i>Aleurodicus dispersus</i> Russell <i>Aleurothrix floccosus</i> (Maskell) <i>Orchamoplatus mammaeferus</i> (Quaintance & Baker) Homoptera: Aleyrodidae
49. <i>Sphaeridium scarabaeoides</i> L. Coleoptera: Hydrophilidae	1909	<i>Haematobia irritans</i> (L.) Diptera: Muscidae	
50. <i>Stethorus siphonulus</i> Kapur Coleoptera: Coccinellidae	1895	<i>Eutetranychus banksi</i> (McGregor) <i>Tetranychus cinnabarinus</i> (Boisduval) <i>Tetranychus tumidus</i> Banks Acariformes: Tetranychidae	
51. <i>Sticholotis ruficeps</i> Weise Coleoptera: Coccinellidae	1895	<i>Eriococcus araucariae</i> Maskell Homoptera: Eriococcidae  <i>Pinnaspis buxi</i> (Bouche) Homoptera: Diaspididae	



52. <i>Symphorobius barberi</i> Banks Neuroptera: Hemerobiidae	1929	<i>Pseudococcus longispinus</i> (Targioni-Tozzetti) Homoptera: Pseudococcidae	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae
53. <i>Telsimia nitida</i> Chapin <sup>a</sup> Coleoptera: Coccinellidae	1895	<i>Lepidosaphes beckii</i> (Newman) <i>Pinnaspis buxi</i> (Bouche) Homoptera: Diaspididae	<i>Aspidiotus destructor</i> Signoret <i>Diaspis boisduvalii</i> Signoret Homoptera: Diaspididae
54. <i>Thyrecephalus albertisi</i> Fauvel Coleoptera: Staphylinidae	1947	<i>Dacus dorsalis</i> Hendel Diptera: Tephritidae	
55. <i>Toxorhynchites amboinensis</i> (Doleschall) Diptera: Culicidae	1954	<i>Aedes albopictus</i> (Skuse) Diptera: Culicidae	
56. <i>Toxorhynchites brevipalpis</i> Theobald Diptera: Culicidae	1950	<i>Aedes albopictus</i> (Skuse) Diptera: Culicidae	
57. <i>Typhlodromus occidentalis</i> Nesbitt <sup>c</sup> Parasitiformes: Phytoseiidae	1975	<i>Tetranychus cinnabarinus</i> (Boisduval) Acariformes: Tetranychidae	

<sup>a</sup>Purposely introduced to control *Aspidiotus* spp. but recorded only from *Asterolecanium bambusae*.

<sup>b</sup>Recorded to have preyed on other unidentified aphids.

<sup>c</sup>First released in 1894 against 'aphids' but establishment was unsuccessful. Establishment was made after reintroduction in 1973 against *P. uncatoides*.

<sup>d</sup>Eggs only.

<sup>e</sup>Mite.

<sup>f</sup>Purposely introduced to control 'diaspine scales' but recorded only from whiteflies.

<sup>g</sup>Purposely introduced in 1895 as *Pentilia nigra* Weise but voucher specimens compare with those of *Telsimia nitida* which was subsequently reintroduced from Guam in 1936.

**TABLE 3.** Purposely Introduced Species of Predatory Insects Which Prey on Target Pest Species and/or Immigrant, Native, or Other Purposely Introduced Species in Hawaii.

<u>Predator</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
1. <i>Cryptolaemus montrouzieri</i> Mulsant Coleoptera: Coccinellidae	1894	<i>Pulvinaria psidii</i> Maskell Homoptera: Coccidae	I - <i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae  I - <i>Coccus viridis</i> (Green) Homoptera: Coccidae  P - <i>Dactylopius opuntiae</i> (Cockerell) Homoptera: Dactylopiidae  I - <i>Dysmicoccus boninsis</i> (Kuwana) I - <i>Dysmicoccus brevipes</i> (Cockerell) I - <i>Eriococcus araucariae</i> (Maskell) I - <i>Ferrisia virgata</i> (Cockerell) I - <i>Nipaecoccus nipae</i> (Maskell) I - <i>Nipaecoccus vastator</i> (Maskell) I - <i>Pseudococcus longispinus</i> (Targioni-Tozzetti) I - <i>Pseudococcus affinis</i> (Maskell) I - <i>Saccharicoccus sacchari</i> (Cockerell) Homoptera: Pseudococcidae  I - <i>Spodoptera mauritia</i> (Boisduval) <sup>a</sup> Lepidoptera: Noctuidae  I - <i>Toxoptera citricida</i> (Kirkaldy) Homoptera: Aphididae  N - <i>Trionymus insularis</i> Ehrhorn Homoptera: Pseudococcidae

2. <i>Diomus ?pumilio</i> Weise Coleoptera: Coccinellidae	1922	<i>Chorizococcus rostellum</i> (Lobdell) <i>Pseudococcus</i> sp. Homoptera: Pseudococcidae	N - <i>Chlorococcus montanus</i> (Ehrhorn) Homoptera: Pseudococcidae
3. <i>Hyperaspis fimbriolata</i> Melisheimer <sup>b</sup> Coleoptera: Coccinellidae	1906		N - <i>Trionymus insularis</i> Ehrhorn Homoptera: Pseudococcidae
4. <i>Montandoniella moraguesi</i> Puton Hemiptera: Anthocoridae	1964	<i>Gynaikothrips ficorum</i> (Marchal) Thysanoptera: Phlaeothripidae	P - <i>Liothrips urichi</i> Karny Thysanoptera: Phlaeothripidae
5. <i>Tythus mundulus</i> (Breddin) Hemiptera: Miridae	1920	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae	N - <i>Kelsia sporobolicola</i> Kirkaldy I - <i>Peregrinus maidis</i> (Ashmead) I - <i>Tarophagus proserpina</i> (Kirkaldy) Homoptera: Delphacidae

<sup>a</sup>Eggs only.

<sup>b</sup>Purposely introduced to control "mealybugs" but recorded only from a native species.

I - Immigrant species.

N - Native species.

P - Purposely introduced species.

**TABLE 4.** Purposely Introduced Species of Parasitic Insects & Fungi Which Attack Only Target Pest Species in Hawaii.

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>
1. <i>Aceratoneuromyia indicum</i> (Silvestri) Hymenoptera: Eulophidae	1950 <sup>a</sup>	<i>Dacus dorsalis</i> Hendel Diptera: Tephritidae
2. <i>Aenasius advena</i> Compere Hymenoptera: Encyrtidae	1923	<i>Ferrisia virgata</i> (Cockerell) Homoptera: Pseudococcidae
3. <i>Agathis ?cincta</i> Cresson Hymenoptera: Braconidae	1965	<i>Ithome concolorella</i> (Chambers) Lepidoptera: Cosmopterigidae
4. <i>Anagrus jawi</i> Fullaway Hymenoptera: Mymaridae	1943	<i>Pycnoderes quadrimaculatus</i> Guerin-Meneville Hemiptera: Miridae
5. <i>Anagrus ananatis</i> Gahan Hymenoptera: Encyrtidae	1935	<i>Dysmicoccus brevipes</i> (Cockerell) Homoptera: Pseudococcidae
6. <i>Anagrus dactylopii</i> (Howard) Hymenoptera: Encyrtidae	1925	<i>Nipaecoccus vastator</i> (Maskell) Homoptera: Pseudococcidae
7. <i>Anagrus fusciventris</i> (Girault) Hymenoptera: Encyrtidae	1904	<i>Pseudococcus longispinus</i> (Targioni-Tozzetti) <i>Pseudococcus</i> sp. ( <i>gallicola</i> Ehrhorn complex) Homoptera: Pseudococcidae
8. <i>Anagrus saccharicola</i> Timberlake Hymenoptera: Encyrtidae	1930	<i>Saccharicoccus sacchari</i> (Cockerell) Homoptera: Pseudococcidae
9. <i>Apanteles scutellaris</i> Muesebeck Hymenoptera: Braconidae	1933	<i>Phthorimaea operculella</i> (Zeller) Lepidoptera: Gelechiidae
10. <i>Aphanomerus pusillus</i> Perkins Hymenoptera: Platygasteridae	1904	<i>Siphanta acuta</i> (Walker) Homoptera: Flattidae

11. <i>Aphidius smithi</i> Sharma & Rao Hymenoptera: Braconidae	1960	<i>Acyrtosiphon pisum</i> (Harris) Homoptera: Aphididae
12. <i>Archytas cirphis</i> (Curran) Diptera: Tachinidae	1924	<i>Agrotis ipsilon</i> (Hufnagel) <i>Peridroma saucia</i> (Hubner) <i>Pseudaletia unipuncta</i> (Haworth) <i>Spodoptera exempta</i> (Walker) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae
13. <i>Baeus latroecti</i> Dozier Hymenoptera: Scelionidae	1939	<i>Latroectus mactans</i> (F.) Araneida: Theridiidae
14. <i>Biosteres fullawayi</i> (Silvestri) Hymenoptera: Braconidae	1914	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae
15. <i>Biosteres kraussi</i> (Fullaway) Hymenoptera: Braconidae	1949	<i>Ceratitis capitata</i> (Wiedemann) <i>Dacus dorsalis</i> Hendel Diptera: Tephritidae
16. <i>Brachymeria agonoxenae</i> Fullaway Hymenoptera: Chalcididae	1948	<i>Agonoxena argaula</i> Meyrick Lepidoptera: Agonoxenidae
17. <i>Bracon chinensis</i> Szepligeti Hymenoptera: Braconidae	1928	<i>Chilo suppressalis</i> (Walker) Lepidoptera: Pyralidae
18. <i>Cales noacki</i> De Santis Hymenoptera: Aphelinidae	1981	<i>Aleurothrixus floccosus</i> (Maskell) Homoptera: Aleyrodidae
19. <i>Ceranisis brui</i> Vuillet Hymenoptera: Eulophidae	1932	<i>Thrips tabaci</i> Lindeman Thysanoptera: Thripidae

**TABLE 4.** Purposely Introduced Species of Parasitic Insects & Fungi Which Attack Only Target Pest Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>
20. <i>Chelonus insularis</i> (Cresson) Hymenoptera: Braconidae	1942	<i>Agrotis ipsilon</i> (Hufnagel) <i>Peridroma saucia</i> (Hubner) <i>Pseudaletia unipuncta</i> (Haworth) <i>Spodoptera exempta</i> (Walker) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae
21. <i>Chrysonotomyia punctiventris</i> (Crawford) Hymenoptera: Eulophidae	1976	<i>Liriomyza</i> spp. Diptera: Agromyzidae
22. <i>Coccidoxenus mexicanus</i> Girault Hymenoptera: Encyrtidae	1967	<i>Ceroplastes cirripediformis</i> Comstock Homoptera: Coccidae
23. <i>Comperiella bifasciata</i> Howard <sup>b</sup> Hymenoptera: Encyrtidae	1908	<i>Aspidiotus</i> sp. <i>Chrysomphalus aonidium</i> (L.) <i>Hemiberlesia rapax</i> (Comstock) <i>Morganella longispina</i> (Morgan) Homoptera: Diaspididae  <i>Saissetia coffeae</i> (Walker) Homoptera: Coccidae
24. <i>Copidosoma truncatellum</i> (Dalman) Hymenoptera: Encyrtidae	1898	<i>Chrysodeixis chalcites</i> (Esper) Lepidoptera: Noctuidae
25. <i>Cotesia erionotae</i> (Wilkinson) Hymenoptera: Braconidae	1973	<i>Pelopidas thrax</i> (L.) Lepidoptera: Hesperidae
26. <i>Cotesia glomeratus</i> (L.) Hymenoptera: Braconidae	1898	<i>Artogeia rapae</i> (L.) Lepidoptera: Pieridae

27. <i>Cotesia plutellae</i> (Kurdjumov) Hymenoptera: Braconidae	1972	<i>Plutella xylostella</i> (L.) Lepidoptera: Yponomeutidae
28. <i>Cotesia ruficrus</i> (Haliday) Hymenoptera: Braconidae	1951	<i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae
29. <i>Diadegma insularis</i> (Cresson) Hymenoptera: Ichneumonidae	1953	<i>Plutella xylostella</i> (L.) Lepidoptera: Yponomeutidae
30. <i>Diglyphus intermedius</i> (Girault) Hymenoptera: Eulophidae	1975	<i>Liriomyza</i> spp. Diptera: Agromyzidae
31. <i>Diglyphus</i> n. sp. Hymenoptera: Eulophidae	1976	<i>Liriomyza</i> spp. Diptera: Agromyzidae
32. <i>Doryctes syagrii</i> (Fullaway) Hymenoptera: Braconidae	1921	<i>Syagrius fulvitaris</i> Pascoe Coleoptera: Curculionidae
33. <i>Encarsia formosa</i> Gahan Hymenoptera: Aphelinidae	1942	<i>Trialeurodes vaporariorum</i> (Westwood) Homoptera: Aleyrodidae
34. <i>Encarsia</i> sp. Hymenoptera: Aphelinidae	1980	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae
35. <i>Encarsia ?haitiensis</i> Dozier Hymenoptera: Aphelinidae	1979	<i>Aleurodicus dispersus</i> Russell Homoptera: Aleyrodidae
36. <i>Eretmocerus haldemani</i> Howard Hymenoptera: Aphelinidae	1952	<i>Trialeurodes vaporariorum</i> (Westwood) Homoptera: Aleyrodidae
37. <i>Eucelatoria</i> sp. Diptera: Tachinidae	1974	<i>Melipotis indomita</i> (Walker) Lepidoptera: Noctuidae
38. <i>Euplectrus plathypenae</i> Howard Hymenoptera: Eulophidae	1902	<i>Agrotis ipsilon</i> (Hufnagel) <i>Peridroma saucia</i> (Hubner) <i>Pseudaletia unipuncta</i> (Haworth) <i>Spodoptera exempta</i> (Walker) Lepidoptera: Noctuidae

**TABLE 4.** Purposely Introduced Species of Parasitic Insects & Fungi Which Attack Only Target Pest Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>
39. <i>Galesus silvestrii</i> Kieffer Hymenoptera: Diapriidae	1913	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae
40. <i>Gambrus ultimus</i> (Cresson) Hymenoptera: Ichneumonidae	1951	<i>Amorbia emigratella</i> Busck Lepidoptera: Tortricidae
41. <i>Ganaspidium utilis</i> Beardsley Hymenoptera: Eucolidae	1976	<i>Liriomyza</i> spp. Diptera: Agromyzidae
42. <i>Glyptapanteles militaris</i> (Walsh) Hymenoptera: Braconidae	1902	<i>Pseudaletia unipuncta</i> (Haworth) Lepidoptera: Noctuidae
43. <i>Glyptocolastes bruchivorus</i> Crawford Hymenoptera: Braconidae	1921	<i>Algarobius bottimeri</i> Kingsolver <i>Callosobruchus chinensis</i> (L.) <i>Caryedon gonagra</i> (F.) <i>Mimosestes amicus</i> (Horn) <i>Mimosestes sallaei</i> (Sharp) Coleoptera: Bruchidae
44. <i>Hambeltonia pseudococcina</i> Compere Hymenoptera: Encyrtidae	1935	<i>Dysmicoccus brevipes</i> (Cockerell) Homoptera: Pseudococcidae
45. <i>Heterospilus prosopidis</i> Viereck Hymenoptera: Braconidae	1910	<i>Algarobius bottimeri</i> Kingsolver <i>Bruchus phaseoli</i> Gyllenhal <i>Callosobruchus chinensis</i> (L.) <i>Mimosestes sallaei</i> (Sharp) <i>Stator pruininus</i> (Horn) Coleoptera: Bruchidae
46. <i>Horismenus</i> sp. Hymenoptera: Eulophidae	1921	<i>Mimosestes sallaei</i> (Sharp) Coleoptera: Bruchidae



47. <i>Lariophagus texanus</i> Crawford Hymenoptera: Pteromalidae	1921	<i>Mimosestes sallaei</i> (Sharp) Coleoptera: Bruchidae
48. <i>Leptomastidea abnormis</i> (Girault) Hymenoptera: Encyrtidae	1915	<i>Planococcus citri</i> (Risso) Homoptera: Pseudococcidae
49. <i>Lixophaga sphenophori</i> (Villeneuve) Diptera: Tachinidae	1910	<i>Rhabdoscelus obscurus</i> (Boisduval) Coleoptera: Curculionidae
50. <i>Lysiphlebius testaceipes</i> (Cresson) Hymenoptera: Braconidae	1923	<i>Aphis craccivora</i> Koch <i>Aphis gossypii</i> Glover <i>Aphis middletoni</i> (Thomas) <i>Aphis nerii</i> Boyer de Fonscolombe <i>Melanaphis sacchari</i> (Zehntner) <i>Rhopalosiphum maidis</i> (Fitch) Homoptera: Aphididae
51. <i>Metaphycus stanleyi</i> Compere Hymenoptera: Encyrtidae	1945	<i>Coccus elongatus</i> (Signoret) <i>Coccus hesperidum</i> L. <i>Coccus viridis</i> (Green) <i>Saissetia coffeae</i> (Walker) Homoptera: Coccidae
52. <i>Ooencyrtus erionotae</i> Ferriere Hymenoptera: Encyrtidae	1973	<i>Pelopidas thrax</i> (L.) Lepidoptera: Hesperiiidae
53. <i>Ooencyrtus johnsoni</i> (Howard) <sup>c</sup> Hymenoptera: Encyrtidae	1940	<i>Murgantia histrionica</i> (Hahn) <sup>c</sup> Homoptera: Delphacidae
54. <i>Ootetrastichus formosanus</i> Timberlake Hymenoptera: Eulophidae	1916	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae
55. <i>Ootetrastichus megameli</i> Fullaway Hymenoptera: Eulophidae	1938	<i>Tarophagus proserpina</i> (Kirkaldy) Homoptera: Delphacidae
56. <i>Opius fletcheri</i> Silvestri Hymenoptera: Braconidae	1916	<i>Dacus cucurbitae</i> Coquillett Diptera: Tephritidae

TABLE 4. Purposely Introduced Species of Parasitic Insects &amp; Fungi Which Attack Only Target Pest Species in Hawaii. (Continued)

Parasite	Year First Released	Target Pest(s)
57. <i>Opius humilis</i> Silvestri Hymenoptera: Braconidae	1913	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae
58. <i>Opius importatus</i> Fischer Hymenoptera: Braconidae	1969	<i>Ophiomyia phaseoli</i> (Tryon) Diptera: Agromyzidae
59. <i>Opius phaseoli</i> Fischer Hymenoptera: Braconidae	1969	<i>Ophiomyia phaseoli</i> (Tryon) Diptera: Agromyzidae
60. <i>Opius</i> sp. Hymenoptera: Braconidae	1961	<i>Amauromyza maculosa</i> (Malloch) Diptera: Agromyzidae
61. <i>Prospaltella smithi</i> Silvestri Hymenoptera: Aphelinidae	1974	<i>Aleurocanthus spiniferus</i> (Quaintance) Homoptera: Aleyrodidae
62. <i>Pseudamblyteles koebelei</i> (Swezey) Hymenoptera: Ichneumonidae	1895	<i>Agrotis ipsilon</i> (Hufnagel) <i>Peridroma saucia</i> (Hubner) <i>Pseudaletia unipuncta</i> (Haworth) <i>Spodoptera exempta</i> (Walker) Lepidoptera: Noctuidae
63. <i>Pseudophycus utilis</i> Timberlake Hymenoptera: Encyrtidae	1922	<i>Nipaecoccus nipae</i> (Maskell) Homoptera: Pseudococcidae
64. <i>Pseudogonatopus hospes</i> Perkins Hymenoptera: Dryinidae	1907	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae
65. <i>Pterocormus purpuripennis</i> (Cresson) Hymenoptera: Ichneumonidae	1895	<i>Spodoptera exempta</i> (Walker) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae

66. <i>Pteromalus luzonensis</i> Gahan	Hymenoptera: Pteromalidae	1975	<i>Papilio xuthus</i> L.	Lepidoptera: Papilionidae
67. <i>Scelio pambertoni</i> Timberlake	Hymenoptera: Scelionidae	1930	<i>Oxya japonica</i> (Thunberg)	Orthoptera: Acrididae
68. <i>Sphaerosyllbe coccophila</i> Tulasne <sup>d</sup>	Moniliales: Moniliaceae	1899	<i>Lepidosaphes bechii</i> (Newman)	Homoptera: Diaspididae
69. <i>Telenomus</i> sp.	Hymenoptera: Scelionidae	1923	<i>Zelus renardii</i> Kolena <sup>e</sup>	Hemiptera: Reduviidae
70. <i>Tetrastichus dactyla</i> Silvestri	Hymenoptera: Eulophidae	1950	<i>Ceratix capitata</i> (Wiedemann)	Diptera: Tephritidae
71. <i>Tetrastichus giffardianus</i> Silvestri	Hymenoptera: Eulophidae	1914	<i>Ceratix capitata</i> (Wiedemann)	Diptera: Tephritidae
72. <i>Trichopoda pennipes</i> F.	Diptera: Tachinidae	1963	<i>Nezara viridula</i> (L.)	Hemiptera: Pentatomidae
73. <i>Trioxys complanatus</i> Quilis	Hymenoptera: Braconidae	1975	<i>Therioaphis maculata</i> (Buckton)	Homoptera: Aphididae
74. <i>Trysilus murgantiae</i> (Ashmead) <sup>e</sup>	Hymenoptera: Scelionidae	1946	<i>Murgantia histrionica</i> (Hahn) <sup>e</sup>	Hemiptera: Pentatomidae
75. <i>Urosigalphus bruchi</i> Crawford	Hymenoptera: Braconidae	1921	<i>Algarobius bollimere</i> Kingsolver	Coloptera: Bruchidae
			<i>Callosobruchus chinensis</i> (L.)	
			<i>Caryedon gonagra</i> (F.)	
			<i>Mimosstes amicus</i> (Horn)	
			<i>Mimosstes saliaei</i> (Sharpe)	

TABLE 4. Purposely Introduced Species of Parasitic Insects &amp; Fungi Which Attack Only Target Pest Species in Hawaii. (Continued)

Parasite	Year First Released	Target Pest(s)
76. <i>Uscana semifumipennis</i> Girault Hymenoptera: Trichogrammatidae	1910	<i>Algarobius battimeri</i> Kingsolver <i>Bruchus phaseoli</i> Gyllenhal <i>Callosobruchus chinensis</i> (L.) <i>Caryedon gonagra</i> (F.) <i>Mimosestes saltai</i> (Sharp) <i>Stator limbatus</i> (Horn) <i>Stator pruinus</i> (Horn) Coleoptera: Bruchidae
77. <i>Verticillium lecanii</i> (Zimmerman) <sup>a</sup> Moniliales: Moniliaceae	ca. 1929	<i>Ceroplastes rubens</i> Maskell <i>Coccus viridis</i> (Green) <i>Eucalymnatus tessellatus</i> (Signoret) <i>Kilijia acuminata</i> (Signoret) <i>Saissetia coffeae</i> (Walker) <i>Saissetia oleae</i> (Olivier) Homoptera: Coccidae
78. <i>Zeteticonus utilis</i> Noyes Hymenoptera: Encyrtidae	1977	<i>Carpophilus</i> spp. Coleoptera: Nitidulidae

<sup>a</sup>First released in 1938 against *Ceratits capitata* (Wiedemann) and *Dacus cucurbitae* Coquillett but no establishment recorded from this liberation. Establishment successful after reintroduction in 1950 against *Dacus dorsalis* Hendel.

<sup>b</sup>The only confirmed host for this species is *C. aonidium*. Other recorded hosts questionable.

<sup>c</sup>May be extinct. Not observed or reported in Hawaii for past 20 years.

<sup>d</sup>Fungus.

<sup>e</sup>An accidental immigrant general predator. Since it also preyed on coccinellids, the egg parasite (*Telenomus* sp.) was purposely introduced for its control.

TABLE 5. Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Other Pest Species in Hawaii.

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
1. <i>Anysis alcocki</i> (Ashmead) Hymenoptera: Pteromalidae	1964	<i>Ceroplastes rubens</i> Maskell Homoptera: Coccidae	<i>Asterolecanium bambusae</i> (Boisduval) Homoptera: Asterolecaniidae  <i>Ceroplastes cirripediformis</i> Comstock <i>Saissetia coffeae</i> (Walker) Homoptera: Coccidae
2. <i>Biosteres arisanus</i> (Sonan) Hymenoptera: Braconidae	1949	<i>Dacus dorsalis</i> Hendel Diptera: Tephritidae	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae
3. <i>Biosteres vandenboschi</i> (Fullaway) Hymenoptera: Braconidae	1947	<i>Dacus dorsalis</i> Hendel Diptera: Tephritidae	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae
4. <i>Campsomoris marginella modesta</i> (Smith) Hymenoptera: Scoliidae	1916	<i>Anomala orientalis</i> (Waterhouse) Coleoptera: Scarabaeidae	<i>Adoretus sinicus</i> Burmeister Coleoptera: Scarabaeidae
5. <i>Dirhinus giffardii</i> Silvestri Hymenoptera: Chalcididae	1913	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae	<i>Dacus cucurbitae</i> Coquillett <i>Dacus dorsalis</i> Hendel Diptera: Tephritidae
6. <i>Eriborus sinicus</i> (Holmgren) Hymenoptera: Ichneumonidae	1928	<i>Chilo suppressalis</i> (Walker) Lepidoptera: Pyralidae	<i>Bactra straminea</i> (Butler) <i>Cryptophlebia illepidia</i> (Butler) Lepidoptera: Tortricidae  N - <i>Hedylepta blackburni</i> (Butler) <i>Omphisa anastomosalis</i> Guenee Lepidoptera: Pyralidae
7. <i>Eucoila impatiens</i> (Say) Hymenoptera: Eucolidae	1906	<i>Haematobia irritans</i> (L.) Diptera: Muscidae	<i>Boettcherisca peregrina</i> (Robineau-Desvoidy) Diptera: Sarcophagidae

**TABLE 5.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Other Pest Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
8. <i>Euryrhopalus propinquus</i> Kerrich Hymenoptera: Encyrtidae	1936	<i>Dysmicoccus brevipes</i> (Cockerell) <i>Dysmicoccus neobrevipes</i> Beardsley Homoptera: Pseudococcidae	<i>Planococcus citri</i> (Risso) Homoptera: Pseudococcidae
9. <i>Haplogonatopus vitiensis</i> Perkins Hymenoptera: Dryinidae	1906	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae	<i>Liburnia paludum</i> (Kirkaldy) <i>Peregrinus maidis</i> (Ashmead) <i>Tarophagus proserpina</i> (Kirkaldy) Homoptera: Delphacidae
10. <i>Marietta carnesi</i> (Howard) <sup>a</sup> Hymenoptera: Aphelinidae	1907	<i>Lepidosaphes</i> sp. Homoptera: Diaspididae	<i>Diaspis echinocacti</i> (Bouche) Homoptera: Diaspididae <i>Parasaissetia nigra</i> (Nietner) <i>Saissetia oleae</i> (Olivier) Homoptera: Coccidae
11. <i>Muscidifurax raptor</i> Girault & Sanders Hymenoptera: Pteromalidae	1913	<i>Musca domestica</i> L. Diptera: Muscidae	<i>Chrysomya megacephala</i> (F.) Diptera: Calliphoridae  <i>Fannia pusio</i> Wiedemann <i>Musca sorbens</i> Wiedemann <i>Stomoxys calcitrans</i> (L.) Diptera: Muscidae  <i>Sarcophagula occidua</i> (F.) Diptera: Sarcophagidae
12. <i>Ooetetrastichus beatus</i> Perkins Hymenoptera: Eulophidae	1905	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae	<i>Draeculacephala minerva</i> Ball <i>Draeculacephala mollipes</i> (Say) Homoptera: Cicadellidae <i>Peregrinus maidis</i> (Ashmead) Homoptera: Delphacidae

13. <i>Opius incisi</i> Silvestri Hymenoptera: Braconidae	1916	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae	<i>Dacus dorsalis</i> Hendel Diptera: Tephritidae
14. <i>Paranagrus optabilis</i> Perkins Hymenoptera: Mymaridae	1904	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae	<i>Peregrinus maidis</i> (Ashmead) Homoptera: Delphacidae
15. <i>Pristomerus spinator</i> (F.) Hymenoptera: Ichneumonidae	1942	<i>Pseudaletia unipuncta</i> (Haworth) Lepidoptera: Noctuidae	<i>Keiferia lycopersicella</i> (Walsingham) Lepidoptera: Gelechiidae
16. <i>Pteromalus puparum</i> (L.) Hymenoptera: Pteromalidae	1898	<i>Artogea rapae</i> (L.) Lepidoptera: Pieridae	<i>Vanessa cardui</i> (L.) Lepidoptera: Nymphalidae
17. <i>Scutellista cyanea</i> Motschulsky Hymenoptera: Pteromalidae	1905	<i>Parasaissetia nigra</i> (Nietner) Homoptera: Coccidae	<i>Ceroplastes cirripediformis</i> Comstock <i>Coccus viridis</i> (Green) <i>Saissetia coffeae</i> (Walker) <i>Saissetia oleae</i> (Olivier) Homoptera: Coccidae
18. <i>Spalangia endius</i> Walker Hymenoptera: Pteromalidae	1914	<i>Musca domestica</i> L. Diptera: Muscidae	<i>Chrysomya megacephala</i> (F.) Diptera: Calliphoridae <i>Fannia pusio</i> Wiedemann <i>Musca sorbens</i> Wiedemann <i>Ophyra chalcogaster</i> Wiedemann Diptera: Muscidae <i>Parasarcophaga ruficornis</i> (F.) Diptera: Sarcophagidae <i>Phaenicia cuprina</i> Wiedemann Diptera: Calliphoridae <i>Ravinia iherminieri</i> (Robineau-Desvoidy) <i>Sarcophagula occidua</i> (F.) Diptera: Sarcophagidae
19. <i>Spalangia nigra</i> Latreille Hymenoptera: Pteromalidae	1967	<i>Musca domestica</i> L. Diptera: Muscidae	<i>Fannia pusio</i> Wiedemann <i>Musca sorbens</i> Wiedemann <i>Ophyra chalcogaster</i> Wiedemann Diptera: Muscidae

**TABLE 5.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Other Pest Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
			<i>Phaenicia cuprina</i> Wiedemann Diptera: Calliphoridae
20. <i>Tachinaephagus zealandicus</i> Ashmead Hymenoptera: Encyrtidae	1968	<i>Musca domestica</i> L. Diptera: Muscidae	<i>Musca sorbens</i> Wiedemann Diptera: Muscidae
21. <i>Tiphia segregata</i> Crawford Hymenoptera: Tiphidae	1917	<i>Anomala orientalis</i> (Waterhouse) Coleoptera: Scarabaeidae	<i>Adoretus sinicus</i> Burmeister Coleoptera: Scarabaeidae
22. <i>Trichogramma chilonis</i> Ishii Hymenoptera: Trichogrammatidae	1929	<i>Chilo suppressalis</i> (Walker) Lepidoptera: Pyralidae	<i>Achaea janata</i> (L.) Lepidoptera: Noctuidae  <i>Agraulis vanillae</i> L. Lepidoptera: Heliconiidae  <i>Eudocima fullonia</i> (Clerck) <i>Heliothis zea</i> (Boddie) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae  <i>Agrius cingulatus</i> (F.) Lepidoptera: Sphingidae  <i>Danaus plexippus</i> (L.) Lepidoptera: Danaidae  <i>Daphnis nerii</i> (L.) <i>Macroglossum pyrrhostictum</i> (Butler) Lepidoptera: Sphingidae  <i>Papilio xuthus</i> L. Lepidoptera: Papilionidae

\*Recorded hosts for this species questionable. *Marietta* spp. are now known to be mostly hyperparasitic.

N - Native pest species.



**TABLE 6.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Immigrant, Native, or Other Purposely Introduced Species in Hawaii.

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
1. <i>Anagrus frequens</i> Perkins Hymenoptera: Mymaridae	1905	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae	N - <i>Kelisia sporobolicola immaculata</i> Muir  I - <i>Liburnia paludum</i> (Kirkaldy) N - <i>Nesosydne leahi</i> (Kirkaldy) I - <i>Peregrinus maidis</i> (Ashmead) Homoptera: Delphacidae
2. <i>Biosteres longicaudatus</i> Ashmead Hymenoptera: Braconidae	1947	<i>Ceratitis capitata</i> (Wiedemann) <i>Dacus dorsalis</i> Hendel Diptera: Tephritidae	I - <i>Dacus cucurbitae</i> Coquillett P - <i>Procecidochares utilis</i> Stone Diptera: Tephritidae
3. <i>Biosteres tryoni</i> (Cameron) Hymenoptera: Braconidae	1913	<i>Ceratitis capitata</i> (Wiedemann) Diptera: Tephritidae	I - <i>Dacus dorsalis</i> Hendel P - <i>Eutreta xanthochaeta</i> Aldrich P - <i>Procecidochares alani</i> Steyskal P - <i>Procecidochares utilis</i> Stone Diptera: Tephritidae
4. <i>Brachymeria obscurata</i> (Walker) Hymenoptera: Chalcididae	1895	N - <i>Hedylepta accepta</i> (Butler) N - <i>Hedylepta blackburni</i> (Butler) Lepidoptera: Pyralidae	I - <i>Amorbia emigratella</i> Busck Lepidoptera: Tortricidae  I - <i>Artogeia rapae</i> (L.) Lepidoptera: Pieridae  P - <i>Blepharomastix ebulealis</i> (Guenee) Lepidoptera: Pyralidae  P - <i>Catabena esula</i> Druce Lepidoptera: Noctuidae

**TABLE 6.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Immigrant, Native, or Other Purposely Introduced Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
			I - <i>Chaetogaedia monticola</i> (Bigot) <sup>a</sup> Diptera: Tachinidae
			I - <i>Chrysodeixis chalcites</i> (Esper) Lepidoptera: Noctuidae
			? - <i>Crociosema blackburnii</i> (Butler)
			? - <i>Cryptophlebia illepida</i> (Butler) Lepidoptera: Tortricidae
			I - <i>Danaus plexippus</i> (L.) Lepidoptera: Danaidae
			I - <i>Decadarchis simulans</i> (Butler) Lepidoptera: Tineidae
			I - <i>Epiphyas postvittana</i> (Walker) Lepidoptera: Tortricidae
			N - <i>Hedylepta monogona</i> (Meyrick)
			I - <i>Herpetogramma licarsisalis</i> (Walker)
			N - <i>Oeobia despecta</i> (Butler)
			N - <i>Oeobia litorea</i> (Butler)
			N - <i>Oeobia nigrescens</i> (Butler)
			N - <i>Oeobia stellata</i> (Butler) Lepidoptera: Pyralidae
			I - <i>Pelopidas thrax</i> (L.) Lepidoptera: HesperIIDae

			I - <i>Pectinophora gossypiella</i> (Saunders) Lepidoptera: Gelechiidae
			I - <i>Polydesma umbricola</i> Boisduval
			I - <i>Simplicia lautokiensis</i> Prout Lepidoptera: Noctuidae
		N - <i>Spheterista reynoldsiana</i> (Swezey) Lepidoptera: Tortricidae	
			I - <i>Trathala flavo-orbitalis</i> <sup>a</sup> (Cameron) Hymenoptera: Ichneumonidae
		N - <i>Vanessa tameamea</i> Eschscholtz Lepidoptera: Nymphalidae	
5. <i>Bracon omiodivorum</i> Terry Hymenoptera: Braconidae	1895	N - <i>Hedylepta accepta</i> (Butler) N - <i>Hedylepta blackburni</i> (Butler) Lepidoptera: Pyralidae	I - <i>Amorbia emigratella</i> Busck I - <i>Epiphyas postvittana</i> (Walker) P - <i>Epismus utilis</i> Zimmerman Lepidoptera: Tortricidae
			N - <i>Hedylepta localis</i> (Butler) I - <i>Spoladea recurvalis</i> (F.) Lepidoptera: Pyralidae
6. <i>Cotesia marginiventris</i> (Cresson) Hymenoptera: Braconidae	1942	<i>Pseudaletia unipuncta</i> (Haworth) <i>Spodoptera exempta</i> (Walker) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae	I - <i>Ethmia nigroapicella</i> (Saalmuller) Lepidoptera: Oecophoridae
			N - <i>Scotorythra caryopis</i> Meyrick N - <i>Scotorythra paludicola</i> (Butler) N - <i>Scotorythra trapezias</i> Meyrick Lepidoptera: Geometridae
			I - <i>Spoladeu recurvalis</i> (F.) Lepidoptera: Pyralidae

**TABLE 6.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Immigrant, Native, or Other Purposely Introduced Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
7. <i>Eupelmus cushmani</i> (Crawford) Hymenoptera: Eupelmidae	1934	<i>Anthonomus eugeni</i> Cano Coleoptera: Curculionidae	I - <i>Agonoxena argaula</i> Meyrick Lepidoptera: Agonoxenidae  P - <i>Apion antiquum</i> Gyllenhal Coleoptera: Curculionidae  I - <i>Araecerus fasciculatus</i> (DeGeer) I - <i>Araecerus levipennis</i> Jordan Coleoptera: Anthribidae  P - <i>Microlarinus lareynii</i> Duval P - <i>Microlarinus typriformis</i> (Wollaston) Coleoptera: Curculionidae  I - <i>Mimosestes sallaei</i> (Sharp) Coleoptera: Bruchidae  P - <i>Procecidochares utilis</i> Stone Diptera: Tephritidae  I - <i>Tenodera angustipennis</i> Saussure <sup>b</sup> Orthoptera: Mantidae
8. <i>Lespesia archippivora</i> (Riley) Diptera: Tachinidae	1895	<i>Pseudaletia unipuncta</i> (Haworth) <i>Spodoptera exigua</i> (Hubner) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae	N - <i>Agrotis crinigera</i> (Butler) N - <i>Agrotis dislocata</i> (Walker) I - <i>Agrotis ipsilon</i> (Hufnagel) N - <i>Anomis hawaiiensis</i> (Butler) N - <i>Anomis noctivolans</i> (Butler) Lepidoptera: Noctuidae  I - <i>Artogeia rapae</i> (L.) Lepidoptera: Pieridae

- I - *Danaus plexippus* (L.)  
Lepidoptera: Danaidae
  - N - *Hedylepta accepta* (Butler)
  - N - *Hedylepta blackburni* (Butler)  
Lepidoptera: Pyralidae
  - N - *Heliothis hawaiiensis* (Quaintance & Brues)
  - I - *Heliothis zea* (Boddie)  
Lepidoptera: Noctuidae
  - I - *Lampides boeticus* (L.)  
Lepidoptera: Lycaenidae
  - N - *Mapsidius iridescens* Walsingham  
Lepidoptera: Scythridae
  - N - *Peridroma coniotis coniotis* (Hampson)  
Lepidoptera: Noctuidae
  - N - *Scotorythra corticea* (Butler)
  - N - *Scotorythra paludicola* (Butler)  
Lepidoptera: Geometridae
  - I - *Spoladea recurvalis* (F.)
  - I - *Uresephita polygonalis* (Denis & Schiffermueller)  
Lepidoptera: Pyralidae
  - I - *Vanessa cardui* (L.)  
Lepidoptera: Nymphalidae
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**TABLE 6.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Immigrant, Native, or Other Purposely Introduced Species in Hawaii. (Continued)

<u>Parasite</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Host(s)</u>
9. <i>Meteorus laphygmae</i> Viereck Hymenoptera: Braconidae	1942	<i>Agrotis ipsilon</i> (Hufnagel) <i>Peridroma saucia</i> (Hubner) <i>Spodoptera exigua</i> (Hubner) <i>Spodoptera exempta</i> (Walker) <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae	I - <i>Agraulis vanillae</i> L. Lepidoptera: Heliconiidae  I - <i>Amyna natalis</i> (Walker) Lepidoptera: Noctuidae  P - <i>Blepharomastix ebulealis</i> Guenee Lepidoptera: Pyralidae  I - <i>Elaphria nucicolora</i> (Guenee) Lepidoptera: Noctuidae  N - <i>Hedylepta accepta</i> (Butler) Lepidoptera: Pyralidae  I - <i>Heliothis zea</i> (Boddie) Lepidoptera: Noctuidae  I - <i>Herpetogramma licarsisalis</i> (Walker) Lepidoptera: Pyralidae  I - <i>Melipotis indomita</i> (Walker) Lepidoptera: Noctuidae  N - <i>Oeobia stellata</i> (Butler) Lepidoptera: Pyralidae  N - <i>Scotorythra paludicola</i> (Butler) N - <i>Scotorythra trapezias</i> Meyrick Lepidoptera: Geometridae

			P - <i>Selca brunella</i> Hampson Lepidoptera: Nolidae
10. <i>Pachycrepoideus vindemiae</i> (Rondani) Hymenoptera: Pteromalidae	1914	<i>Ceratitis capitata</i> (Wiedemann) <i>Dacus cucurbitae</i> Coquillett Diptera: Tephritidae	I - <i>Dacus dorsalis</i> Hendel Diptera: Tephritidae I - <i>Drosophila melanogaster</i> Meigen I - <i>Drosophila</i> spp. I - <i>Gitonides perspicax</i> (Knab) <sup>f</sup> Diptera: Drosophilidae P - <i>Lixophaga sphenophori</i> (Villeneuve) Diptera: Tachinidae
11. <i>Paranagrus perforator</i> Perkins Hymenoptera: Mymaridae	1904	<i>Perkinsiella saccharicida</i> Kirkaldy Homoptera: Delphacidae	N - <i>Aloha ipomoeae</i> Kirkaldy Homoptera: Delphacidae
12. <i>Perisierola emigrata</i> (Rohwer) Hymenoptera: Bethyilidae	1953	<i>Maruca testulalis</i> (Geyer) Lepidoptera: Pyralidae	I - <i>Anatrachyntis rileyi</i> (Walsingham) Lepidoptera: Gelechiidae I - <i>Cryptoblabes gnidiella</i> (Milliere) Lepidoptera: Pyralidae ? - <i>Cryptophlebia illepida</i> (Butler) Lepidoptera: Tortricidae I - <i>Ectomyelois ceratoniae</i> (Zeller) Lepidoptera: Pyralidae P - <i>Epinotia lantana</i> Busck Lepidoptera: Tortricidae I - <i>Pectinophora gossypiella</i> (Saunders) Lepidoptera: Gelechiidae

**TABLE 6.** Purposely Introduced Species of Parasitic Insects Which Attack Target Pest Species and Immigrant, Native, or Other Purposely Introduced Species in Hawaii. (Continued)

Parasite	Year First Released	Target Pest(s)	Other Recorded Host(s)
13. <i>Pholetesor bedelliae</i> (Viereck) Hymenoptera: Braconidae	1945	<i>Bedelia orchilella</i> Walsingham Lepidoptera: Lyonetiidae	I - <i>Bucculatrix thurberiella</i> Busck Lepidoptera: Lyonetiidae N - <i>Philodoria hauicola</i> Swezey Lepidoptera: Gracillariidae
14. <i>Polynema ciliata</i> (Say) Hymenoptera: Mymaridae	1941	<i>Megamelus angulatus</i> Osborn Homoptera: Delphacidae	N - <i>Nesosydne halia</i> (Kirkaldy) Homoptera: Delphacidae
15. <i>Trichogramma japonicum</i> Ashmead Hymenoptera: Trichogrammatidae	1928	<i>Chilo suppressalis</i> (Walker) Lepidoptera: Pyralidae	P - <i>Sepedon</i> sp. Diptera: Sciomyzidae
16. <i>Trichopoda pilipes</i> (F.) <sup>d</sup> Diptera: Tachinidae	1962	<i>Nezara viridula</i> (L.) Hemiptera: Pentatomidae	N - <i>Coleotichus blackburniae</i> White Hemiptera: Scutelleridae
17. <i>Trissolcus basalis</i> (Wollaston) Hymenoptera: Scelionidae	1962	<i>Nezara viridula</i> (L.) Hemiptera: Pentatomidae	N - <i>Coleotichus blackburniae</i> White Hemiptera: Scutelleridae I - <i>Plautia stali</i> Scott Hemiptera: Pentatomidae

<sup>a</sup>Parasite of many Lepidoptera.

<sup>b</sup>Eggs only.

<sup>c</sup>Predator of Pseudococcidae.

<sup>d</sup>Eggs of *T. pilipes* were found on other species of insects, such as *Hyalopeplus pellucidus* Kirkaldy (Miridae), *Jadera haematoloma* (Herrich-Schaeffer) (Rhopalidae), *Tenodera australasiae* (Leach) (Mantidae), *Thyanta accerra* McAtee and *Plautia stali* Scott (Pentatomidae) on few occasions. No progeny developed from these eggs, however.

I - Immigrant species.

N - Native species.

P - Purposely introduced species.

? - Uncertain whether native or immigrant species.



TABLE 7. Purposely Introduced Species of Phytophagous Insects (&amp; a Fungus) Which Attack Only Target Weeds in Hawaii.

<u>Species</u>	<u>Year First Released</u>	<u>Target Weed(s)</u>
1. <i>Acinia picturata</i> (Snow) Diptera: Tephritidae	1959	<i>Pluchea odorata</i> (L.) Cass. Compositae
2. <i>Apion antiquum</i> (Gyllenhal) Coleoptera: Curculionidae	1957	<i>Emex australis</i> Steinheil <i>Emex spinosa</i> (L.) Campdera Polygonaceae
3. <i>Apion ulicis</i> (Forester) Coleoptera: Curculionidae	1927	<i>Ulex europaeus</i> L. Papilionatae
4. <i>Archlagocheirus funestus</i> (Thomson) Coleoptera: Cerambycidae	1951	<i>Opuntia megacantha</i> (L.) Cactaceae
5. <i>Blepharomastix ebulealis</i> Guenee Lepidoptera: Pyralidae	1969	<i>Clidemia hirta</i> (L.) D. Don Melastomataceae
6. <i>Bochorus fatualis</i> (Lederer) Lepidoptera: Pyralidae	1958	<i>Melastoma malabathricum</i> L. Melastomataceae
7. <i>Bruchus atronotatus</i> Pic Coleoptera: Bruchidae	1932	<i>Schinus terebinthifolius</i> Raddi Anacardiaceae
8. <i>Cactoblastes cactorum</i> (Berg) Lepidoptera: Pyralidae	1950	<i>Opuntia megacantha</i> (L.) Cactaceae
9. <i>Catabena</i> (= <i>Neogalea</i> ) <i>esula</i> Druce Lepidoptera: Noctuidae	1955	<i>Lantana camara</i> L. Verbenaceae
10. <i>Cercospora</i> sp. (leaf spot fungus) Moniliales: Moniliaceae	1974	<i>Ageratina riparia</i> (Regel) K. & R. Compositae

**TABLE 7.** Purposely Introduced Species of Phytophagous Insects (& a Fungus) Which Attack Only Target Weeds in Hawaii. (Continued)

Species	Year First Released	Target Weed(s)
11. <i>Chrysolina quadrigemina</i> Suffrain Coleoptera: Chrysomelidae	1965	<i>Hypericum perforatum</i> L. Guttiferae
12. <i>Cremastobombycia lantanella</i> Busck Lepidoptera: Gracillariidae	1902	<i>Lantana camara</i> L. Verbenaceae
13. <i>Dactylopius opuntiae</i> (Cockerell) Homoptera: Dactylopiidae	1949	<i>Opuntia megacantha</i> (L.) Cactaceae
14. <i>Episimus utilis</i> Zimmerman Lepidoptera: Olethreutidae	1954	<i>Sciuhinus terebinthifolius</i> Raddi Anacardiaceae
15. <i>Eutreta xanthochaeta</i> Aldrich Diptera: Tephritidae	1902	<i>Lantana camara</i> L. Verbenaceae
16. <i>Hypena strigata</i> F. Lepidoptera: Noctuidae	1957	<i>Lantana camara</i> L. Verbenaceae
17. <i>Lantanophaga pusillidactyla</i> (Walker) Lepidoptera: Pterophoridae	1902	<i>Lantana camara</i> L. Verbenaceae
18. <i>Liothrips urichi</i> Karny Thysanoptera: Thripidae	1953	<i>Clidemia hirta</i> (L.) D. Don Melastomataceae
19. <i>Octoloma scabripennis</i> Guerin Coleoptera: Chrysomelidae	1902	<i>Lantana camara</i> L. Verbenaceae
20. <i>Oidaematophorus beneficus</i> Yano & Heppner Lepidoptera: Pterophoridae	1973	<i>Ageratina riparia</i> (Regel) K. & R. Compositae

21. <i>Ophiomyia lantanae</i> (Froggatt) Diptera: Agromyzidae	1902	<i>Lantana camara</i> L. Verbenaceae
22. <i>Plagiohammus spinipennis</i> Thomson Coleoptera: Cerambycidae	1954	<i>Lantana camara</i> L. Verbenaceae
23. <i>Priophorus morio</i> Lepeletier Hymenoptera: Tenthredinidae	1966	<i>Rubus argutus</i> Link Rosaceae
24. <i>Procecidochares alani</i> Steyskal Diptera: Tephritidae	1973	<i>Ageratina riparia</i> (Regel) K. & R. Compositae
25. <i>Procecidochares utilis</i> Stone Diptera: Tephritidae	1944	<i>Eupatorium adenophorum</i> Spreng. Compositae
26. <i>Schreckensteinia festaliella</i> Hubner Lepidoptera: Schreckensteiniidae	1963	<i>Rubus argutus</i> Link Rosaceae
27. <i>Selca brunella</i> Hampson Lepidoptera: Nolidae	1964	<i>Melastoma malabathricum</i> L. Melastomataceae
28. <i>Syngamia haemorrhoidalis</i> Guenee Lepidoptera: Pyralidae	1956	<i>Lantana camara</i> L. Verbenaceae
29. <i>Tetraeuresta obscuriventris</i> Loew Diptera: Tephritidae	1961	<i>Elephantopus mollis</i> H.B.K. Compositae
30. <i>Trichotaphe aenigmatica</i> Clarke Lepidoptera: Gelechiidae	1955	<i>Pluchea odorata</i> (L.) Cass. Compositae
31. <i>Uroplata girardi</i> Pic Coleoptera: Chrysomelidae	1920	<i>Lantana camara</i> L. Verbenaceae
32. <i>Zeuxidiplosis giardi</i> (Keiffer) Diptera: Cecidomyiidae	1966	<i>Hypericum perforatum</i> L. Guttiferae

TABLE 8. Purposely Introduced Species of Phytophagous Insects Which Attack Target Weeds and/or Other Plants in Hawaii.

<u>Species</u>	<u>Year First Released</u>	<u>Target Weed(s)</u>	<u>Other Recorded Plant(s)<sup>a</sup></u>
1. <i>Athesapeuta cyperi</i> Marshall Coleoptera: Curculionidae	1922	<i>Cyperus rotundus</i> L. Cyperaceae	W - <i>Cyperus esculentus</i> L. W - <i>Cyperus polystachyos</i> Rottb. W - <i>Cyperus tenuifolius</i> Michx. Cyperaceae
2. <i>Bactra venosana</i> (Zeller) Lepidoptera: Tortricidae	1922	<i>Cyperus rotundus</i> L. Cyperaceae	W - <i>Cyperus brevifolius</i> (Rottb.) Hassk. W - <i>Cyperus esculentus</i> L. W - <i>Cyperus monocephalus</i> (Rottb.) W - <i>Cyperus tenuifolius</i> Michx. Cyperaceae
3. <i>Chrysolina hyperici</i> (Forster) <sup>b</sup> Coleoptera: Chrysomelidae	1965		W - <i>Hypericum degeneri</i> Fosb. Guttiferae
4. <i>Croesia zimmermani</i> Clarke Lepidoptera: Tortricidae	1963	<i>Rubus argutus</i> Link Rosaceae	N - <i>Rubus hawaiiensis</i> Gray Rosaceae
5. <i>Epinotia lantana</i> Busck Lepidoptera: Tortricidae	1902	<i>Lantana camara</i> L. Verbenaceae	B - <i>Litchi chinensis</i> Sonn. Sapindaceae  B - <i>Stenolobium stans</i> (L.) Seem. Bignoniaceae  B - <i>Tabebuia chrysantha</i> (Jacq.) Nichols Bignoniaceae
6. <i>Leptobyrssa decora</i> Drake Hemiptera: Tingidae	1969	<i>Lantana camara</i> L. Verbenaceae	B - <i>Duranta repens</i> L. Verbenaceae

7. <i>Microlarinus lareynii</i> (Jacquelin du Val) Coleoptera: Curculionidae	1962	N - <i>Tribulus cistoides</i> L. <i>Tribulus terrestris</i> L. Zygophyllaceae	W - <i>Amaranthus spinosus</i> L. Amaranthaceae W - <i>Chenopodium album</i> L. Chenopodiaceae W - <i>Malva parviflora</i> L. Malvaceae
8. <i>Microlarinus typriformis</i> (Wollaston) Coleoptera: Curculionidae	1963	N - <i>Tribulus cistoides</i> L. <i>Tribulus terrestris</i> L. Zygophyllaceae	W - <i>Amaranthus spinosus</i> L. Amaranthaceae W - <i>Chenopodium album</i> L. Chenopodiaceae W - <i>Malva parviflora</i> L. Malvaceae
9. <i>Strepsicrates smithiana</i> Walshingham Lepidoptera: Olethreutidae	1955	<i>Myrica faya</i> Aiton Myricaceae	W - <i>Myrica cerifera</i> L. Myricaceae
10. <i>Strymon bazachii gundlachianus</i> (Bates) Lepidoptera: Lycaenidae	1902	<i>Lantana camara</i> L. Verbenaceae	W - <i>Hyptis pectinata</i> L. B - <i>Ocimum basilicum</i> L. Labiatae
11. <i>Strymon</i> (= <i>Thmolus</i> ) <i>echion</i> L. Lepidoptera: Lycaenidae	1902	<i>Lantana camara</i> L. Verbenaceae	B - <i>Capsicum annuum</i> L. Solanaceae B - <i>Cordia sebestena</i> L. Boraginaceae B - <i>Datura candida</i> (Pers.) W - <i>Solanum nigrum</i> L. B - <i>Solanum tuberosum</i> L. Solanaceae

**TABLE 8.** Purposely Introduced Species of Phytophagous Insects Which Attack Target Weeds and/or Other Plants in Hawaii.  
(Continued)

<u>Species</u>	<u>Year First Released</u>	<u>Target Weed(s)</u>	<u>Other Recorded Plant(s)<sup>a</sup></u>
12. <i>Teleonemia scrupulosa</i> Stal Heteroptera: Tingidae	1902	<i>Lantana camara</i> L. Verbenaceae	N - <i>Myoporum sandwicense</i> (DC) Gray Myoporaceae  W - <i>Xanthium</i> sp. Compositae

<sup>a</sup>Status of some plants as true hosts undetermined. Ability of most insects to complete development on these recorded plants not verified.

<sup>b</sup>Purposely introduced to control *Hypericum perforatum* L. but recorded only from *H. degeneri*.

B - Beneficial species.

N - Native species.

W - Weed species.

TABLE 9. Purposely Introduced Species of Scarabaeid Dung Beetles in Hawaii.

Species	Year First Released
1. <i>Canthon humectus</i> (Say)	1923
2. <i>Copris incertus prociduus</i> Say	1922
3. <i>Euoniticellus africanus</i> Harold	1974
4. <i>Oniticellus</i> (= <i>Liatongus</i> ) <i>militaris</i> Laporte	1957
5. <i>Onitis alexis</i> Klug	1973
6. <i>Onitis vanderkelleni</i> Landsberge	1976
7. <i>Onthophagus binodis</i> Thunberg	1973
8. <i>Onthophagus gazella</i> (F.)	1957
9. <i>Onthophagus incensus</i> Say	1923
10. <i>Onthophagus nigriventris</i> D'Orbigny	1975

Since both larvae and adult beetles feed only on what they were purposely introduced to destroy, they are considered to be specific.

A total of 29 species of scarabaeid beetles was purposely introduced and released in Hawaii. Of these, 10 became established (Table 9). These beetles, together with some immigrant species of dung beetles, have contributed to reducing populations of the horn fly and other species of dung-breeding Diptera in open pasturelands. In a 1966 experiment in open pasture on the island of Hawaii, 96% fewer flies emerged from cattle droppings with beetles present than from beetle-excluded cattle droppings. (Bornemissza 1976.)

### Snails, Birds, Fishes and Amphibians

Among the established species of biological control introductions, this group of mollusks and vertebrates has probably generated the most controversy in recent years (Table 10).

Seventeen species of predatory snails were liberated in Hawaii for pestiferous snail control, including 14 species for *Achatina fulica* Bowdich; two for *Bradybaena similis* (Ferussac) and one for *Subulina octona* Bruguiere. Only three species were successfully established; two species of *Gonaxis* which are soil inhabiting predators of *A. fulica* eggs, and a free living snail, *Euglandina rosea* (Ferussac), released to prey on *A. fulica* but which has been implicated as one of several causes of the decline and extinction of native tree snails, especially in the genus *Achatinella* (Hart 1978). Other possible causes for the decimation and extinction of *Achatinella* have been discussed or mentioned in several publications (Cooke 1941; Hart 1975, 1978, 1979; Howarth 1985; Kondo 1972; Mead 1961, 1963a,b; Welch 1938).

**TABLE 10.** Purposely Introduced Species of Predatory Snails, Birds, Fishes and Amphibians Which Prey on Target Pest Species and/or Other Species of Organisms in Hawaii.

<u>Species</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
<b>SNAILS</b>			
1. <i>Euglandina rosea</i> (Ferussac) Stylommatophora: Oleacinidae	1955	<i>Achatina fulica</i> Bowdich Stylommatophora: Achatinidae	N - <i>Achatinella mustelina</i> Mighels Stylommatophora: Achatinellidae
2. <i>Gonaxis kibweziensis</i> (Smith) Stylommatophora: Streptaxidae	1952	<i>Achatina fulica</i> Bowdich Stylommatophora: Achatinidae	
3. <i>Gonaxis quadrilateralis</i> Preston Stylommatophora: Streptaxidae	1957	<i>Achatina fulica</i> Bowdich Stylommatophora: Achatinidae	
<b>BIRDS</b>			
1. <i>Bubulcus ibis</i> L. Ciconiiformes: Ardeidae	1959	<i>Haematobia irritans</i> L. <i>Musca domestica</i> L. Diptera: Muscidae  Other livestock pests	B - <i>Leiopisa metallicum</i> (O'Shaughnessy) Squamata: Scincidae  B - <i>Macrobrachium rosenbergi</i> Deman Decapoda: Palamonidae  * - <i>Mus musculus</i> L. Rodentia: Muridae  * - <i>Periplaneta americana</i> L. Orthoptera: Blattidae  * - <i>Procambarus clarkii</i> (Girard) Decapoda: Cambaridae  * - <i>Rattus</i> sp. Rodentia: Muridae



2. <i>Tyto alba</i> (Scopoli) Strigiformes: Tytonidae	1958	<i>Rattus</i> spp. <i>Mus musculus</i> L. Rodentia: Muridae	N - <i>Anous stolidus pileatus</i> (Scopoli) Charadriiformes: Laridae N - <i>Bulweria bulwerii</i> (Jardin & Selby) N - <i>Puffinus pacificus</i> Salvin N - <i>Puffinus puffinus newelli</i> Henshaw Procellariiformes: Procellariidae  N - <i>Sterna fuscata oahuensis</i> Bloxam N - <i>Sterna lunata</i> Peale Charadriiformes: Laridae
<b>FISHES</b>			
1. <i>Gambusia affinis</i> (Baird & Girard) Cyprinodontiformes: Poeciliidae	1905	<i>Aedes</i> spp. <i>Culex quinquefasciatus</i> Say Diptera: Culicidae	N - <i>Megalagrion pacificum</i> (McLachlan) Odonata: Coenagriidae
2. <i>Mollienesia</i> (= <i>Poecilia</i> ) <i>latipinna</i> LeSueur Cyprinodontiformes: Poeciliidae	1905	<i>Aedes</i> spp. <i>Culex quinquefasciatus</i> Say Diptera: Culicidae	
<b>AMPHIBIANS</b>			
1. <i>Bufo marinus</i> (L.) Anura: Bufonidae	1932	<i>Anomala orientalis</i> (Waterhouse) Coleoptera: Scarabaeidae	* - <i>Adoretus sinicus</i> Burmeister Coleoptera: Scarabaeidae  * - <i>Agrius cingulatus</i> (F.) Lepidoptera: Sphingidae  B - <i>Apis mellifera</i> L. Hymenoptera: Apidae  * - <i>Coptotermes formosanus</i> Shiraki Isoptera: Rhinotermitidae  * - <i>Geotomus pygmaeus</i> (Dallas) Hemiptera: Cydnidae  * - <i>Herpetogramma licarsisalis</i> (Walker) Lepidoptera: Pyralidae

**TABLE 10.** Purposely Introduced Species of Predatory Snails, Birds, Fishes and Amphibians Which Prey on Target Pest Species and/or Other Species of Organisms in Hawaii. (Continued)

<u>Species</u>	<u>Year First Released</u>	<u>Target Pest(s)</u>	<u>Other Recorded Prey</u>
			<ul style="list-style-type: none"> <li>* - <i>Melipotis indomita</i> (Walker) Lepidoptera: Noctuidae</li> <li>* - <i>Pantomorus cervinus</i> (Boheman) Coleoptera: Curculionidae</li> <li>* - <i>Pheidole megacephala</i> (F.) Hymenoptera: Formicidae</li> <li>* - <i>Pycnoscelus surinamensis</i> (L.) Orthoptera: Blaberidae</li> <li>* - <i>Scolopendra subspinipes</i> Leach Scolopendromorpha: Scolopendridae</li> <li>* - <i>Sphenophorus venatus vestitus</i> Chittenden Coleoptera: Curculionidae</li> <li>* - <i>Spodoptera mauritia</i> (Boisduval) Lepidoptera: Noctuidae</li> <li>* - Tenebrionid beetles</li> <li>? - Wasp, black</li> </ul>
2. <i>Dendrobates auratus</i> Girard Anura: Dendrobatidae	1932	Noxious insects	
3. <i>Rana rugosa</i> Schlegel Anura: Ranidae	ca. 1895	Noxious insects	

\* - Pest species.

B - Beneficial species.

N - Native species.

Of the three species of birds purposely introduced and liberated for biological control, the barn owl, *Tyto alba* (Scopoli), and the cattle egret, *Bubulcus ibis* L., became established on all major islands. Although rats and mice are the primary food of the barn owl, it also has been reported to prey on six species of native birds. (Berger 1981; Byrd and Telfer 1980.) The statewide population of the cattle egret has been gradually increasing since the original release of 177 birds during 1959 - 1961 on Kauai, Oahu, Maui, Molokai and Hawaii. The cattle egret has commonly been observed to feed on flies associated with cattle in pastures, rangelands and feeding pens; on crayfish in watercress farms; on mice in alfalfa fields; on prawns in aquaculture farms; on various insects in recently mown parks and golf courses and in garbage dumps; and on small rats and mice as well as insects in recently harvested cane and pineapple fields (Berger 1981; Byrd et al. 1980; R. A. Heu, pers. comm.; Walker 1983). In 1981, the statewide population of the cattle egret was estimated to be 30,000. Because of the large number of egrets roosting and congregating near the airports, concerns have been expressed that they pose a hazard to aviation. Several near collisions have been reported (Anon. 1982).

Three species of freshwater fishes were purposely introduced and subsequently released for mosquito control. Two of these mosquito larvivorous species, *Gambusia affinis* (Baird & Girard), and *Mollienesia latipinna* Le Sueur, became well established in streams, ponds, and estuaries in Hawaii (Brock 1960, Kanayama 1967). Together with some aquaria species, such as the guppy, *Poecilia reticulata* (Peters), which were apparently dumped in streams and ponds by home aquarists who tired of their hobby, they play a vital role in contributing to the State's mosquito control program (Kanayama 1967; G. M. Toyama, pers. comm.). *G. affinis*, however, has been accused of disrupting native aquatic ecosystems and destroying native species of insects such as the damselfly, *Megalagrion pacificum* (McLachlan) (Howarth 1985).

The number of species of toads introduced to control insect pests of agricultural crops is unclear but at least three species were involved, one of which is established today (McKeon 1978; S. W. Tinker, pers. comm.). The giant neotropical toad, *Bufo marinus* L., is common in lowlands of Hawaii, Kauai, Maui, Molokai and Oahu and is often seen, especially on warm, rainy nights, preying on various species of insects and other arthropods. Pemberton (1934) gave a detailed account of what it is capable of eating when fed in cages. Some of the objections against this species include: (1) during the termite swarming months (April-July) or when toads are active on rainy nights, large numbers are found on roads and constitute a hazard to automobile drivers; (2) small dogs have died following attacks on this toad due to the toxic secretion from its paratoid glands; and (3) the noise at night of a large group of males during breeding season can be a nuisance in residential areas. (Oliver 1949; Oliver and Shaw 1953.)

Apparently four species of frogs were purposely introduced into Hawaii to control insects, two of which are established today (McKeown

1978; S. W. Tinker, pers. comm.). The wrinkled frog, *Rana rugosa* Schlegel, is found in mountain streams on Hawaii, Kauai, Maui and Oahu. The green and black poison-arrow frog, *Dendrobates auratus* Girard, is found only in wet valleys of the Koolau range on Oahu. For protection against predators, this species secretes a poisonous substance from its skin glands. However, the toxin is harmless to people unless ingested or rubbed in the eyes or open wounds. (McKeown 1978; Oliver and Shaw 1953.)

### SPECIFICITY OF PURPOSELY INTRODUCED SPECIES

Table 11 summarizes the total number of specific and non-specific species of the established biological control organisms listed in Tables 2 to 10.

Of the 243 established species of purposely introduced biological control organisms in Hawaii, 157 (64.6%) are host-specific in that they have not been reported to affect any organisms other than those for which they were released to control.

The non-specific species are separated into two categories: (1) those which have been recorded to attack only pest species and (2) those which attack pest, native and/or beneficial species.

Fifty-three species (21.8%) of biological control organisms fall into the first category and, in spite of the fact that they are not specific, they are considered to be useful biological control agents.

**TABLE 11.** Compilation of Tables 2 to 10. Number of Specific and Non-Specific Species of Established Biological Control Introductions: 1890 - 1985.

Type of Organisms	Total No. Established Species	Total No. Specific Species	Non-Specific	
			Total No. of Species attacking Pest Species only	Total No. of Species attacking Pest, Native and/or Beneficial Species
Predatory Insects & Mites	62	32	25	5
Parasitic Insects	115	76	22	17
Insect Pathogens	2	2	—	—
Phytophagous Insects	43	31	6	6
Plant Pathogen	1	1	—	—
Dung Beetles	10	10	—	—
Predatory Snails	3	2	0	1
Birds	2	0	0	2
Fishes	2	1	0	1
Toads	1	0	0	1
Frogs	2	2	—	—
	243	157	53	33

The remaining 33 species (13.6%) of established biological control introductions fall into the second category. These 33 species have been recorded to prey on or attack a total of 69 pest species, 40 native species and 27 beneficial species in addition to their intended target species.\* Of the 33 species, 20 (8.2% of the 243 established species) have been reported to utilize native organisms as hosts or prey. These 20 species include (a) four species of predatory insects which prey on a total of three species of native insects, (b) 11 species of parasitic insects which use a total of 27 native species of insects as hosts, (c) two species of phytophagous insects which feed and breed on two separate species of native plants, (d) one species of predatory land mollusk which has been implicated as one of the causes for the demise of a species of native land mollusk, (e) the barn owl which has been found to prey on six species of native birds, and (f) a species of fish which has been accused of causing the extinction of a native species of damselfly.

Seventeen of the 33 species (7.0% of the 243 established biological control introductions) have been recorded to attack 27 species of beneficial organisms, including plants. These 17 species are (a) two species of predatory insects which prey on two separate species of purposely introduced biological control insects, (b) nine species of parasitic insects which utilize a total of 13 species of purposely introduced insects (11 of which are phytophagous species introduced for weed control) as hosts, (c) four species of weed control insects which were found feeding on a total of nine species of beneficial plants, (d) the cattle egret which has been recorded to prey on the Malaysian prawn and a species of skink, and (e) the giant neotropical toad which has been reported to feed on the honey bee. Many of the published accounts of the non-target hosts and prey of these 33 species were based on a single or a few observations.

## CONCLUSION

During the 96-year span from 1890 to 1985, 210 (86.4%) of the 243 established species of purposely introduced biological control organisms have contributed in controlling about 200 pestiferous species of plants and animals without having caused any recorded adverse effects on desirable species. This record is remarkable considering that quarantine studies and procedures for the release of biological control organisms during the earlier introduction programs were not as intensive and restrictive as they are today. Of the 243 established species, 157 (64.6%) have restricted their attack to only those target species for which they were intended to control, while another 53 (21.8%) attack both target and non-target pest species. Although specificity of the purposely introduced

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\*Except *Hyperaspis fimbriolata* Melsheimer which was purposely introduced to control pestiferous "mealybugs" but which has been recorded to prey only on a native mealybug species.

biological control organisms is only one of several measurements of a successful biological control program, the trend towards increased specificity reflects the intent of a Board of Agriculture policy adopted in 1944 which formed a review system to determine which biological control organisms would be released in Hawaii. Of the established species released prior to 1944, 54.7% are considered to be specific, while 77.4% of those approved for release since 1944 are known to attack only their intended target pest species. Specificity of the released organisms has also improved over the years; 88% (37 of 42 species) and 96% (29 of 30 species) of the established organisms released during the past 20, and 15 years, respectively, have been recorded to attack only the target pest species.

Thirty-three (13.6%) of the 243 established species of purposely introduced organisms have been reported to attack pest, native and/or beneficial species. Of these, 20 (8.2%) have been reported from native species, while 17 (7.0%) have been reported from beneficial organisms. Some biological control introductions have been implicated as causing the extinction of some of our native biota, especially native moths. However, only six species of purposely introduced parasitic insects have been recorded to attack native species of Lepidoptera. Most of these records were based on a single or a few observations, suggesting that such occurrences may be uncommon. Of these six purposely introduced species, only one is associated with a native moth thought to be extinct. Contrary to the notion that biological control introductions have caused the extinction of many of our native moths, immigrant species and other biotic and abiotic factors may play a more important role in their demise. It would be interesting to tabulate the recorded lepidopterous hosts and prey of the many immigrant species of parasites and predators for comparison with those of the purposely introduced ones. However, such a compilation has yet to be made.

Some biological control organisms have been reported to attack other species of organisms, including plants, which are considered to be beneficial. Most of these records again were based on relatively few observations and may not necessarily constitute common occurrences.

It is recognized that some risks are inherent in biological control programs, as in any other pest control strategies. Because of this risk, scientifically based procedures, developed over many years, are used as guidelines to reduce risks of biological control introductions in Hawaii. The present system of review and recommendation to the Board of Agriculture by the scientific Advisory Subcommittee on Entomology and the Advisory Committee on Plants and Animals, before release of biological control agents from the quarantine facility for mass propagation and distribution, was developed to reduce the probability that released organisms will be a threat to our environment. In addition, the present philosophy of entomologists engaged in biological control programs in Hawaii is to seek natural enemies which are highly host specific whenever possible, and to recommend for release only those species which are judged not to be a threat to non-target organisms by virtue of their proven

host specificity, their ecological specificity, or the lack of suitable hosts among the native biota. The fact that no purposely introduced species, approved for release in the past 21 years, has been recorded attacking any native or other desirable species in Hawaii attests to the soundness of the present review system and philosophy.

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### REFERENCES CITED

- Anonymous. 1982. More on Big Island cattle egrets. 'Elepaio 43:19-20.
- Baldwin, P.H., C.W. Schwartz, and E.R. Schwartz. 1952. Life history and economic status of the mongoose in Hawaii. Jour. of Mammal. 33:335-356.
- Beardsley, J.W. 1952. A fungus parasite of *Coccus viridis* (Green) in Hawaii. Master's thesis. Univ. of Hawaii, Honolulu. 59 pp.
- . 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.
- Berger, A.J. 1981. Hawaiian Birdlife. Univ. Press of Hawaii. 2nd ed. 260 pp.
- Bornemissza, G.E. 1976. The Australian dung beetle project — 1965-1975. Austral. Meat Res. Comm. Rev. 20:1-30.
- Brock, V.E. 1960. The introduction of aquatic animals into Hawaiian waters. Intern. Rev. der Gesamten Hydrobiol. 45:463-480.
- Byrd, G.V. and T.C. Telfer. 1980. Barn owls prey on birds in Hawaii. 'Elepaio 41:35-36.
- Byrd, G.V., F. Zeillemaker and T.C. Telfer. 1980. Population increases of cattle egret on Kauai. 'Elepaio 41:25-28.
- Caum, E.L. 1933. The exotic birds of Hawaii. B. P. Bishop Mus. Occ. Pap. 10:1-55.
- Clausen, C.P., D.W. Clancy and Q.C. Chock. 1965. Biological control of the Oriental fruit fly (*Dacus dorsalis* Hendel) and other fruit flies in Hawaii. USDA, ARS Tech. Bull. No. 1322. 102 pp.
- Cooke Jr., C.M. 1941. Hawaiian land shells. Paradise of the Pacif. 53:20-25
- DeBach, P. 1964. Successes, trends, and future possibilities, pp. 673-713. In P. DeBach (ed.), Biological Control of Insect Pests and Weeds. Reinhold Publ. Corp., New York.
- Doty, R.E. 1945. Rat control on Hawaiian sugarcane plantations. Hawaiian Planters' Record 49:72-241.
- Fullaway, D.T. 1952. Biological control of insect pests in the Hawaiian islands since 1925. Biennial Rpt. Bd. of Commissioners of Agr. and For., Terr. of Hawaii. pp. 98-105.
- Gagne, W.C. and F.G. Howarth. 1982. Conservation status of endemic Hawaiian Lepidoptera. Proc. 3rd Congr. Eur. Lepid., Cambridge. pp. 74-84.
- Hart, A.D. 1975. Living jewels imperiled. Defenders of Wildlife Mag. pp. 482-486, Washington, D.C.
- . 1978. The onslaught against Hawaii's tree snails. Nat. Hist. 87:46-57.
- . 1979. A survival status report on the endemic tree snail genus *Achatinella* (Swainson) from Oahu. A Report for the Office of Endangered Species, U.S. Fish & Wildlife Service, Dept. of Interior. 25 pp.
- Howarth, F.G. 1985. Impact of alien land arthropods and mollusks on native plants and animals in Hawaii, pp. 149-179. In C.P. Stone and J.M. Scott (eds.), Hawaii's Terrestrial Ecosystems: Preservation and Management, Proc. of a Symp. June 5-6, 1984, Hawaii's Volcanoes Nat. Park. Coop. Nat. Park Res. Studies Unit, Univ. of Hawaii, Honolulu.

- Illingworth, J.F. 1929. Preliminary notes on pests of agricultural crops of Kona. Proc. Hawaii. Entomol. Soc. 7:248-254.
- Kanayama, R.K. 1967. Hawaii's aquatic animal introductions. Proc. 47th Ann. Conf. West Assoc. State Game and Fish Comm., Honolulu, Hawaii, July 1967. pp. 123-133.
- Kondo, Y. 1972. Land mollusca, guide to excursion 111. 10th Pac. Sc. Congr. (Rev. Ed.) Univ. of Hawaii with support from Hawaii. Bot. Gard. Found. pp. 70-73. Honolulu.
- Kotinsky, J. 1906. Report of the assistant entomologist. Haw. Bd. Commissioners Agr. & For. Ann. Rpt. 1905. pp. 113-144.
- Kramer, R.J. 1971. Hawaiian Land Mammals. Charles E. Tuttle Co., 347 pp.
- McKeown, S. 1978. Hawaiian Reptiles and Amphibians. Oriental Publ. Co., Honolulu. 80 pp.
- Mead, A.R. 1961. The Giant African Snail, a Problem in Economic Malacology. Univ. of Chicago Pr. 257 pp.
- 1963 a. Disease, decline, and predation in giant African snail populations in Hawaii. Am. Malacol. Union Ann. Rept., 1963. p. 22.
- 1963 b. A flatworm predator of the giant African snail, *Achatina fulica* in Hawaii. Malacologia 1:305-311.
- Oliver, J.E. 1949. The peripatetic toad. Nat. Hist. 58:29-33.
- Oliver, J.E. and C.E. Shaw. 1953. The amphibians and reptiles of the Hawaiian islands. Zoologica 38:65-95.
- Pemberton, C.E. 1934. Local investigations on the introduced tropical American toad *Buffo marinus*. Hawaiian Planters' Record 38:186-192.
- 1964. Highlights of the history of entomology in Hawaii 1778-1963. Pacif. Insects 6:689-729.
- Steffan, W.A. 1968. Hawaiian *Toxorhynchites* (Diptera: Culicidae). Proc. Hawaii. Entomol. Soc. 20:141-155.
- Swezey, O.H. 1931. Records of introductions of beneficial insects into the Hawaiian islands, pp. 368-378. In F.X. Williams (comp.), Handbook of Insects and Other Invertebrates of Hawaiian Sugar Cane Fields. Exp. Sta. Hawaii. Sugar Planters' Assn.
- 1936. Biological control of the sugarcane leafhopper in Hawaii. Bull. Exp. Sta. Hawaii. Sugar Planters' Assn. 21:57-101.
- 1939. Recent records of the introduction of beneficial insects into the Hawaiian islands. Proc. Hawaii. Entomol. Soc. 10:349-352.
- Tanada, Y. 1956. An annotated list of infectious diseases of insects in Hawaii. Part II. Proc. Hawaii. Entomol. Soc. 16:149-155.
- 1957. An annotated list of infectious diseases of insects in Hawaii. Proc. 8th Pacif. Sci. Congr., Manila. pp. 1235-1250.
- Tomich, P.Q. 1986. Mammals in Hawaii. Bishop Museum Press, Honolulu. 2nd ed. 375 pp.
- Walker, R.L. 1983. Cattle egret rookery on Molokai. 'Elepaio 43:91-91.
- Welch, D.A. 1938. Distribution and variations of *Achatinella mustelina* Mighels in the Waianae Mountains, Oahu. Bull. B. P. Bishop Mus. 152:1-164.
- Zimmerman, E.C. 1948. Insects of Hawaii. Vol. 5. Homoptera: Sternorhyncha. Univ. of Hawaii Press, Honolulu. 464 pp.
- 1978. Insects of Hawaii. Vol. 9. Microlepidoptera, Part I. Univ. Press of Hawaii, Honolulu. 882 pp.