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Biological Control Activities in the Mariana Islands from 1911 to 1988.

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Abstract—Biological control started in the Marianas in 1911. Biocontrol agents have been introduced to control herbivorous insects, weeds, dung, molluscs, livestock pests, mosquitoes and household pests. In all, 104 species of insects, two predatory mites, three snails, one nematode and four vertebrates have been intentionally introduced to Guam for the purposes of controlling 41 pest species. Of the insect species, 34 established, 48 did not establish, 5 established temporarily and the status of the rest is not known. Additional introductions were made to other islands in the Marianas. Among the pests most successfully controlled by biological agents were *Achatina fulica, Aleurocanthus spiniferus, Aleurothrixus floccosus, Aspidiotus destructor, Brontispa mariana, B. palauensis, Epilachna vigintisexpunctata philippinensis, Nipaecoccus viridis, Erionota thrax, Penicillaria jocosatrix,* and *Spodoptera litura.* Two weeds, *Lantana camara* and *Chromolaena odorata* have been successfully controlled by herbivorous insects. Most attempts at biological control in the Marianas have been transfers of species successfully introduced elsewhere. Most species introduced from temperate climatic zones failed to establish. Species which established on Hawaii, frequently established on Guam as well. Reasons for failure to establish are varied. Against Homopteran pests, 58% of the introduced natural enemies established. The establishment rate against Lepidoptera and Diptera was low.

Introduction

The introduction of new pests is a serious and recurring problem on islands including Guam (Schreiner and Nafus, 1986; Beardsley, 1979). Because of these pests, the need for biological control programs has been apparent to island entomologists, and biological control has had a long history as an important and valued control technique. In the Marianas the introduction of exotic insects for biological control purposes began with the establishment of the Agricultural Experiment Station in 1911 and has continued to the present time.

In 1911, D. T. Fullaway imported and released the ladybeetle *Cryptolaemus montrouzieri* Mulsant for the control of mealybugs and parasites (*Spalangia* sp.) of various filth flies. Fullaway left in 1912, and no further biocontrol work was done until 1925 when a new entomologist, S. R. Vandenberg, arrived. During his tenure on Guam, Vandenberg imported parasites of the Asian corn borer *Ostrinia furnacalis* Guenée, filth flies, and *Rhabdoscelus obscurus* Boisduval. He also brought in coccinellid predators of various scales and mealybugs including *Aspidiotus destructor* Signoret and *Icerya purchasi* Maskell. Vandenberg worked from 1925 until 1932, after which the agricultural experiment station was closed.

In the 1930s, the Japanese, in particular the Japanese South Seas Development Corporation (Nanyokaihatsu kabushiki kaisha), introduced some organisms for biological control. Their introductions were made in the islands of Rota, Tinian, and Saipan, which were under Japanese control. The most notable introductions were *Trichogramma chilonis* Ishii, an egg parasite attacking several species of Lepidoptera, *Rodolia pumila* Weise, and the drongo *Dicroros macrocerus* S. Baker. The drongo was released on Rota and eventually migrated to Guam, where it is now considered to be somewhat of a pest.

Biological control activities were largely suspended on Guam from the closing of the Agricultural Experiment Station in 1933 until after WWII. In 1947, the Department of the Navy asked the National Academy of Sciences to form an advisory board to survey the insects of the islands and to initiate biological control of the major pests. Work began in 1947 on several insects and continued until 1954 when the committee discontinued the project. Under this program, G. Peterson made a series of releases of parasites or predators of *Aleurocanthus spiniferus* (Quaintance), *Epilachna philippinensis* Dieke, *O. furnacalis* and *Achatina fulica* Bowdich. A program to control two fruit flies, *Dacus cucurbitae* and *D. orientalis,* was initiated in 1950, continued into the 1960s. Except for the introduction of fruitfly parasites, biocontrol efforts were largely suspended after Peterson left in 1957. About 1967 biological control activities were renewed and, by 1975, a large number of exotic natural enemies had been imported and released. Many of these natural enemies were introduced to control pests which had arrived on Guam in the 1950s or later. Most of the work was done by the Guam Department of Agriculture, principally by R. Muniappan, although R. N. Spencer also introduced species. After 1976, the focus of the biocontrol activity shifted from the Department of Agriculture to the Agricultural Experiment Station, which was established in 1976 at the University of Guam.

For purposes of discussion, we have divided the biological control activities into major groups including crop and plant pests, weed control, medical, household, and veterinary pests. Most of the discussion will be centered on biological control efforts after 1955, since many of the older projects have already been reviewed. Some review of these older cases is included for completeness, in particular where there is pertinent data which is not easily accessible in the literature. Reference to obscure literature, agency reports, and personal communications was necessary to ensure comprehensive coverage. Much of the information comes from unpublished reports of various agencies or offices, including the Hawaii Department of Agriculture, the Guam Agricultural Experiment Station, the Trust Territory entomologist, and the Saipan Department of Natural Resources.

Crop and plant pests

A listing of all the known, deliberate introductions of biological control agents and their establishment status is presented in Table 1. A number of other beneficial species have become accidentally established in recent years or have switched from native species to exotic pests. A partial list of the more important species is given in Table 2.

SCALES AND MEALYBUGS

Mealybugs and *Pulvinaria psidii*

Scales and mealybugs were among the first targets of biological control in the Marianas. In 1911, Fullaway (1912) released the predaceous lady beetle *C. montrouzieri* to

Table 1. Summary of the beneficial natural enemies introduced to control various organisms in the Mariana Islands. The years 1911 to 1988 are covered for the islands Guam (G), Rota (R), Aguijan (A), Tinian (T), Anatahan (An), Pagan (P) and Saipan (S). In relation to the level of control we are adopting the following definitions: (H) high—populations of the target organism are low and it is no longer considered to be a problem; (G) good—populations of the target organism are usually low but outbreaks occur regularly; (P) partial—populations of the target pest are lower but it is still a significant pest; (U) unsuccessful—the biocontrol agent established but had little or no effect on the target organism; (E) established—the biocontrol agent established but we have no information on its impact on the target; (T) temporary—the biocontrol agent established initially but later disappeared; (N) not established; (A) species present before being imported; (?) status totally unknown.

Pest	Target crop	Biocontrol species Parasite/Predator	Island	Control level	Number Released	Number Shipments	Year	Origin	Reference
Homoptera									
Aphis		*Platyomus lividigaster* Mulsant	G	?	55	1	1953	Hawaii	Pemberton, 1954
		Coleoptera: Coccinellidae							HDOA[1]
		Orcus chalybeus (Boisd.)	G	?	13	1	1953	Hawaii	Pemberton, 1954
		Coleoptera: Coccinellidae			154	1	1953		HDOA
Aleurocanthus spiniferus	Citrus	*Amitus hesperidum* Silv.	G	H	28100	2	1952	Mexico	Peterson, 1955a
(Quaintance)		Hymenoptera: Aphelinidae							HDOA
		Encarsia smithi (Silv.)	G	H	17000	2	1952	Mexico	Peterson, 1955a
		Hymenoptera: Aphelinidae							HDOA
		Eretmocerus serius Silv.	G	T	13500	2	1952	Mexico	Peterson, 1955a
		Hymenoptera: Aphelinidae							HDOA
		Prospaltella opulenta Silv.	G	N	88	2	1952	Mexico	Peterson, 1955a
		Hymenoptera: Aphelinidae							HDOA
		Prospaltella clypealis Silv.	G	N	30	2	1952	Mexico	Peterson, 1955a
		Hymenoptera: Aphelinidae							HDOA
Aleurodicus dispersus	Guava,	*Encarsia haitiensis* Dozier	G	G	155	2	1981	Hawaii	Nechols, 1981,
Russell	Plumeria,	Hymenoptera: Aphelinidae							HDOA
	etc.	*Nephaspis oculatus* (Blatchley)	G	G	4425	3	1981	Hawaii	Nechols, 1981,
		Coleoptera: Coccinellidae							HDOA
Aspidiotus destructor	Coconut	*Azya trinitatis* Marshall	S	?	?	?	1960	Trinidad	Chapin, 1965
Signoret		Coleoptera: Coccinellidae							
		Cryptognatha nodiceps Marshall	S	?	?	2	1960	Trinidad	Chapin, 1965
		Coleoptera: Coccinellidae	G	?	?	?	?	Fiji	Rao et al., 1971
		Pseudoscymnus anomalus	R	?	390	1	1964	Palau	Trust Territory[2]
		Chapin	S	A	?	1	1962	Truk	Trust Territory
		Coleoptera: Coccinellidae							

Table 1. (*continued*)

Pest	Target crop	Biocontrol species Parasite/Predator	Island	Control level	Number Released	Number Shipments	Year	Origin	Reference
		Rhizobius satelles Blackburn	G	N	4–5	1	1925	California	Vandenberg, 1926
		Coleoptera: Coccinellidae	G	N	6	1	1925	California	Vandenberg, 1926
(also against citrus			G	E		1	1971	N Caledonia	Muniappan, 1975
scales)			S	?	?	?	1968	Belau	Trust Territory
		2 coccinellid beetles	G	?[3]	?	?	1924	Philippines	Anon., 1925
		Comperiella bifasciata Howard	G	N	23–25	1	1926	California	Vandenberg, 1928
		Hymenoptera: Encyrtidae						(Orient)[4]	
Coptosoma xanthogramma (White)	Beans	*Trissolcus* sp. Hymenoptera: Scelionidae	G	?	150	1	1968	Hawaii	Muniappan, unpubl. HDOA
Furcaspis oceanica	Coconut	*Adelencyrtus oceanicus* (Doutt)	S	H	142	2	1948	Palau, Yap	Bryan, 1949
(Ldgr)		Hymenoptera: Encyrtidae	G	In progress			1988	Ulithi	Marutani & Muniappan, 1988
Heteropsylla cubana	Leucaena	*Curinus coeruleus* Mulsant	G	E	308	1	1986	Hawaii	
Crawford		Coleoptera: Coccinellidae	S	E	600	1	1986	Hawaii	HDOA
Icerya purchasi Maskell	Citrus	*Rodolia cardinalis* (Mulsant)	G	TH[5]	8	1	1926	Hawaii	Anon., 1926
		Coleoptera: Coccinellidae						(California)	
Icerya aegyptiaca (Dougl.)	Breadfruit, etc.	*Rodolia breviuscula* Weise Coleoptera: Coccinellidae	G	N	?	3	1948	India	Pemberton, 1954
		Rodolia pumila Weise	S	H	?	?	1928	Taiwan	Beardsley, 1955
		Coleoptera: Coccinellidae	An	?	?	?	1959	Belau	SDNR[6], 1959
Nipaecoccus viridis	Leucaena	*Anagyrus dactylopi* Howard	S	?	9	1	1980	Hawaii	SDNR, 1980
(Newstead)		Hymenoptera: Encyrtidae	G	?	?	?	1980	Hawaii	
		Delphastus pusillus (LeConte) Coleoptera: Coccinellidae	S	?	9	1	1980	Hawaii	SDNR, 1980
Nezara viridula L.	Several hosts	*Trissolcus basalis* Woll. Hymenoptera: Scelionidae	G	?	?	?	?	Fiji	Rao et al., 1971
Parasaissetia coffeae (Walker) & *P. nigra* (Niet.)	Several hosts	*Coccophagus lycimnia* Walker Hymenoptera: Aphelinidae	G	N	?	?	1954	California	Peterson, 1957a
		Coccophagus rusti Compere Hymenoptera: Aphelinidae	G	N	?	?	1954	California	Peterson, 1957a
		Metaphycus helvolus (Compere) Hymenoptera: Encyrtidae	G	E	?	?	1954	California	Peterson, 1957a

		Metaphycus lounsburyi (Howard) Hymenoptera: Encyrtidae	G	E	?	?	1954	California	Peterson, 1957a
		Metaphycus luteolus (Timberlake) Hymenoptera: Encyrtidae	G	?	?	?	1954	California	Peterson, 1957a
		Metaphycus stanleyi Compere Hymenoptera: Encyrtidae	G	?	?	?	1954	California	Peterson, 1957a
		Scutellista cyanea Motsch. Hymenoptera: Pteromalidae	G	E	?	?	1954	California	Peterson, 1957a
Target not specified, known to feed on *P. oleae* (Bernard), *Pulvinaria psidii* Maskell & mealybugs	Several hosts	*Azya orbigera* Mulsant Coleoptera: Coccinellidae	G	E	?	?	1936?	(Hawaii?)	Chapin, 1965
		Cryptolaemus montrouzieri	G	E?	40–50	1	1911	Hawaii	Fullaway, 1912
		Mulsant	G	E	?	1	1926	Hawaii	Vandenberg, 1928
		Coleoptera: Coccinellidae	S	H	?	?	?	?	Esaki, 1940
Tarophagus proserpina (Kirkaldy)	Taro	*Cyrtorhinus fulvus* Knight Hemiptera: Miridae	G	H	?	1	1947	Hawaii (Philippines)	Pemberton, 1954
Lepidoptera									
Argyroploce schistaceana (Snellen)	Sugarcane	*Trichogramma chilonis* Ishii	S	P	?	?	1935	Philippines	Esaki, 1952
		Hymenoptera:	R	E	?	?	?	?	
		Trichogrammatidae	T	E	?	?	?	?	
Ostrinia furnacalis (Guenée)	Corn	*Lydella thompsoni* Herting	G	TH	1465[7]	1	1930–1	Japan	Vandenberg, 1933
		Diptera: Tachinidae	G	N	609	2	1952–5	US	Peterson, 1955b
			S	N	?	1	1956	US	Gardner, 1958
		Agathis agilis (Cressman) Hymenoptera: Braconidae	G	N	6	?	1954	US	Peterson, 1955b
		Chelonus annulipes Wesmael	G	N	3093	2	1952–5	US	Peterson, 1955b
		Hymenoptera: Braconidae	S	N	?	?	?	?	Peterson, 1955b
		Macrocentris grandii Goidanich Hymenoptera: Braconidae	G	N	6719	2	1952–5	US	Peterson, 1955b
		Campoplex alkae (Ellinger & Sachtleben) Hymenoptera: Ichneumonidae	G	N	<65[8]		1930–31	Japan	Vandenberg, 1933
		Eriborus terebrans (Gravenhorst) Hymenoptera: Ichneumonidae	G	N	301	2	1952–54	US–N.J	Peterson, 1955b
		Exeristes roborator (F.) Hymenoptera: Ichneumonidae	G	N	1083[9]	1	1926–31	US	Vandenberg, 1930

Table 1. *(continued)*

Pest	Target crop	Biocontrol species Parasite/Predator	Island	Control level	Number Released	Number Shipments	Year	Origin	Reference
		Trathala flavoorbitalis (Cameron) Hymenoptera: Ichneumonidae	G	A	<141[10]	1	1930–31	Japan	Vandenberg, 1933
		Trichogramma chilonis Ishii	G	P	?[11]	?	1971	India	Muniappan, unpubl.
		Hymenoptera: Trichogrammatidae	G	P	?[11]	?	1972	Taiwan	Muniappan, unpubl.
		Trichomma cnaphalocrocis Uchida Hymenoptera: Ichneumonidae	G	N	26	1	1986	Taiwan	
Papilio polytes L.	Citrus	*Apanteles papilionis* Viereck Hymenoptera: Braconidae	G	N?	?	?	1971	India	Muniappan, unpubl.
		Pteromalus luzonensis Gahan Hymenoptera: Pteromalidae	G	P	?	3	1973–4	India	Muniappan, 1982a
Erionota thrax (L.)	Banana	*Apanteles erionotae* Wilkinson Hymenoptera: Braconidae	G	P	825	2	1974	Hawaii	Muniappan, 1982a; HDOA
			S	G	300	1	1974	Guam	SDNR, 1975
Penicillaria jocosatrix Guenée	Mango	*Aleiodes* sp. nr. *circumscriptus* (Nees) Hymenoptera: Braconidae	G	T	453	18	1986–7	India	
		Euplectrus sp. nr. *parvulus* Ferriere Hymenoptera: Eulophidae	G	H	858	19	1986–7	India	
		Blepharella lateralis Macquart Diptera: Tachindae	G	H	45	8	1986	India	
		Trichogramma platneri Nagarkatti Hymenoptera: Trichogrammatidae	G	?	80	1	1986	California	
Pericyma cruegeri (Butler)	Poinciana	*Brachymeria albotibilalis* (Ashmead) Hymenoptera: Chalcidae	G	U	?	?	1973	Papua New Guinea	Muniappan, unpubl.
		Echthromorpha insidiator Smith Hymenoptera: Ichneumonidae	G	N	?	?	1973	Papua New Guinea	Muniappan, unpubl.

Plutella xylostella (L.)	Cabbage	*Diadromus collaris* Gravenhorst Hymenoptera: Ichneumonidae	G	?	?	3	1975	India	Muniappan, unpubl.
		Diadegma insularis (Cresson) Hymenoptera: Ichneumonidae	G	?	124	1	1975	Hawaii	HDOA
		Apanteles plutellae Kurdjimov	G	T	?	3	1971–2	India	Muniappan, unpubl.
		Hymenoptera: Braconidae	G	N	dead	2	1972	Taiwan	Muniappan, unpubl.
		Tetrastichus sokolowskii Kurdjimov Hymenoptera: Eulophidae	G	?	50	?	1973	India	Muniappan, unpubl.
Spodoptera litura (F.) & *S. mauritia* (Boisd.)		*Telenomus remus* Nixon Hymenoptera: Scelionidae	G	G	?	?	1971	India	Muniappan, unpubl.
		Telenomus nawai Ashmead Hymenoptera: Scelionidae	G	G	?	?	1936	Hawaii	Swezey, 1946
		Lespesia archippivora (Riley) Diptera: Tachinidae	G	?	97	1	1958	Hawaii (California)	HDOA
		Calosoma blaptoides tehuacanum (Lapouge) Coleoptera: Carabidae	G	?	11	1	1958	Hawaii	HDOA
Coleoptera									
Adoretus sinicus Burmeister	Beans, Corn	*Campsomeris marginella modesta* (Smith) Hymenoptera: Scoliidae	G	P	?	?	1950–1	Hawaii (Philippines)	Pemberton, 1954
Anomala sulcatula Burmeister	Sugarcane	*Campsomeris annulata* F.	S	G	?	?	1940	Philippines	Esaki, 1952
		Hymenoptera: Scoliidae	G[12]	E	?	?	?	?	
Brontispa mariana Spaeth	Coconut	*Tetrastichus brontispae* (Ferr.)	S	G	5035	4	1948	Java	Lange, 1950
		Hymenoptera: Eulophidae	R	G	250	2	1948	Java	Lange, 1950
		Hispidophila brontispae (Ferr.)	S	N	282	3	1948	Malaya	Lange, 1950
		Hymenoptera: Trichogrammatidae	R	N	50	1	1948	Malaya	Lange, 1950
Brontispa palauensis (Esaki and Chujo)	Coconut	*Tetrastichus brontispae* Hymenoptera: Eulophidae	G	G[13]	?	1	1974	Saipan	Muniappan et al., 1980
			G	G[13]	40	1	1974	N Caledonia	Muniappan, unpubl.
			G	G[13]	?	1	1974	Vanuatu	Muniappan, unpubl.
			G	G[13]	?	1	1974	Solomon Isl.	Muniappan, unpubl.
Epilachna vigintisexpunctata philippinensis (Dieke)	Eggplant, Tomato	*Aplomyiopsis epilachnae* (Aldr.)	G	N	3100	1	1950	Mexico	Peterson, 1955c
		Diptera: Tachinidae	G	N	416	2	1952	Mexico	Peterson, 1955c
		Pediobius foveolatus Crawford	G	G	154[14]	1	1954	Philippines	Peterson, 1955c
		(Philippine strain)	S	E	?	?	1950s	Guam	Trust Territory
		Hymenoptera: Eulophidae	R	E	?	?	1950s	Guam	Trust Territory
		P. foveolatus (US strain)	G	E	?	1	1974	US (India)	Muniappan, unpubl.
			S	?	?	?	1985	US (?)	

Table 1. *(continued)*

Pest	Target crop	Biocontrol species Parasite/Predator	Island	Control level	Number Released	Number Shipments	Year	Origin	Reference
Cosmopolites sordidus (Germ.)	Banana	*Plaesius javanus* Erichson Coleoptera: Histeridae	G	E	450	?	1947	Fiji (Java)	Bryan, 1949
		Hololepta minuta Erichson Coleoptera: Histeridae	G	?	<1335[15]	3	1953–4	Trinidad	Peterson, 1957a HDOA
		Hololepta quadridentata (F.) Coleoptera: Histeridae	G	?	<1335[15]	3	1953–4	Trinidad	Peterson, 1957a HDOA
Rhabdoscelus obscurus (Boisduval)	Sugarcane, Palms	*Lixophaga sphenophori* (Vill.) Diptera: Tachinidae	G	T	?	3	1926	Hawaii	Vandenberg, 1929
			G	T	101	1	1927	Hawaii	Vandenberg, 1930
			S	N	350	?	1928	Guam	Vandenberg, 1930
Diptera									
Dacus cucurbitae Coquillett	Cucurbits	*Opius fletcheri* Silvestri Hymenoptera: Braconidae	G	T	150	2	1937	Hawaii	Anon., 1937a, b
			G	?	?	?	1950	Hawaii	Pemberton, 1954
			G	U	600	1	1953	Hawaii	HDOA
			G	U	42	1	1955	Hawaii	HDOA
			G	U	162	2	1959	Hawaii	HDOA
			G	U	12	1	1960	Hawaii	HDOA
			G	U	?	?	1967	Hawaii	Muniappan, unpubl.
		Opius humilis Silvestri Hymenoptera: Braconidae	G	?	?	?	1937	Hawaii	Anon., 1937d
		Biosteres longicaudatus watersi (Full.) Hymenoptera: Braconidae	G	N	?	?	1950–2	Hawaii	Clausen, 1978
Dacus dorsalis Hendel eradicated in 1960s	Mango, Guava, Citrus,	*Biosteres longicaudatus compensans* (Silvestri) Hymenoptera: Braconidae	GS	N	460[16]	1	1952	Hawaii	HDOA
	Avocado, Papaya	*Biosteres longicaudatus formosanus* (Fullaway) Hymenoptera: Braconidae	GS	N	535[16]	1	1952	Hawaii	HDOA
			G		260	1	1955	Hawaii	HDOA
		Biosteres longicaudatus (Ashm.) Hymenoptera: Braconidae	G	N	16100	8	1959	Hawaii	HDOA
			G		3000	2	1960	Hawaii	HDOA

		Biosteres longicaudatus novacalendonicus (Fullaway) Hymenoptera: Braconidae	G	N	300	1	1955	Hawaii	HDOA
		Biosteres longicaudatus malaiensis (Fullaway) Hymenoptera: Braconidae	GS	N	455[16]	1	1952	Hawaii	HDOA
		Biosteres oophilus (Fullaway)	G	N	300	1	1955	Hawaii	HDOA
		Hymenoptera: Braconidae	GS	N	7250[16]	8	1959	Hawaii	HDOA
			G	N	500	2	1960	Hawaii	HDOA
		Biosteres vandenboschi (Full.)	GS	N	?	?	1950	Hawaii	Clausen, 1978
		Hymenoptera: Braconidae	GS	N	?	?	1952,5	Hawaii	Clausen, 1978
		Opius incisi Silvestri	GS	N	?	?	1950	Hawaii	Clausen, 1978
		Hymenoptera: Braconidae	GS	N	?	?	1952,5	Hawaii	Clausen, 1978
		Dirhinus giffardii Silvestri	GS	N	7650[16]	8	1959	Hawaii	HDOA
		Hymenoptera: Chalcididae	G	N	2500	2	1960	Hawaii	HDOA
		Syntomosphyrum indicum Silvestri Hymenoptera: Eulophidae	G	T?	8000	1	1952	Hawaii	HDOA; Peterson, 1957a
			G	T?	5000	2	1955	Hawaii	HDOA; Peterson, 1957a
			G	T?	77000	6	1959	Hawaii	HDOA
			G	T?	1000	1	1960	Hawaii	HDOA
		Tetrastichus giffardianus	G	?	3000	2	1959	Hawaii	HDOA
		Silvestri Hymenoptera: Eulophidae	G	?	4000	1	1960	Hawaii	HDOA
Liriomyza trifolii Burgess	Beans, etc.	*Ganaspidium utilis* Beardsley Hymenoptera: Eucoilidae	G	E	2100	1	1985	Hawaii	
		Diglyphus begini (Ashmead) Hymenoptera: Eulophidae	G	N	<200	2	1983	California	
Ophiomyia phaseoli (Tryon)	Beans	*Opius importatus* Fischer	G	?	<470[17]	3	1971	Hawaii	HDOA
		Hymenoptera: Braconidae	G	?	<200[17]	1	1972	Hawaii	HDOA
		Opius phaseoli Fischer	G	?	<470[17]	3	1971	Hawaii	HDOA
		Hymenoptera: Braconidae	G	?	<200[17]	1	1972	Hawaii	HDOA
General predators									
Insects in general		*Polyspilota aeruginosa* (Goeze) Orthoptera: Mantidae	G	N	?	2	1972	W. Africa via England	Muniappan, unpubl.
Insects in general		*Spodromantis* sp. Orthoptera: Mantidae	G	N	?	?	1972	Cameroon via England	Muniappan, unpubl.

Table 1. (*continued*)

Pest	Target crop	Biocontrol species Parasite/Predator	Island	Control level	Number Released	Number Shipments	Year	Origin	Reference
Insects in general		*Sibylla pretiosa Stål* Orthoptera: Mantidae	G	N	?	?	1972	Malawi via England	Muniappan, unpubl.
Insects in general		*Dicrurus macrocercus haterti* S.Baker Passeriformes: Dicruridae	R	E	?	?	1935	Taiwan	Baker, 1951
Pests in general		*Bufo marinus* L.	G	H[18]	19	1	1937	Hawaii	Anon., 1937b
			G	H	41	1	1938	Hawaii	Anon., 1938
Acari									
Tetranychus cinnabarinus (Boisduval)		*Phytoseiulus persimilis* Athias-Henriot Acari: Phytoseiidae	G	?	?	?	1979?	?	Andres & McMurtry, 1979
		Typhlodromus occidentalis Nesbitt Acari: Phytoseiidae	G	?	?	?	1979?	?	Andres & McMurtry, 1979
Molluscs									
Achatina fulica Bowdich		*Euglandina rosea* Ferussac Mollusca: Oleacinidae	G	E	1037	3	1958	Hawaii (Florida)	HDOA; Muniappan, 1982b
			S	E	500	1	1958	Hawaii	HDOA
			A	?	?	1	1963	Saipan	Trust Territory
		Gonaxis quadrilateralis (Preston) Mollusca: Streptaxidae	G	N	450	2	1967	Hawaii (E. Africa)	HDOA; Muniappan, 1982b
			S	E	?	?	?	?	Trust Territory
		Gonaxis sp.	P	?	?	?	1963	Saipan	Trust Territory
		Gonaxis kibweziensis E.A.Smith Mollusca: Streptaxidae	A	G	300	1	1950	Mombasa, E. Africa	Pemberton, 1954; Eldredge, 1988
			G	E	?	1	1957	Aguijan	Peterson, 1957a

	Lamprigera tenebrosa (Walker) Coleoptera: Lampyridae	G	?	933	6	1955	Ceylon	Peterson, 1957b
Target unknown[19]	*Sepedon macropus* Walker Diptera: Sciomyzidae	G	?	537	2	1959	Hawaii (Nicaragua)	HDOA
	Sciomyza dorsata Zetterstadt Diptera: Sciomyzidae	G	?	500	1	1961	Hawaii (Denmark)	HDOA

[1] Shipment records of the Hawaii Department of Agriculture. The exact number released is not known, only the number shipped.

[2] Reports of the Trust Territory Entomologist, Micronesia

[3] Rao et al., 1971 list these as established but give no names or sources. Indicates that very few survived shipment and no indication of establishment is given.

[4] Places of origin in parentheses refer to the original source of the natural enemy.

[5] Reports of the Saipan Department of Natural resources

[6] *R. cardinalis* has been replaced by *R. pumila,* an accidental introduction to Guam. *R. cardinalis* has not been collected on Guam since 1945.

[7] Of this total 982 were field released and the rest were retained for rearing. An additional 4,819 were released from reared material.

[8] The majority of the 65 were retained in an unsuccessful rearing effort. Only a very few were released.

[9] Of these 1113 were released, 477 males and 636 females. An additional 20 females and 10 males were held for breeding. In 1928, an additional 537 females and 313 males were bred and released.

[10] Part of this shipment was held for an unsuccessful attempt at rearing.

[11] Imported as *T. australicum.* A shipment identified only as egg parasite of *O. furnacalis* was shipped from Taiwan. This is likely *T. chilonis* but could be another species as well. *T. ostriniae* Peng & Chang also occurs in Taiwan and is common in corn fields.

[12] The occurrence of this parasite on Guam may be fortuitous or may have been introduced by the Japanese. No records of its introduction were found.

[13] Which of the strains established and what their contribution to the control is, is not known.

[14] The shipment was split and 100 were field released. From the 54 parasites held in the laboratory, an additional 3,275 were bred and released.

[15] *H. minuta* and *H. quadridentata* were introduced as *Leionota* sp. Shipments were of both species in unknown proportions.

[16] The shipments were sent to Guam and then split. A proportion was released on Guam and the rest on Saipan. No records are available to indicate how much was actually released on each island.

[17] *O. importatus* and *O. phaseoli* were mixed in the shipment. The exact proportions released are unknown although *O. importatus* was probably more abundant.

[18] The marine toad was credited with vastly reducing populations of the garden slug *Veronicella leydigi* Simroth (Anon., 1938) and providing some reduction of the banana corm weevil (Anon., 1937c).

[19] *S. macropus* and *S. dorsata* were introduced but there is no record of for what or why. They were introduced to Hawaii as predators of the liverfluke snail *Lymnae ollula* Gould.

Table 2. Biological control of exotic species in the Mariana Islands by fortuitously introduced (F) or native (N) species. Only Guam (G) and Saipan (S) are covered. Degree of control is defined as: (H) high—populations of the exotic pest are low and it is not a problem; (G) good—populations of the exotic pest are usually low but outbreaks occur regularly; (P) partial—populations of the target pest are lower but it is still a significant pest

Pest	Target	Biocontrol species	Island	Status	Control	References
Aphids	Various crops	*Menochiles sexmaculatus* (F.) Coleoptera: Coccinellidae	G	F	G	
		Coelophora inaequalis (F.) Coleoptera: Coccinellidae	G	N	G	
		Harmonia arcuata (F.) Coleoptera: Coccinellidae	G	N	G	
		Ischiodon scutellaris (F.) Diptera: Syrphidae	G	N	G	
Aleurothrixus floccosus (Maskell)	Citrus Guava	*Eretmocerus* sp.? Hymenoptera: Aphelinidae	G	F	H	
Aspidiotus destructor Signoret	Coconut other	*Telsimia nitida* Chapin Coleoptera: Coccinellidae	G	N	H	Vandenberg, 1928
		Chilocorus nigritus (F.) Coleoptera: Coccinellidae	G	F	H	
		Pseudoscymnus anomalus Chapin Coleoptera: Coccinellidae	G S	F F	H ?	

Icerya purchasi Maskell	Citrus	*Rodolia pumila* Weise Coleoptera: Coccinellidae	G	F	H	
Icerya aegyptiaca (Dougl.)	Breadfruit, etc.	*Rodolia pumila*	G	N	?	
Nipaecoccus viridis (Newstead)	Leucaena	*Anagyrus indicus* Shaffee et al. Hymenoptera: Encyrtidae	G	F	H	Nechols & Seibert, 1985
Erionota thrax (L.)	Banana	*Ooencyrtus erionotae* Ferriere Hymenoptera: Encyrtidae	G	F	G	Muniappan, 1982a
Liriomyza trifolii Burgess	Beans	*Gronotoma micromorpha* (Perkins) Hymenoptera: Eucoilidae	G	F	P	Schreiner et al., 1986
		Disorygma pacifica (Yoshimoto) Hymenoptera: Eucoilidae	G	F	P	Schreiner et al., 1986
		Hemiptarsenus semialbiclavus Girault Hymenoptera: Eulophidae	G	N	G	Schreiner et al., 1986
		Chrysonotomyia formosa (Crawford) Hymenoptera: Eulophidae	G	N	G	Schreiner et al., 1986
Achatina fulica Bowdich	Vegetables, Fruits	*Platydemus manokwari* Beauchamp Tricladida: Rhynchodemidae	G S	F F?	H ?	Muniappan, 1982b
Lantana camara L.	Lantana	*Lantanophaga pusillidactyla* Walker Lepidoptera: Pterophoridae	G	F	P	Muniappan, 1988
		Suidasia pontifica Oudemans Acari	G	F?	P	Muniappan, 1988

control mealybugs. Adults of the first generation were emerging in the field when Fullaway left in 1912 and no further follow-up on this release was made. Vandenberg reimported *C. montrouzieri* in 1925 for the control of mealybugs and the soft scale *Pulvinaria psidii* Maskell. The beetle is established, although no estimate of its effectiveness in controlling any of the mealybugs or *P. psidii* has ever been made. It has been noted to feed on several species of mealybug including *Nipaecoccus viridis* (Newstead) (Nechols and Seibert, 1985).

Aspidiotus destructor

Another scale which was the target of early biological control efforts was the coconut or transparent scale *Aspidiotus destructor* Signoret. In 1918, an outbreak of *A. destructor* took place which severely damaged many trees. The outbreak caused considerable concern, since the scale had killed between 70 and 80% of the coconuts on Yap and Saipan. This outbreak, which continued to be severe through 1924, lead to the importation of *Rhyzobius satelles* Blackburn (= *Lindorus lophanthae* (Blaisdell)) and *Comperiella bifasciata* Howard from California (Vandenberg, 1926, 1928), and two unidentified species of coccinellid beetles from the Philippines (Rao et al. 1971). Although Rao et al. (1971) list the coccinellids as established, we doubt this since a status report of the Guam Agricultural Experiment Station states that few specimens survived shipment (Anon., 1925). No further mention of them or what species they were is reported nor is any indication given that they established. The attempts to establish *R. satelles* failed. Two shipments were sent but few beetles survived. The four or five survivors in the first shipment were consumed by ants during the rearing effort. The six survivors in the second shipment were successfully reared, and 22 progeny were released. These beetles did not do well in the release area as they were not able to compete with a native coccinellid which quickly eliminated *A. destructor* infestations in the release area (Vandenberg, 1928). A combination of the native predator and two parasites, a species of *Aspidiotiphagus* and *Aphytis chrysomphali* (Mercet), reduced the scale outbreak to unimportant levels by early 1926. The native coccinellid was called *Cryptogonus orbiculus* (Gyllenhal) by Vandenberg, but was actually *Telsimia nitida* Chapin (Esaki, 1952). *C. orbiculus* also occurs on Guam, however it is uncommon, and its hosts are unknown (Chapin, 1965). Later, attempts were made to ship *T. nitida* (as *C. orbiculus*) to Fiji, but the beetle did not survive shipment.

Cryptognatha nodiceps Marshall was sent to Guam from Fiji prior to 1959 (Rao et al., 1971). No information is available about the shipment or the release. It has not been collected on Guam to date. In 1971, *Rhyzobius satelles* Blackburn (as *R. pulchellus* Montrouzier) was introduced to Guam from New Caledonia to aid in the control of coconut scales and citrus scales. A single specimen of *R. satelles* was recovered in 1978, indicating establishment. The beetle, however, is very uncommon; an intensive survey of coconut insects in 1984 yielded no specimens. *A. destructor* is not an economic problem on Guam at this time and appears to be controlled by a combination of *T. nitida, Pseudoscymnus anomalus* Chapin, and *Chilocorus nigritus* (F.). Both *P. anomalus* and *C. nigritus* apparently were fortuitous introductions. *P. anomalus* was first found on Guam in 1958. *C. nigritus* appeared in the 1960s and was abundant enough that it was shipped to Hawaii in 1972 for control of coconut scale. *P. anomalus* was also shipped at that time

(Davis, 1972). *T. nitida* was shipped to Pohnpei from Saipan in 1939 (Esaki, 1952) and to Hawaii in 1936 to control the scale *Pinnaspis buxi* (Bouché) (Swezey, 1940).

In Saipan the scale was probably controlled by *T. nitida*, which is distributed throughout the Marianas (Esaki, 1940). Esaki indicated that there were no important problems with *A. destructor* after the initial outbreak around 1910. However, in 1960, *Azya trinitatis* Marshall and *Cryptognatha nodiceps* Marshall, both predators of *A. destructor* from Trinidad, were released. There is no record of whether they established or not. *P. anomalus* was also released in 1962 on Saipan and in 1964 on Rota. Although *P. anomalus* was recorded as established in 1963 on Saipan, the beetle had previously been collected from Saipan in 1960 (Chapin, 1965), an occurrence which emphasizes the need to do preliminary surveys before spending time and money making unnecessary releases. The beetle, however, had not been previously collected on Rota and its status on Rota at this time is unknown. In 1968, *R. satelles* was collected on Palau and released on Saipan. No follow-up on the status of this beetle has been made. Currently *P. anomalus, T. nitida* and *C. nigritus*, which was first found on Saipan in 1970, are all present and effecting control of *A. destructor.*

Parasaissetia coffeae* and *P. nigra

Two other scales which have been the targets of an intensive biological control program on Guam are *Parasaissetia coffeae* (Walker) and *P. nigra* (Nietner). Prior to 1936, a coccinellid, *Azya orbigera* Mulsant, was released against either these scales or *P. oleae* (Bernard), on which it is also known to feed (Clausen, 1978). *A. orbigera* established (Chapin, 1965), but its value as a control agent has never been assessed. In 1954, a series of parasites was released against *P. coffeae* and *P. nigra* (Table 1), of which at least three, *Metaphycus helvolus* (Compere), *M. lounsburyi* (Howard), and *Scutellista cyanea* Motsch. established (Peterson, 1957a). The status of two other parasites (Table 1) has not been determined. Although no formal study of their impact has ever been made, our observations suggest a fairly high degree of success for *P. nigra,* as this scale is uncommon and difficult to find. *P. coffeae* is more common, particularly on guava, but rarely attains levels which are damaging, suggesting at least partial success. Unfortunately no information is available on the pre-release populations of the scale or their economic impact. Formal assessment of the degree of success needs to be made.

Furcaspis oceanica

The coconut red scale *Furcaspis oceanica* (Lindinger), an endemic species in the Carolines and Marshalls, was discovered in Saipan in 1943 (Esaki, 1952) and proceeded to become a serious pest (Pemberton, 1954). Sometime after 1954 it appeared on Guam, and is now a serious pest in the central part of the island (Muniappan, 1987; Marutani and Muniappan, 1988). In the localities where it is abundant, the undersides of the coconut leaves and young coconut fruits are entirely covered with scales and the leaves have a distinct yellow cast. Some leaves on some heavily infested coconuts are dying from the impact of this scale.

Biological control efforts against this scale began in 1947. R. L. Doutt found a new species of wasp, *Adelencyrtus oceanicus* (Doutt), on Ulithi and released it on Saipan in 1948 (Pemberton, 1954). No evidence that the wasp established were noted by Bryan (1949) or Pemberton and both recommended further work. None of the records of the Department of Natural Resources or Trust Territory Records indicate further work was done, but recently Marutani and Muniappan (1988) surveyed the scales on Saipan and found that *A. oceanicus* had established and had reduced the coconut red scale to extremely low levels. *A. oceanicus* was released in 1988 to control the scale on Guam.

Icerya purchasi and *I. aegyptiaca*

The cottony cushion scale *Icerya purchasi* (Maskell) and the Egyptian fluted scale *I. aegyptiaca* (Douglas) were early targets of biological control in the Marianas. On Guam *Rodolia cardinalis* (Mulsant) was obtained from Hawaii and released in 1926. A vigorous breeding program was established, and the beetle was released at all sites where *I. purchasi* could be found (Vandenberg, 1929). The beetle was highly effective, and the scale and beetle nearly vanished, leading Vandenberg to suggest that reintroduction might be necessary every few years. However, an outbreak of *I. purchasi* in 1929 was quickly brought under control by the beetle, lessening his fears (Vandenberg, 1931). *R. cardinalis* was present as late as 1945, but it has not been found since then. Neither *I. purchasi* nor *I. aegyptiaca* is currently a problem, but the predominant predator on them throughout the Marianas is *R. pumila* Weise not *R. cardinalis*. *R. pumila* was brought to Saipan before WWII mis-identified as a form of *R. cardinalis* (Esaki, 1952, Beardsley, 1955) and was probably spread to the rest of the Marianas either accidentally or by the Japanese. There are no records of its being intentionally moved within the Marianas. *R. breviuscula* Weise was also introduced but only 12 individuals were released (Chapin, 1965) and establishment is doubtful.

Nipaecoccus viridis

Recently the mealybug *N. viridis* (= *N. vastator* (Maskell)) was found in the Marianas. In the mid-1970s it was present in outbreak levels and was severely damaging *Leucaena leucocephala* (Lam.) de Hit, an important source of firewood and the basis of a charcoal industry on Saipan. On Saipan the parasite *Anagyrus dactylopii* (Howard) and *Delphastus pusillus* were introduced for biological control. The status of these natural enemies are not known at this time. On Guam, *Anagyrus indicus* Shaffee et al., probably a fortuitous introduction, effectively controlled the mealybug (Nechols and Seibert, 1985).

APHIDS

At least two species have been introduced to the Marianas for the control of aphids. The coccinellids *Platyomus lividigaster* (Mulsant) and *Orcus chalybeus* (Boisduval) were introduced from Hawaii in 1953 (Pemberton, 1954). Neither species has been collected since, so we assume that these species did not establish. A third species of coccinellid may have been introduced in the early 1900s (Briggs, 1920), but there are no records mentioning which species it was. Briggs refers to it as a red lady beetle with black spots which was feeding on aphids and mealybugs. He states it was imported from Hawaii and reared by the Agricultural Station in large numbers some years previously. There are several species of lady beetle on Guam conforming to that description, all of which are probably native or recent, accidental introductions. We suspect this may not have been a new introduction and that Briggs was confusing the lady beetle he observed with the introduction of *C. montrouzieri* in 1911.

WHITEFLIES

Since 1950, three whiteflies have been accidentally introduced to Guam. Two of these, *Aleurocanthus spiniferus* (Quaintance) and *Aleurodicus dispersus* Russell, have been the targets of active biological control programs. *A. spiniferus* was successfully controlled by *Amitus hesperidum* Silvestri and *Encarsia smithi* (Silvestri). *E. smithi* was the more important parasite of the two (Peterson, 1955a). Several other species were introduced but failed to establish permanently (Table 1). Biological control of *A. spiniferus* continues to be good, and both *A. hesperidum* and *E. smithi* are still present. *E. smithi* was recently sent from Guam to Kosrae and Pohnpei in the Carolines.

A. dispersus, the spiraling whitefly, is a recent immigrant to Micronesia, and has become a serious pest on a wide variety of plants (Schreiner and Nafus, 1986). Two species, *Encarsia ?haitiensis* Dozier and *Nephaspis oculatus* (Blatchley), were introduced to control *A. dispersus* (Table 1). Both established and, on plumeria, reduced population levels of the whitefly from 50–100 whiteflies per leaf to less than 10 (Nechols, 1982). However, the whitefly is still common and there are periodic outbreaks, particularly on certain hosts such as sea grape (*Coccoloba* sp).

Nezara viridula* and *Coptosoma xanthogramma

The southern green stinkbug *Nezara viridula* L. occurs on Guam, but is relatively rare and difficult to find. *Trissolcus basalis* (Wollaston) was shipped to Guam from Fiji sometime prior to 1959 for control of *N. viridula* (Rao et al., 1971), but we have no information on whether it was released or not. In 1968, a *Trissolcus* species was imported from Hawaii as an egg parasite of the platispid *Coptosoma xanthogramma* (White). *C. xanthogramma* is a pest of beans on Guam and was probably a new introduction to Guam at that time. No preliminary surveys were done, and there is no information as to what the economic importance of *C. xanthogramma* was. No follow-up has been done on whether the parasite established or not. *C. xanthogramma* is not abundant on commercial beans at this time and is not an economic pest, although it is sometimes abundant on certain species of noncommercial beans including jicama. A *Telenomus* species has been recovered from *N. viridula* eggs. Further follow-up on the status of *Trissolcus* sp. and *T. basalis* needs to be done.

Tarophagus proserpina

Tarophagus proserpina (Kirkaldy) was first recorded on Guam in 1924. At that time it was considered to be in outbreak proportions (Swezey, 1946), but in 1936, Swezey reported that the taro planthopper was not a serious pest. He stated that the taro planthopper was uncommon in dry-land taro, and, although common on wetland taro near ditches, it was not particularly damaging. A dryinid parasite, *Haplogonatopus vitiensis* Perkins, was found attacking the taro planthopper in small numbers. It was introduced to Hawaii in 1906 from Fiji to control the sugarcane leafhopper (Swezey, 1946), but in Guam, *H. vitiensis* was probably native or an accidental introduction. A hyperparasite, *Echthrogonatopus exitiosus* Perkins, attacks *H. vitiensis* on Guam and may reduce its effectiveness.

In 1947, Pemberton (1954) shipped the egg predator *Cyrtorhinus fulvus* Knight from Hawaii to Guam. This mirid is a specific predator of the eggs of the taro planthopper and had successfully controlled the planthopper in Hawaii. *C. fulvus* established and has been credited with keeping planthopper populations at non-damaging levels, although the degree of control provided by *C. fulvus* needs formal evaluation since there is controversy about the status of the taro planthopper as a pest. Occasionally *T. proserpina* becomes abundant on taro, but populations seldom remain high for long intervals. *C. fulvus* were shipped from Guam to Pohnpei and possibly to other islands in the early 1950s (Pemberton, 1954).

Heteropsylla cubana

In 1985, the psyllid *Heteropsylla cubana* Crawford was first noticed attacking *Leucaena leucocephala* on Guam. It quickly reached damaging numbers. In certain localities stands of *L. leucocephala,* an important source of firewood and agricultural structural material, were killed. In other areas the growing tips of the plants were stunted, opening the canopy and allowing various vines and herbaceous species to invade. Frequently guinea grass, which is of little economic importance, replaced the leucaena. In spots where vines predominated, the vines frequently overtopped *L. leucocephala,* shading it out and eventually killing it. In 1986 the ladybeetle *Curinus coeruleus* Mulsant was obtained from Hawaii and released. About 500 beetles were shipped, but the shipment was delayed in transit and about half the beetles died before arrival. The survivors were released in lots of about 60 at four sites. At one of the sites an infestation on an unidentified mealybug on wild bittermelon was noticed. This was not observed at the other release sites. During subsequent visits during the first week the beetle was noted to be feeding on the mealybug and not on the psyllids, which were extremely abundant. One year following release, the beetle was found established only at the site where the mealybug was and not at the other three sites. Numerous larvae and adults have been found feeding on the psyllids. The effectiveness of the beetle is currently being evaluated. Preliminary results suggest the beetle is having little effect on psyllid populations.

C. coeruleus was also released in Saipan in 1986. We recovered specimens in 1988.

LEPIDOPTERA

At least nine species of Lepidoptera have been the targets of biological control programs in the Marianas.

Ostrinia furnacalis

Perhaps the most intensive program has been conducted against the Asian corn borer *Ostrinia furnacalis,* a serious pest of corn throughout the Marianas. Biocontrol introductions against the Asian corn borer were started in 1926 and have continued to the present day (Table 1). To date, only one parasite intentionally released, *Trichogramma chilonis* Ishii, has established and persisted. *Lydella thompsoni* Herting established on Guam in the early 1930s and provided excellent control of the Asian corn borer initially (Vandenberg, 1933; Swezey, 1941a), but by 1950 the tachinid had disappeared (Peterson, 1955b). Attempts to re-establish it from U.S. sources failed (Nafus and Schreiner, 1986a).

Many of the parasites introduced for the control of *O. furnacalis* were from temperate zone sources or were parasites of a closely related species, *O. nubilalis*. None of the introductions from these sources established. In many cases, fairly large releases or extended rearing and release efforts were made to no avail. *Exeristes roborator* (F.) was reared and released by the thousands in the 1920s but only a few, nonpersistant field recoveries could be made (Vandenberg, 1926, 1928, 1929, 1930, 1933). We are not certain why releases consistently failed, but there are several factors which may be important other than, or in addition to, climatic factors or an inappropriate host. Corn as a crop is seasonal, generally being planted in widely scattered areas at the end of the dry season and again at the end of the wet season. In the off-season little corn is grown. Between crops the Asian corn borer can be found on a variety of alternate hosts, although it is relatively scarce. To establish and be successful, any introduced parasites must be able to find the borer on its alternate hosts or to switch to other species of Lepidoptera. *T. chilonis*, *Xanthopimpla punctata* (F.), *Brachymeria albotibilalis* (Ashmead), and *Tetrastichus ?inferens* Yoshimoto all attack the Asian corn borer on Guam (Table 2). All of these parasitoids have fairly broad host ranges and none of them is particularly effective at controlling the Asian corn borer (Nafus and Schreiner, 1986a). *X. punctata* is an ichneumonid wasp which is common on Guam but only occasionally is found on the Asian corn borer. *X. punctata* apparently is a relative newcomer to Micronesia as it was not found in the early surveys (Townes, 1958). *Tetrastichus ?inferens* is also new to the Marianas and its occurrence on *O. furnacalis* is a new host record (Nafus and Schreiner, 1986a). In 1987 a species of *Echthromorpha* new to Guam was found parasitizing *O. furnacalis* pupae. The parasite was more common in pupae located in the tassel, but a total of only 0.2% of the pupae were parasitized. This parasite also attacks several other species of Lepidoptera.

Another factor which may be inhibiting pupal and larval parasites is predation by ants and earwigs. In 1986 *Trichomma cnaphalocrocis* Uchida was collected in Taiwan and released in a field cage on Guam. Efforts were made to keep *Solenopsis geminata* (F.) and other ants out of the cage, but the ants managed to attack most of the pupae and only a single parasitized pupa survived. Pupal parasites are present in the Marianas but they are normally rare (Nafus and Schreiner, 1986a). General predation by ants may be contributing to the poor establishment record.

Plutella xylostella

The diamondback moth *Plutella xylostella* (L.) is a serious problem on cabbage and related crops in Northern Guam. Beginning in 1971, several attempts to import parasites were made. Four species were released, some repeatedly, but none established (Table 1). In part this may have been because the releases were made in farm fields which were subsequently treated with insecticides. The diamondback remains a serious pest of cole crops. The only parasite attacking the diamondback on Guam is *Chelonus blackburni*

Cameron, which is not particularly effective. Additional biological control efforts are needed, but, before any natural enemies are imported, the wild hosts of the diamondback need to be identified. Releases could then be made on wild hosts where there are good populations of the diamondback rather than in farm fields which may be treated with insecticides. To date, the alternate hosts of the diamondback have not been identified on Guam.

Pericyma cruegeri

Another moth which has not yielded any success to biological control is the poinciana looper, *Pericyma cruegeri* (Butler). This moth entered Guam around 1971 and became a serious pest. *P. cruegeri* defoliates most of the poincianas three to five times each year, usually during the period from August to February. After February the moth is uncommon, although outbreaks can occur at other times of the year. Muniappan (1973) found a tachinid *Exorista civiloides* (Bar.) parasitizing about 1% of the pupae. In 1973 Muniappan introduced *Brachymeria albotibilalis* (Ashmead) (as *B. euploeae* (Westwood)) from Papua New Guinea. *B. albotibilalis* established but has had little effect on *P. cruegeri* as it parasitizes a low percentage of pupae. *B. albotibilalis* is a very generalized parasitoid and it attacks a wide range of other Lepidoptera including the Asian corn borer (Nafus and Schreiner, 1986a). Additional work is needed in finding new sources of natural enemies which are specialized and are more effective. A possible source may be Malaysia, where the moth occurs but is rare.

Papilio polytes

Three parasites, *Apanteles papilionis* Viereck, *Pteromalus luzonensis* Gahan and *Telenomus* sp., were released to control the swallowtail *Papilio polytes* L. This is an abundant butterfly on Guam which can often be quite damaging to certain species or varieties of citrus, particularly young plants. *P. luzonensis* established and provides partial control, but the butterfly is still very abundant and causes considerable damage. *A. papilionis* did not establish, and the status of the *Telenomus* sp. is unknown. The butterfly is also attacked by a *Trichogramma* species (Muniappan, 1982a).

In part, the abundance of *P. polytes* may be related to its use of *Triphasia trifoliata* (Burmann F.I.) P. Wilson as an alternate host. This is an extremely common plant in the limestone forest areas on Guam. The effectiveness of the parasites attacking *P. polytes* on this host are unknown and need to be investigated. Additional parasites for this species need to be located which can keep the butterfly at very low levels on this host plant as well as other citrus hosts.

Erionota thrax

The introduced larval parasite *Apanteles erionotae* Wilkinson in combination with a self-introduced egg parasite *Ooencyrtus erionotae* Ferriere and a local *Trichogramma* sp. have been partially effective at controlling the banana skipper *Erionota thrax* (L.). Outbreaks of the skipper can occur at the beginning of the wet season and are severe enough to reduce yield. Muniappan (1982a) provides more information about these species.

Argyroploce schistaceana

The Japanese introduced *Trichogramma chilonis* Ishii into Saipan, Rota, and Tinian in 1935 for control of *Argyroploce schistaceana* (Snellen) on sugarcane. This egg parasitoid was bred in large numbers and used in inundative releases (Esaki 1952). The parasitoid is now firmly established throughout the Marianas. It attacks a wide variety of eggs of Lepidoptera including *O. furnacalis*, *Hypolimnas bolina* (L.), *H. anomala* (Wallace), and *Agrius convolvuli*. (L.). It is probably providing good biological control of *A. convolvuli* (Nafus and Schreiner, 1986b).

Spodoptera litura and *S. mauritia*

Cutworms or cluster caterpillars, *Spodoptera litura* (F.) and *S. mauritia* (Boisd.) are numerous in the Marianas and are problems on a wide variety of crops and ornamentals. *S. litura* is a problem on taro and a minor pest on beans, cabbage, corn, tomatoes, and other crops. In the early 1930s it was a serious problem on banana leaves as well (Swezey, 1941b). *S. mauritia* is predominantly a pest of turf, both at private residences and on golf courses, at the beginning of the wet season in June or July. In 1936, *Telenomus nawai* Ashmead was brought from Hawaii and released to control *S. litura*. It established and attacked the eggs of both *S. litura* and *S. mauritia* (Swezey, 1941b). *T. nawai* was credited with controlling *S. litura* on banana, and by 1938 it was no longer considered a problem on this plant (Anon., 1938).

S. litura continued to be a problem on other hosts, and additional efforts to improve biological control were made. In 1958, *Lespesia archippivora* (Riley) and *Calosoma blaptoides tehuacanum* (Lapouge) were released (Table 1), and in 1971, *Telenomus remus* Nixon was obtained from India. *Telenomus remus* established and appears to be the dominant parasite on *S. mauritia* at this time. Neither *L. archippivora* or *C. blaptoides* have been recovered, and it seems probable that they did not establish. Another parasite *Apanteles marginiventris* (Cress.), which was not purposefully introduced to Guam, has been reared from *S. litura* in several locations on Guam.

Penicillaria jocosatrix

Recently an effort to control the mango shoot caterpillar *Penicillaria jocosatrix* Guenée was initiated. This noctuid caterpillar feeds on the new leaves, flowers and green fruits of mango. It can reduce the leaf area on a tree by as much as 50% or more, and is particularly serious on non-local mango varieties. It also has been found to nearly completely strip all of the flowers from those trees which do flower and has been found eating the skin and meat of fruits up until they are nearly mature. On Guam it is a major problem on mango, although in other parts of the world it appears to be uncommon.

In 1986 and early 1987 four natural enemies were released for control of this caterpillar. These are: *Trichogramma platneri* Nagarkatti, *Aleiodes* sp. nr. *circumscriptus* (Nees), *Euplectrus* sp. nr. *parvulus* Ferriere, and *Blepharella lateralis* Macquart. *T. platneri* is an egg parasite which prefers Lepidoptera in the canopies of trees. It was imported from California. The other three parasites were introduced from India. A series of 18 releases of *Aleiodes* sp. were made over a period of about one year (1986–87). A total of

453 wasps were released in Agat, Dededo, Yigo, Barrigada, Mangilao, Piti, and Inarajan. This is a larval parasite which attacks the first three instars. The development time is about 11–13 days. *Aleiodes* sp. established and spread out from the release sites but then disappeared about seven months after the final release. No specimens have been recovered since August, 1987.

Euplectrus sp. is a gregarious ectoparasitoid which lays its eggs primarily on the first three instars. At oviposition the wasp stings the larvae and arrests the development of the caterpillar. Development of the wasp is rapid: taking only eight to ten days to go from egg to newly emerged wasps. Pupation takes place under the collapsed larval skin of the caterpillar. Nineteen releases of *Euplectrus* sp. were made in seven villages during 1986 and 1987. A total of 858 wasps were released. In July 1987, *Euplectrus* was recovered from all release sites and parasitize up to 39% of the caterpillars.

B. lateralis was released in eight lots ranging from 3 to 11 flies each in Yigo and Dededo. A total of 45 living flies were released and many of these were in poor condition as the fly did not ship well and could not be reared in the laboratory. The tachinid fly lays minute black eggs on the new growth. The larvae feed internally in the fifth instar caterpillars or in the pupae. Pupation often takes place in the mango shoot caterpillar pupa. In August, 1987, 15 of 225 (6.7%) caterpillars from several villages were parasitized by the tachinid, suggesting a rapid buildup and spread of this species despite the low numbers released. Evaluation of the effectiveness and degree of success of these parasites is underway.

COLEOPTERA

Releases of parasites or predators for control of at least seven species of beetle have been made.

Adoretus sinicus

Campsomeris marginella modesta (Smith) was released in 1950 for control of *Adoretus sinicus* Burmeister. *A. sinicus* feeds on a wide variety of plants, chewing ragged holes in the leaves. It frequently damages corn and beans, although in most cases the damage is probably not sufficient to reduce yield. The beetle also feeds on several ornamental plants including roses and creates unsightly damage on the foliage. *C. marginella* established and has been partially successful at controlling the beetle (Pemberton, 1954), but the beetle is still very abundant and additional control measures are needed.

Anomala sulcatula

In 1940 *Campsomeris annulata* (F.) was released by the Japanese against *Anomala sulcatula* Burmeister, a pest of sugar cane in Saipan. The wasp established (Esaki, 1952) but no assessment of its impact was made, although Krombein (1949) felt it was probably very effective. The wasp was collected on Guam for the first time in 1945 (Krombein, 1949). It is not known how the wasp got to Guam. In 1946 *C. manokwariensis* (Cameron), which also attacks *A. sulcatula,* was found on Guam (Krombein, 1950). Most likely it was introduced to Saipan from the Philippines at the same time as *C. annulata* as these species are very similar, and then made its way to Guam in the same way as *C. annulata*. Esaki (1952) suggested the 1940 shipment to Saipan probably contained both species as more than one species was identified from the original shipment. Both wasps were later collected on Guam and sent to Hawaii for control of *A. sulcatula*. At the present time *A. sulcatula* is uncommon, but the effectiveness of the wasps is unknown since sugar cane in no longer grown commercially in the Marianas.

Brontispa mariana and *B. palauensis*

Originally the Marianas were free of hispines which attack coconuts; however, two species have become established, *Brontispa mariana* Spaeth on Saipan, Tinian, and Rota and *B. palauensis* (Esaki and Chujo) on Guam. By 1939, *B. mariana* was severely damaging coconut on Saipan. Esaki (1952) stated that ". . . nearly all the plantations on the island were destroyed." Biological control activities started in 1947 when W. H. Lange was sent to Malaya to search for parasites. He found two species of parasites, *Tetrastichus brontispae* (Ferriere) and *Hispidophila brontispae* (Ferriere), on another hispid, *Plesispa nipae* Maul, on coconut. Both species were shipped to Saipan in 1948 and released on Saipan and Rota. *T. brontispae* established on both islands and effected partial control, but *H. brontispae* did not establish. There are still periodic outbreaks of the beetle, but the damage is considerably less severe than before the introduction of *T. brontispae*.

In 1973 *B. palauensis* appeared on Guam and became a serious problem on coconut (Muniappan, 1982a). Strains of *T. brontispae* were obtained from Saipan, New Caledonia, and Vanuatu and released on Guam. The parasite established and parasitized about 30% (sometimes up to 75%) of the *B. palauensis* larvae and pupae (Muniappan et al., 1980). Periodic outbreaks of the beetle still occur. Additional biological control work is needed.

Epilachna vigintisexpunctata

The Philippine lady beetle, *Epilachna vigintisexpunctata philippinensis* (Dieke), is a pest of eggplant, potato and tomato. Peterson introduced *Aplomyiopsis epilachnae* (Aldr.) and *Pediobius foveolatus* Crawford (as *P. epilachnae* (Rohwer)) in 1950–54 for control of the beetle. *A. epilachnae*, a parasite of *E. varivestis* Muls. from Mexico, did not establish. *P. foveolatus* was brought in from the Philippines where it had been collected on *E. vigintisexpunctata*. The wasp established and parasitized about 75% of the beetles (Peterson, 1955c). In the late 1950s the wasp was sent to Saipan and Rota. It established on both islands and exerted partial control of the beetle. However, on Saipan the beetle remained a serious pest.

In 1974 a strain of *P. foveolatus* was introduced to Guam from the United States. This strain originated in India, and emerged from the larva rather than the pupa as in the Philippine strain. We do not know for certain if the introduction of the second strain was successful, but we have reared parasites from both the pupa and the larva. Currently the Philippine lady beetle is only occasionally a serious pest on Guam.

On Saipan, a strain of *P. foveolatus* was obtained from a laboratory population in

Delaware, U.S.A., in 1985 and released. The status of that strain is not known but we suspect the release failed as many of the release sites were unsuitable or were destroyed by construction soon after the release.

Cosmopolites sordidus

Three species of histerid beetles, *Plaesius javanus* Erichson, *Hololepta minuta* Erichson and *H. quadridentata* (F.), were released on Guam from 1947 to 1954 for control of the banana weevil, *Cosmopolites sordidus* (Germ.). *P. javanus* established (Pemberton, 1954) but no follow-up on its effectiveness was made. The status of the other two species is unknown.

Rhabdoscelus obscurus

Rhabdoscelus obscurus (Boisduval) attacks coconut, other palms, and sugarcane. The larvae tunnel in the trunks and growing tips of palms or bore in the stalks of sugarcane. Infested palms are weakened. Entry holes caused by the beetles allow disease organisms to enter the palms. An effort to control the pest was initiated in 1926 by Vandenberg. The tachinid *Lixophaga sphenophori* (Vill.) was obtained from Hawaii. A few flies were released in the field and the rest were kept for a breeding program. After various trials and tribulations, Vandenberg got a healthy colony going only to discover that the fly had established in the field either from escapes or from the original release of about 20 flies. Approximately 50% of the field collected larvae of the weevil were parasitized (Vandenberg, 1930). In 1928 the fly was collected and sent to Saipan to control the weevil there. Unfortunately, the establishment was temporary on Guam and after 1929 the tachinid was no longer present (Vandenberg, 1931). It also failed to establish on Saipan (Vandenberg, 1930).

DIPTERA

Dacus cucurbitae and *D. dorsalis*

Several species of parasites were introduced from Hawaii from 1937 through 1962 to control *Dacus cucurbitae* Coquillett and *D. dorsalis* Hendel. Against *D. dorsalis,* seven species and five subspecies of *Biosteres longicaudatus* were released (Table 1). Only one of these, *Syntomosphyrum indicum* Silvestri, established, although its continued presence is doubtful unless it can successfully use *D. cucurbitae* or *D. ochrosiae* Malloch as a host. *D. dorsalis* was eradicated from all of the Marianas islands in 1962, and fruit fly surveys since then have yielded no specimens. A subspecies of *B. longicaudatus* was collected on Guam in 1936 from *D. ochrosiae* (Swezey, 1946).

Three species of parasitoids were specifically released for control of *D. cucurbitae* (Table 1). *Opius fletcheri* Silvestri was repeatedly released, first in 1937 (Anon., 1937a) and then again in the 1950s. In 1937 both *O. fletcheri* and *Opius humilis* Silvestri were sent from Hawaii. Part of the shipments were released, and part was retained to rear them

(Anon., 1937a). *O. fletcheri* established and was reported to cause 6.1% mortality in the release fields (Anon., 1937d). In 1953, *O. fletcheri* was re-released, and additional releases were made periodically through 1967. It was recovered in 1971, but no follow-up on its parasitization rate was done. Certainly it has not provided good control of *D. cucurbitae:* the melon fly is extremely abundant and causes substantial economic losses of cucumbers, bittermelon, watermelon and cantaloupe.

Liriomyza trifolii

The leafminer *Liriomyza trifolii* Burgess is a relative newcomer to Guam, first appearing around 1978 (Schreiner and Nafus, 1986). It occurs on a wide variety of crops including watermelon, cantaloupe, cucumber, tomato, and beans (both *Vigna* and *Phaseolus*). In the Marianas, however, it is only a serious pest on beans and occasionally on tomatoes. Several parasitoids including *Gronotoma micromorpha* (Perkins), *Disorygma pacifica* (Yoshimoto), *Gronotoma* sp., *Hemiptarsenus semialbiclavus* Girault and *Chrysonotomyia formosa* (Crawford) (Yoshimoto and Ishii, 1965; Schreiner et al., 1986) attack *L. trifolii* on Guam, but the leafminer is still a problem on beans at certain seasons of the year even when insecticides are not used. Attempts have been made to introduce additional natural enemies. Two species have been released so far, *Ganaspidium utilis* Beardsley and *Diglyphus begini* (Ashmead). *G. utilis* was released in groups of 200 at several locations over a period of several months. *G. utilis* established and has become the dominant parasitoid on *L. trifolii*. *D. begini* was released in low numbers at a time when leafminers where being heavily parasitized by local parasites. Three releases were made. Continuous monitoring for several years after the release indicates that *D. begini* did not establish.

Ophiomyia phaseoli

Another pest of beans is the bean fly *Ophiomyia phaseoli* (Tryon). The bean fly mines in the petiole and stem, often killing seedlings and reducing the vigor of older vines. Two parasites, *Opius importatus* Fischer and *O. phaseoli* Fischer, were released for control of the bean fly in 1971–1972. These parasites were not recovered in limited surveys in 1988. *H. semialbiclavus* and an unidentified wasp were the only parasites reared.

GENERAL PREDATORS

Three mantids, *Polyspilota aeruginosa* (Goeze), *Sibylla pretiosa* Stål, and *Spodromantis* sp., were released in 1972. None of these mantids has been collected since, and we feel that they did not establish.

The drongo *Dicrurus macrocercus* S. Baker was released by the Japanese in Rota in 1935 for insect control (Baker, 1951). It spread to Guam in 1961, apparently on its own. It was considered a pest because of its aggressive behavior towards native birds.

The toad *Bufo marinus* L. was brought to Guam from Hawaii in 1937 by Oakley. Initially 19 individuals were released at Agana Springs (Anon., 1937b), and the following year an additional 41 toads were released (Anon., 1938). Progeny of these toads were actively spread around the island. The toad was credited with reducing populations of the garden slug *Veronicella leydigi* Simroth (Anon., 1938) and the banana weevil (Anon., 1937c). The slug was noted to be abundant prior to the introduction of the toad. In one field about 500 slugs were being removed with sharpened sticks each day. As the toad moved into infested areas, the slugs were vastly reduced (Swezey, 1941c). Currently slugs are extremely rare. Instead, the toad has become a nuisance (Eldredge, 1988). It is extremely abundant near human habitation and areas with standing water. Densities of 185 to 225 toads per hectare have been recorded in these areas (Chernin, 1979). It may have affected the native insect and mollusc fauna, but no impact studies have been done. Toads were found on Tinian, Saipan and Rota in 1944, apparently having been brought there during the Japanese occupation (Townes, 1946). Whether the toads were intentionally or accidentally moved, is not known.

MITES

Phytoseiulus persimilis Athias-Henriot and *Typhlodromus occidentalis* Nesbitt were introduced to Guam to control *Tetranychus cinnabarinus* (Boisduval). *T. cinnabarinus* is a common mite on Guam and attacks many plant species. It can be severely damaging at times. No follow-up on the release has been done, and we do not know if these predaceous mites established or not.

MOLLUSCS

The giant African snail *Achatina fulica* Bowdich appeared in the Marianas in Rota, Tinian, and Saipan between 1936 and 1938 and was first found on Guam in 1945. The African snail was a serious agricultural pest of vegetables and young fruit trees. It is also a vector of the rat lungworm and can spread several Phytophthora fungus diseases (Muniappan, 1982b). In the Marianas biological control began with the release of the predatory snail *Gonaxis kibweziensis* E. A. Smith on the island of Agiguan. *G. kibweziensis* became numerous, and *A. fulica* declined in abundance (Pemberton, 1954). Later *G. kibweziensis* was liberated on Guam along with two other predatory snails, *G. quadrilateralis* (Preston) and *Euglandina rosea* Ferussac. *G. kibweziensis* and *E. rosea* established and exerted some control on *A. fulica* (Muniappan, 1982b), but the snail remained a problem until the flatworm *Platydemus manokwari* Beauchamp (Tricladida: Rhynchodemidae) accidentally established. *P. manokwari* has reduced *A. fulica* to noneconomic levels (Muniappan, 1982b, 1983). *G. quadrilateralis* and *E. rosea* and probably *G. kibweziensis* were also introduced to Saipan. *E. rosea* and at least one of the *Gonaxis* species were said to have established there. *P. manokwari* has now been found on Saipan and Tinian as well as on Guam (Eldredge 1988). *Lamprigera* (= *Lamprophorus*) *tenebrosus* (Walker) was also introduced to Guam to control *A. fulica* but failed to establish (Peterson, 1957b; Muniappan, 1982b).

Two sciomyzid flies, *Sepedon macropus* Walker and *Sciomyza dorsata* Zetterstadt were imported from Hawaii in 1959 and 1961 (Table 1). These predatory flies were brought into Hawaii to control the liverfluke snail *Galba viridis* (Quoy & Gaimard). No information, other than the importation record, is available as to why these flies were brought to Guam or if they were released.

WEEDS

Two species of weeds, *Lantana camara* L. and *Chromolaena odorata* (L.), have been the targets of biological control work.

Lantana camara

Efforts to control *L. camara* began in 1958 on Guam with the introduction of *Salbia haemorrhoidalis* Guenée. From 1967 through 1971, seven other species were introduced (Table 3). Of these, three established and four failed (Table 3) (Muniappan, 1988a). *S. haemorrhoidalis* also failed to establish (Muniappan, 1988a). Two other arthropods were found on lantana, the plume moth *Lantanophaga pusillidactyla* (Walker) and a mite *Suidasia pontifica* Oudemans associated with scorched buds. Both of these species were fortuitous introductions. *L. pusillidactyla* feeds on the buds and flowers and according to Muniappan (1988a) has reduced fruit set from 14–20 berries to 1–2. *Ophiomyia lantanae* (Froggatt) also attacks the berries. In areas where the fly was found, seed weight was reduced by 40% and between 58% and 75% of the seeds were infested (Muniappan, 1988a). In the central portions of Guam, lantana is scarce, but there are some large stands in northern Guam. Further details are given by Muniappan (1988a).

Two species, *Teleonemia scrupulosa* Stål and *Uroplata girardi* Pic, were sent to Saipan for lantana control. *T. scrupulosa* established. The status of *U. girardi* is unknown (Table 3).

Chromolaena odorata

Chromolaena odorata is an important range weed in the Marianas. On Tinian and Rota it is extremely abundant on range pastures and had eliminated most of the useful forage plants. On Guam and Saipan it is a common weed of roadsides and fields. On Guam it started to become very abundant by 1985.

Attempts to control the weed through the use of biological control agents were initiated in 1984. An arctiid moth *Pareuchaetes pseudoinsulata* Rego Barros was imported from Trinidad and India (the Indian population was originally from Trinidad). The moth was reared in the laboratory and released first on Guam and later in the Northern Marianas Islands. Initially, late instar larvae were released in lots of up to 800 (Seibert, 1985). These releases failed to produce establishment, in part due to predation by toads, spiders and other general predators on the caterpillars. The release techniques were modified so that a minimum of 500 adult moths were released at a site. This method resulted in establishment in all release areas. Rapid defoliation of the *Chromolaena* followed. Virtually all of the above ground vegetation was stripped. Shoots resprouting at ground level were also consumed, and within a year over 90% of the plants were killed. The moth spread rapidly, and by 1987 had reached almost all areas of Guam. At this time, the release has resulted in

Table 3. Natural enemies released for biological control of weeds in the Marianas. The islands Guam (G), Rota (R), Tinian (T), Saipan (S), and Aguijan (A) are covered. In relation to the level of control we are adopting the following definitions: (H) high—populations of the target organism are low and it is no longer considered to be a problem; (G) good—populations of the target organism are usually low but outbreaks occur regularly; (E) established—the biocontrol agent established but we have no information on its impact on the target; (N) not established; (?) nothing known.

Target weed	Biocontrol species	Island	Deg. Cont	Number Rel.	Number Ships	Year	Origin	Reference
Chromolaena odorata (L.)	*Pareuchaetes pseudoinsulata*	G	G	>2500[1]	7	1984	Trinidad	Seibert, 1984, 1985
	Rego Barros	R	E	1500	2	1986	Guam	Seibert, 1986
	Lepidoptera: Arctiidae	T	E	500	1	1986	Guam	Seibert, 1986
		S	E	?	?	1987?	Guam	Muniappan, 1988b
		A	E	?	?	1987?	Guam	Muniappan, 1988b
	Mescinia nr. *parvula* Zeller	G	N	8	1	1984	Trinidad	Seibert, 1984
	Lepidoptera: Pyralidae	G	N	21	2	1986	Trinidad	Quarantine Records
		G	N	6	1	1987	Trinidad	Quarantine Records
	Melanagromyza eupatoriella	G	N	24	2	1986	Trinidad	Quarantine Records
	Spencer	G	N	31	1	1987	Trinidad	Quarantine Records
	Diptera: Agromyzidae							
	Apion brunneonigrum B.B.	G	N	860	4	1984	Trinidad	Seibert, 1984
	Coleoptera: Curculionidae							
Lantana camara L.	*Salbia haemorrhoidalis* Guenée	G	N	30	1	1958	Hawaii	HDOA[2]
	Lepidoptera: Pyralidae							
	Plagiohammus spinipennis (Thomson)	G	N	?	2	1973	Australia	Muniappan, 1988
	Coleoptera: Cerambycidae							
	Teleonemia scrupulosa Stål	G	H[3]	?	2	1969, 71	Saipan	Muniappan, 1988, and unpubl.
	Homoptera: Tingidae							
		S	E	?	1	1963	Belau	Trust Territory[4]

	Leptobyrsa decora Drake Homoptera: Tingidae	G	N	2800	3	1971	Hawaii	HDOA; Muniappan, 1988
	Uroplata girardi Pic	G	H[3]	370	1	1967	Hawaii	HDOA; Muniappan, 1988
	Coleoptera: Chrysomelidae	G	H[3]	175	1	1968	Hawaii	HDOA; Muniappan, 1988
		S	?	110	1	1963	Hawaii	HDOA
	Octotoma scabripennis Guerin-Meneville Coleoptera: Chrysomelidae	G	N	1000	1	1971	Hawaii	HDOA; Muniappan, 1988
	Hypena strigata (F.) Lepidoptera: Noctuidae	G	N	200	1	1967	Hawaii	HDOA; Muniappan, 1988
	Ophiomyia lantanae (Froggatt) Diptera: Agromyzidae	G	H[3]	200	1	1971	Hawaii	HDOA; Muniappan, 1988
Potamogeton sp.[5] aquatic weed	*Oreochromis mossambicus* (Peters) Pisces: Cichlidae	G	?	?	?	1956	?Hawaii	Brock and Takata, 1956
Utruilana sp.[6] aquatic weed	*O. mossambicus*	G	?	?	?	1956	?Hawaii	Rao et al., 1971
aquatic weeds	*Tilapia zilli* Gervaise	G	N	?	?	?1956	?Hawaii	

[1] Shipments were sent as eggs (8,300 sent, 3,020 survived shipment, 0 survived to establish colony), larvae (30 sent, 20 alive), and pupae (163 sent, 12 survived to lay eggs). A laboratory colony was established from the 32 larvae and pupae which survived shipment (Seibert, 1984).

[2] Shipment records of the Hawaii Department of Agriculture. The exact number released is not known, only the number shipped.

[3] A high degree of lantana control has been achieved but the contribution of individual species is not known.

[4] Reports of the Trust Territory Entomologist, Micronesia

[5] The identification of the weed is not certain. The species listed by Brock and Takata (1956) is not known to occur on Guam and is not found in the habitat listed. *Hydrilla verticillata* (L.) Royle is found in the reservoir and is a problem at this time. No *Potamogeton* is currently found in the reservoir, although it is possible it was eliminated by *S. mossambicus*.

[6] Rao et al., 1971 list this species as being controlled. There are no record of this species occurring on Guam. Rao et al. give no citation for the record so we were unable to verify control of this species. Brock and Takata (1956) do not mention it in their report.

successful suppression of the weed, but the moth is still in an invasion phase, and it is too early to tell if the weed will recover when moth numbers decline. The moth has also become established in Rota, Saipan, Tinian and Aguijan (Muniappan, 1988b, Seibert, 1989).

Several other insects have been released to aid in the control of *Chromolaena*. To date there is no evidence that any of these established. *Apion brunneonigrum* B.B., a curculionid feeding on the seed heads, was released in early 1984 at the beginning of the dry season on Guam. During the dry season the above ground growth of *Chromolaena* dies. Because of the poor condition of the host plants at the time of the release, the beetle was not expected to establish and no recoveries of it have been made. Low numbers of *Mescinia* nr. *parvula* Zeller, a small moth which bores in the stem tips, were released in late 1984 and again in late 1986 and early 1987. At the same time, a stem-boring agromyzid fly, *Melanagromyza eupatoriella* Spencer was also released. Although it is still too early to assess establishment, we doubt these species will establish because the stands were defoliated by *P. pseudoinsulata* soon after the releases took place. The defoliation was unexpected since the moth was not present in the area or nearby at the time the site was selected (T. Seibert, personal communication).

AQUATIC WEEDS

An aquatic weed *Potamogeton* sp. was considered to be a potentially serious pest in the water reservoir of Fena Lake in southern Guam. The fish *Oreochromis mossambicus* (Peters) was released in the lake to control this weed (Brock and Takata, 1956). According to them, within a year the weed was under very good control. The species of *Potamogeton* is in dispute. The two species currently found on Guam seem to be found only in flowing water and never in reservoirs. Perhaps the fish have successfully eliminated them from the standing water environment. Rao et al. (1971) state that *O. mossambicus* also controlled *Utruilana* sp. However this weed is not mentioned in Brock and Takata (1956), and there is no reference in Rao et al. (1971) for the source of their information. The species of *Utruilana* currently found on Guam is not found in standing water such as reservoirs. *Tilapia zilli* Gervaise is found in the reservoir and may have been introduced in the late 1950s. *O. mossambicus* is primarily a detritivore and it does not seem likely that it would have successfully controlled a macrophytic plant, unless the males uprooted them while making their nests. *T. zilli* is known to feed on macrophytes, but was not yet present in the reservoir at the time when the *Potamogeton* was said to have been controlled by fish. The shallow parts of the reservoir are currently choked with *Hydrilla verticillata* (L.) Royle, and the fish do not control this species (Leith et al., 1984).

HOUSEHOLD, VETERINARY, AND MEDICAL PESTS

Most of the biological control introductions in this category have been directed towards mosquitoes and filth flies. One natural enemy of cockroaches, *Ampulex compressa* (F), a parasite of the American cockroach, was released but failed to establish. At least two other species of cockroach parasite are present on Guam, but do not parasitize enough cockroaches to keep them from being a problem.

For mosquito control, two predatory mosquitoes, a nematode, and a fish have been released (Table 4). The predatory mosquitoes failed to establish and there has been no

Table 4. Natural enemies released for biological control of household, medical, veterinary pests in the Marianas. The years 1911 to 1988 are covered for the islands Guam (G), Tinian (T), Pagan (P) and Saipan (S). In relation to the level of control we are adopting the following definitions: (P) partial—populations of the target pest are lower but it is still a significant pest; (U) unsuccessful—the biocontrol agent established but had little or no effect on the target organism; (E) established—the biocontrol agent established but we have no information on its impact on the target; (T) temporary—the biocontrol agent established initially but later disappeared; (N) not established; (?) nothing known.

Pest	Type of pest	Biocontrol species	Island	Cont level	Number Rel.	Number Ships	Year	Origin Parasite	Reference
Orthoptera									
Periplaneta americana (L.)	Household	*Ampulex compressa* (F.) Hymenoptera: Ampulicidae	G	N	8	1	1953	Hawaii	HDOA[1]
					30	1	1954	(New Caledonia)	HDOA
Aedes albopictus (Skuse) & *Aedes pandani* Stone	Medical	*Toxorhynchites brevipalpis* Theobald Diptera: Culicidae	G	N	?	?	1954	Hawaii (S. Africa)	Pemberton, 1954
		Toxorhynchites splendens (Wiedemann) Diptera: Culicidae	G	N	?	?	1954	Indo-Malaya	Pemberton, 1954
Mosquitoes	Medical	*Reesimermis nielseni* Tsai and Grundmann Nematoda: Mermithidae	G	?	?	?	1974	Louisiana	Muniappan, unpubl.
		Gambusia affinis Baird & Girard Pisces: Poeciliidae	G	E	?	?	1945?	?	Krumholz, 1948
			S	E	?	?	1945?	?	Krumholz, 1948
			T	E	?	?	1945?	?	Krumholz, 1948
			P	E	?	?	1945?	?	Krumholz, 1948
Stomoxys calcitrans L. & *Musca domestica* L.	Livestock	*Spalangia cameroni* Perkins Hymenoptera: Pteromalidae	G	?	?	?	1911	Hawaii	Fullaway, 1912
			G	E	159[2]	2	1928	Hawaii	Vandenberg, 1929
Musca sorbens Wd.		*Spalangia endius* Walker Hymenoptera: Pteromalidae	G	P	26500	reared	1930–2		Vandenberg, 1933
Haematobia irritans L.	Livestock	*Copris incertus prociduus* Say Coleoptera: Scarabaeidae	G	E?	86	2	1953	Hawaii	HDOA; Peterson, 1957a
		Onthophagus incensus Say Coleoptera: Scarabaeidae	G	N	32	2	1953	Hawaii	HDOA; Peterson, 1957a

[1] Shipment records of the Hawaii Department of Agriculture. The exact number released is not known, only the number shipped.

[2] *S. cameroni* and *S. endius* were mixed in culture. The exact proportion received and released is not known. Both were reared in culture as well as direct field released. In 1928, 788 were reared in culture and released. Breeding continued but no data for the numbers released is given in 1929. In 1930–32, 26,500 were released from the breeding program.

follow-up on the status of the nematode. The mosquitofish *Gambusia affinis* (Baird & Girard) has established in many of the springs and swamps in the Marianas (Maciolek, 1984). Its impact has never been evaluated.

To control various species of flies including *Haematobia irritans* L., *Stomoxys calcitrans* L., *Musca domestica* L., and *M. sorbens* Wd., two species of *Spalangia* and two dung beetles have been released (Table 4). *Spalangia cameroni* Perkins and *S. endius* Walker were sent in a mixed species culture to Guam from Hawaii in 1928 (Bryan, 1949). Some parasites were released and a few kept for rearing. Both species established and became abundant (Vandenberg, 1933), but, by 1936, *S. cameroni* had become scarce (Swezey, 1941d). *S. calcitrans* and *M. domestica* are uncommon, but whether this is due to parasitization or other factors is not known. *H. irritans* and *M. sorbens* are abundant in certain localities, but no evaluations on the effect of the parasites on their populations has been made. There have been changes in agricultural and sanitary practices since 1928 which could have substantially affected the populations of all of these flies. Guam has become less agrarian and more urban. Fewer livestock are reared and modern urban health practices are used. Study of the impact of *Spalangia* is needed before the degree of success can be assessed.

The dung beetles *Copris incertus prociduus* (Say) and *Onthophagus incensus* Say were released in 1953 (Peterson, 1957a). *C. incertus* estabished initially, but no recent collections have been made. No collections of *O. incensus* have been made, indicating that it did not establish.

RECENT FORTUITOUS INTRODUCTIONS

In the early 1970s three species of potter wasps, *Delta circinalis* (F.), *D. pyriforme* (F.) (Schreiner and Nafus, 1986), and *D. campaniformis esuriens* Saussure established on Guam. These wasps prey on a wide variety of caterpillars and probably aid in the control of several species. They are extremely abundant and at times are nuisances because they built mud nests on house walls or other places which annoy homeowners. Another general predator accidentally introduced before 1972 is the praying mantis *Hierodula patellifera* (Serville), which has become extremely abundant, and is frequently observed feeding on a variety of economically injurious insects.

An important introduction was an *Eretmocerus* sp., which apparently came with its host, the woolly whitefly *Aleurothrixus floccosus* (Maskell). This whitefly was first noticed in 1984 on citrus and guava (Schreiner and Nafus, 1986). In late 1984 extensive sooty mold deposits and high numbers of woolly whiteflies were present. The first counts done in March of 1985 had mean populations of over 140 woolly whiteflies per ten leaves. Recently populations have declined to very low levels and the woolly whitefly has become scarce. Parasitization rates by *Eretmocerus* have consistently been about 60%. The woolly whitefly is considered to be under good control now and is not an economic problem.

Another significant introduction to Guam is the coccinellid *Menochiles sexmaculatus* (F.). Prior to 1965, in Micronesia this lady beetle was only known from Palau. Since that time, it has appeared in Guam and in the Northern Marianas and is one of the most common predators observed on aphids. Although no formal assessment of its value has been made, its abundance suggests it is an important component of the natural enemy complex on Guam. Another lady beetle preying on aphids which is present on Guam is *Olla v-nigrum* (Mulsant) (= *abdominalis* (Say)). *O. v-nigrum* may have been introduced through commerce (Chapin, 1965). It is not an abundant or conspicuous beetle and is much less important than *M. sexmaculatus* in controlling aphids. Recently it has been found to have become abundant on leucaena infested with *H. cubana,* and is probably feeding on this insect.

Discussion

The Marianas have been the focus of considerable work in biological control. In all, 103 species of insects as well as two predatory mites, three snails, one nematode and four vertebrates have been intentionally introduced to Guam for the purposes of controlling 41 pest species. Of the insect species, 34 established, 48 did not establish, five temporarily established, one was already present before the release and the status of the rest (25 cases) is not known. In the Commonwealth of the Northern Marianas, 28 species of insects have been released. Of these, 11 species established, 11 failed to establish, one was already present prior to release and the fate of seven is unknown. In addition to the insects, three species of snails and several vertebrates were introduced to control various pests.

Most of the biological control work done in the Marianas has not involved a critical study of how great a degree of control was obtained by the biocontrol agents. Pre/post release surveys, cage checks, insecticide checks or other evaluation assessment methods have rarely been done, so it is difficult to assess how much pest populations have been reduced or how much each biological control agent has contributed. In many cases no follow-up has been done at all, even to the extent of checking to see if the species established. This is a serious weakness in the biological control efforts in the Marianas and probably throughout many of the islands in the Pacific. In part, this is due to a shortage of manpower in relation to the number of new pests which establish each year and an emphasis on a quick solution to new problems. Once a problem is reduced in severity, pressure is placed on the entomologist to move on to new problems, and there is little support for documentation of the degree of success or for which natural enemy was responsible for control.

Judging from published literature where available, or from the current abundance of the pest where we have no better information, a high degree of control was obtained against five crop pests and two weeds on Guam and two crop pests on Saipan (see Tables 1 & 3 for species and definition of control). Four other exotic crop pests are under a high degree of control by fortuitously introduced or native parasites and predators (Table 2). A good degree of control for most of the year, with some outbreaks, was obtained in the case of five pests on Guam, three on Saipan, and one on Rota (Tables 1 & 2). Partial control was obtained against eight pests on Guam and one in Saipan (Tables 1, 3 & 4). For many species no information is available. Better follow-up is needed on almost all of the species introduced.

On Guam, the rate of establishment was highest for natural enemies introduced to control Homoptera and Coleoptera (Table 5). Against Homoptera, for those cases for which the outcome is known, 58% of the parasites and predators established permanently. Against Coleoptera, only nine natural enemies were released and four of these estab-

Table 5. Establishment rate of insects introduced for biological control of crop pests on Guam in relation to the order of the target species.

Target order	Establishment status: Yes		No		Temporary		Number not evaluated	Present before release
	Number	%	Number	%	Number	%		
Coleoptera	4	67	1	17	1	17	3	0
Diptera	3	20	11	73	1	7	3	0
Homoptera	14	58	9	38	1	4	6	0
Lepidoptera	7	35	10	50	3	15	7	1

lished. The success rate against Lepidoptera (35%) and Diptera (20%) was lower. In part, the poor success rate for these orders was due to a failed effort to control the Asian corn borer and the oriental fruitfly. Although numerous species of biocontrol agents were released to control these two species, only one established (Table 1). The success rate was somewhat lower than the success rate against the same orders in Hawaii, but considerably higher than for the continental United States or for California alone (Ehler and Andres, 1983). Presumably the rate of successful introductions was lower than for Hawaii because the introductions were performed with much less effort at evaluation and rearing than is the case for biocontrol agents released in Hawaii. On the other hand, despite the lack of effort, the success rate was high in comparison to continental areas, suggesting, as some have argued, that it may be easier to establish biological control agents on islands.

One of the goals of biological control workers is to understand why some species successfully establish and perform well while other species fail to establish or to exert any meaningful control over their host populations. Knowledge of all the important factors would allow biocontrol workers to better predict which natural enemies would be more likely to be useful and which would not. Unfortunately, no consistent predictors are yet known, although a number of variables which seem to be important have been suggested. Among these variables are genetic diversity, climatic suitability, correctness of host species or biotype and characteristics of the natural enemy. We would like to discuss some of these concepts with respect to the success rates introducing natural enemies to Guam. Our analysis will concentrate on the natural enemies of crop pests since this is a large group and encompasses the majority of the introductions to Guam (76 species). In some cases, we did not have information on all components of the analysis (such as the number released or the origin of the insect): thus, the numbers discussed in each section will not always total 76 species.

The number of organisms needed for release to get establishment is an important variable to know in any biological control program. On one hand, it is expensive and time-consuming to rear or collect natural enemies, but, on the other hand, importing and releasing too few may result in failure of a potentially good natural enemy to establish. Failure could result from too low numbers to overcome natural levels of mortality, to find mates, or from problems associated with low genetic diversity. Potentially, poor genetic diversity could cause the release to fail even after temporary establishment. This could happen if the organism did not have enough adaptability to respond to environmental conditions, to differences in the host, or if inbreeding problems or genetic bottlenecks develop.

We examined the effect of the number of organisms released on whether the introduced natural enemy established permanently or not. If fewer than 100 individuals were released, 18% of the releases established (Table 6). With a higher release rate, a better success rate was apparent, although the success rate did not continue to increase linearly. The release of moderate numbers of organisms, between 100 and 1000, produced as good an establishment rate as releases of large numbers. Release of very few individuals does occasionally result in success and is worth trying if larger numbers are not available. For example, in Egypt *Rodolia cardinalis* established from a release of six individuals (Clausen, 1978).

Matching similar climates is considered to be extremely important in determining whether natural enemies will establish or not. Most biocontrol cases where climatic matching has been a significant factor were in temperate latitudes or in desert climates where extremes of climate such as lethal temperatures or humidity or very seasonal weather were important. We were unable to precisely identify the climatic conditions from where our natural enemies originated as in most cases only the country was given at best. We attempted to examine the issue to some extent by checking to see if beneficials from tropical zones established better than ones imported from other latitudes. This is a very gross comparison, since even within a country in a tropical zone there can be dramatic differences in microclimates which could be highly important. Still some differences were apparent (Table 7). Releases of beneficials imported from temperate latitudes failed to establish permanently in 11 of 12 cases (92%) while releases of beneficials originating from tropical or subtropical latitudes succeeded about 50% of the time.

Another important consideration in biological control is which host to get your natural enemy from and how wide its host range should be. Should the natural enemy come from the same host, or can it come from a closely related host? Is it better to import natural enemies with wide host ranges, or should they be specialized? In terms of establishment rate, the generalized predators (including a carabid, several coccinellids, two tachi-

Table 6. Establishment rate of insects introduced for biological control of crop pests on Guam in relation to the number of organisms released. In some cases only the shipment number is known and the exact number released is not known.

	Establishment status							
	Yes		No		Temporary		Number not evaluated	Present before release
Release number	Number	%	Number	%	Number	%		
<100	2	18	9	82	0	0	2	0
101–500	5	38	6	46	2	15	2	1
501–1000	3	60	2	40	0	0	5	0
>1000	4	29	7	50	3	21	0	0

Table 7. Establishment rate of insects introduced for biological control of crop pests on Guam in relation to climatic factors. Climate is reported in a broad sense as temperate, subtropical, or tropical.

Climatic zone	Establishment status: Yes		No		Temporary		Number not evaluated	Present before release
	Number	%	Number	%	Number	%		
Tropical	18	44	19	46	4	10	12	0
Subtropical	8	57	6	43	0	0	4	0
Temperate	1	8	10	84	1	8	2	1

Table 8. Establishment rate of insects introduced for biological control of crop pests on Guam in relation to the host specificity and the correctness of the host of the organisms released. Insects which are relatively host specific are separated on the basis of being introduced for control of the same species as they came from or for another species which is related but which they have probably not been exposed to before.

Host range of natural enemy	Establishment status: Yes		No		Temporary		Number not evaluated	Present before release
	Number	%	Number	%	Number	%		
Generalist	5	45	6	55	0	0	3	0
Specialized same host	15	56	8	30	4	14	8	1
Specialized different host	3	25	8	67	1	13	3	0

nids, and two trichogrammatids) and the specialists from the same host established at approximately the same rate (Table 8). Specialists taken from one host and released against another, established at a distinctly lower rate. Only three of 12 releases resulted in permanent establishment. One of these was *Tetrastichus brontispae* on *Brontispa palauensis* (and on *B. mariana* in Saipan). *T. brontispae* was collected in southeast Asia from several locations and from several hosts. In Malaysia it was collected from *Plesispa nipae* Maulik and *P. reichei* Chapuis and in Java from *Brontispa longissima javana* Weise and *B. longissima celebensis* Gestro. It was then introduced to Saipan against *B. mariana* and later to Guam for control of *B. palauensis*. Both *Brontispa* species are endemic to Micronesia but *T. brontispae* is not. *B. mariana* occurs on the islands and atolls in the region of Yap and Truk and *B. palauensis* was originally found only in Palau. *T. brontispae* established on both species and provided fairly good control although there are still some seasonal outbreaks. *T. brontispae* is somewhat generalized in that it attacks several species of hispines within the same subfamily and within the genus *Brontispa*. It, however, had not been exposed to the Micronesian species before, but was able to switch and actually may have provided better control of them than of the original hosts. Parasitization rates up to

77% in larvae and 89% in pupae were found in *B. mariana* by Doutt (1950). In *B. palauensis* lower parasitization rates were recorded, generally around 30% but up to 75% (Muniappan et al., 1980), but this is still substantially higher than in the native host where parasitization rates were around 16% (Lange, 1953). Both of these new hosts may have lacked defensive abilities. Certain strains of *B. longissima* are known to be able to kill *T. brontispae* through phagocytic encapsulation and melanization (Tjoa, 1965).

The other two successful introductions originating from different hosts were two parasites, *Encarsia smithi* and *Amitus hesperidum*, taken from *Aleurocanthus woglumi* Ashby in Mexico and successfully used against *A. spiniferus*. However, these may not constitute a switch of hosts. The geographical range of *A. spiniferus* and *A. woglumi* overlap, both originally being southeast Asian species, and both parasites have been taken from *A. spiniferus* within its native range (Clausen, 1978). It is unclear which whitefly host *E. smithi* originated from as shipments of this parasitoid to Mexico came from both Malaya where both hosts occur and the Pakistan area where *A. spiniferus* does not occur. The most likely original of host of *A. hesperidum* was *A. woglumi* as the parasitoid was collected in Pakistan (Clausen, 1978). This suggests that the specific strain of *A. hesperidum* used probably had not been exposed to *A. spiniferus* before. *E. smithi* is the more common parasitoid on Guam.

Of the five generalists which are known to have established, one was rated as providing partial control, another was considered unsuccessful and the rest could not be rated for effectiveness. Among the 18 specialists rated, seven provided a high degree of control, seven a good level, two partial control and two were unsatisfactory.

We also examined the establishment rate of biocontrol agents that were collected in their native environment and released, with the establishment rate of biocontrol agents successfully introduced to a new location, and then transferred to the Marianas. Of the natural enemies brought directly from their native home to the Marianas, 28% established compared to 56% for those species already proven successful at another site (Table 9). Thus, there was a higher establishment rate for natural enemies originating from populations which had already successfully made the transition to a new location.

Among the families of insects introduced for biological control (Table 10), the ones

Table 9. Establishment rate of insects introduced for biological control of crop pests on Guam in relation to the origin of organisms released. Species are grouped as to whether they were transferred directly from the original source area of the pest or if they were a transfer of technology and had already been established in another location, and then brought from that location.

	Establishment status							
	Yes		No		Temporary		Number not evaluated	Present before release
	Number	%	Number	%	Number	%		
Previously successful	20	56	14	39	2	5	10	0
New attempt	7	28	14	56	4	16	9	1

Table 10. Establishment rates of families of parasitic or predacious natural enemies released for biological control of pests attacking crops on Guam.

Order	Family	Establishment status					Target groups
		yes	no	temp	unk	Already present	
Coleoptera	Carabidae	0	0	0	1	0	Lepidoptera
	Coccinellidae	6	4	0	3	0	Homoptera
	Histeridae	1	0	0	2	0	Coleoptera
Diptera	Cecidomyiidae	0	0	0	1	0	Homoptera
	Sciomyzidae	0	0	0	2	0	Unknown
	Tachinidae	1	2	2	2	0	Coleoptera, Lepidoptera
Hemiptera	Miridae	1	0	0	0	0	Homoptera
Hymenoptera	Aphelinidae	3	4	1	0	0	Homoptera
	Braconidae	3	14	1	2	0	Diptera, Lepidoptera
	Chalcidae	1	1	0	0	0	Diptera, Lepidoptera
	Eucoilidae	1	0	0	0	0	Diptera
	Encyrtidae	3	1	0	3	0	Homoptera
	Eulophidae	3	1	1	3	0	Diptera, Coleoptera, Lepidoptera
	Ichneumonidae	0	5	0	2	1	Lepidoptera
	Pteromalidae	0	0	0	2	0	Homoptera, Lepidoptera
	Scelionidae	2	0	0	1	0	Hemiptera, Lepidoptera
	Scoliidae	1	0	0	0	0	Coleoptera
	Trichogrammatidae	1	0	0	1	0	Lepidoptera
Orthoptera	Mantidae	0	3	0	0	0	General predators
Totals		27	35	5	25	1	

with the highest establishment rates were Eulophidae (60%), Encyrtidae (75%) and Coccinellidae (60%). The lowest establishment rate was in the Ichneumonidae (0%), Braconidae (17%), Aphelinidae (38%) and Tachinidae (20%).

Based on the success and failure experienced on Guam in introducing biological control agents, we suggest the following guidelines for importing biological control agents to Pacific Islands in tropical areas. The host from which the natural enemy is collected should be the same as the target host, and the collection should be from tropical or subtropical sources rather than temperate areas. Sufficient material should be sent or collected so that between 200 and 1,000 specimens are available for release. If possible, agents which have been used successfully elsewhere, should be imported from the area where they were used. Although species with broad and narrow host ranges establish about equally well, species which are more specialized will probably produce a higher degree of control and should be preferred over those with a wide host range. Species with very broad host preferences should be avoided as they may cause problems by attacking non-target species. As a first choice, parasites and predators from the families of Coccinellidae, Encyrtidae, and Eulophidae are recommended.

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