A review of entomophagous insects in the Cook Islands

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Abstract

Available information concerning entomophagous insects introduced to the Cook Islands is summarized. Host-parasite associations determined through rearing field-collected insects from Rarotonga and Aitutaki, October 1975, are given; other parasites and predators known to occur in the Cook Islands are listed.

INTRODUCTION

The Cook Islands (Fig. 1) are divided into two distinct groups: the Northern Cooks with 7 atolls and the Southern Cooks with 2 atolls and 8 islands of volcanic origin. Rarotonga, the largest island, has a mountainous interior and peripheral lowland areas of agriculture (Fig. 2).

Information concerning entomophagous insects in the Cooks is sparse: Lever (1938) reported on some beneficial insects sent from Fiji to various Pacific Islands; Dumbleton

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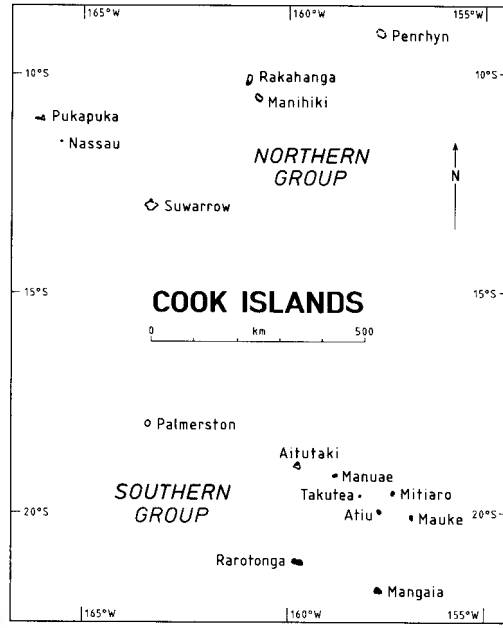
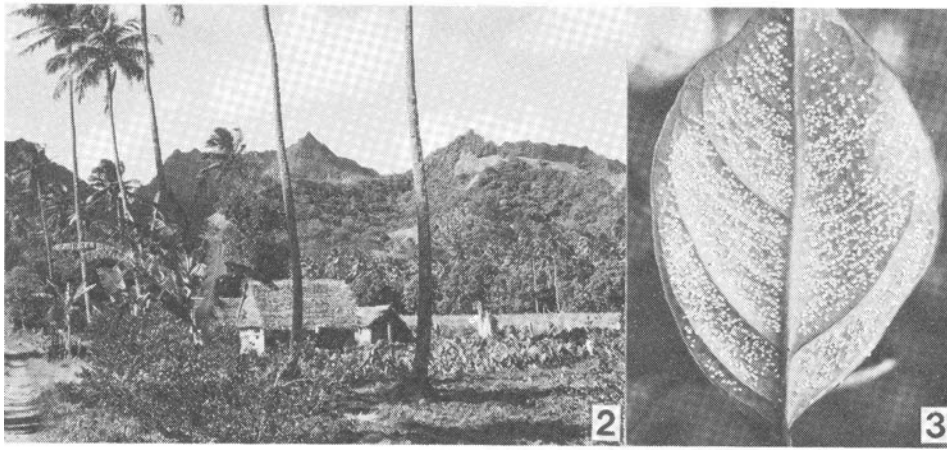


Figs 1-3. 1 (right). Map of the Cook Islands, South Pacific. 2 (below left). Totokoitu, Rarotonga (photograph Deitz). 3 (below right). Heavy infestation of citrus whitefly, *Orchamoplatus mammaeferus*, on orange leaf (photograph Deitz).



(1957) gave an extensive report on the parasites and predators of the South Pacific which included useful information on the Cook Islands; Krauss (1961) listed some insects found on Aitutaki; Taylor (1967) listed 20 species of ants occurring in the Cook Islands; Rao *et al.* (1971) reviewed the biological control of insects in Southeast Asia and the Pacific; and Simmonds (1971) commented on biological control in the Cooks after visiting the islands of Rarotonga, Mangaia, Atiu, Mauke, and Aitutaki. In a world review of literature concerning introduced entomophagous arthropods to 1968, Clausen (1978) gave the biology for many pests and natural enemies discussed here. Marples (1960) reviewed the spider fauna of the Cook Islands and Niue. In addition, several entomologists have mentioned parasites and predators in unpublished [and sometimes undated] reports dealing with the Cook Islands: Dumbleton [1953]; Given [1960a], 1960b, Sankaran 1974a, b, c; and Valentine [1975]. The present paper is based in part on an unpublished report by Walker and Deitz (1977).

In October 1975, the authors were among a party of 4 entomologists from Entomology Division, DSIR, Auckland, who surveyed insects associated with crop pests on Raro-

tonga and Aitutaki. In addition to our general collecting of pests, parasites, and predators, we endeavoured to determine host-parasite associations by rearing host insects collected in the field. The present paper summarizes these rearing studies and the limited information available concerning insect natural enemies in the Cook Islands. Parasites are discussed first, under the pest groups which they attack, then predators are discussed under the taxonomic group to which they belong. The results of our studies are still incomplete because of difficulties in obtaining identifications for some of the material.

The abbreviations "DSIR" and "UNDP" are used after insect names to indicate that specimens are in the collections of Entomology Division or the former United Nations Development Programme/Food and Agriculture Organization, Survey of Agricultural Pests and Diseases in the South Pacific Region, both housed at Entomology Division, DSIR, Auckland.

PARASITES

The earliest known introductions of parasites to the Cook Islands (Table 1) were discussed by Given [1960a] who thoroughly searched local records on Rarotonga and Aitutaki. Although he found correspondence with Hawaii, dating back to 1917, which concerned possible parasite introductions to control fruit fly (*Dacus melanotus* Coquillett), not until 1926 was *Diachasma* (now known as *Opius* sp.) sent from Honolulu, via Auckland, but none reached the Cook Islands. The following year specimens of *Tetrastichus* sp. and *Opius tryoni* Cameron or *O. humilis* Silvestri were sent from Honolulu to Auckland. This time the *Opius* (48 males, 1 female) and 18 *Tetrastichus* (both sexes) were liberated on Rarotonga; however, no specific names were recorded for either parasite [Given 1960a]. Since 1927, hymenopterous parasites have been introduced not only to control fruit fly but also the American cockroach, the green vegetable bug, aphids, mealybugs, scale insects, the diamondback moth, and various noctuid moths (Table 1).

Hymenopterous parasites collected, but not reared, on the Cook Islands in 1975 were: ICHNEUMONIDAE: *Pterocormus "promissorius* Erichson", Rarotonga, *Netelia* sp., Rarotonga, *Opius* sp., Rarotonga, Aitutaki; BRACONIDAE: nr. *Microchelonus curvimaculatus* (Cameron), Rarotonga; *Apanteles* sp(p)., Rarotonga, Aitutaki; EVANIIDAE: *Szepligetella sericea* (Cameron), Aitutaki, *Evania appendigaster* (Linnaeus), Aitutaki; ENCYRTIDAE: *Tachinaephagus ?zealandicus* Ashmead, Rarotonga; PTEROMALIDAE: *Ophelosia* sp., Aitutaki (DSIR). In addition Krauss (1961) found the braconid *Agathis* sp., and the ichneumonid *Idechthis canescens* (Gravenhorst) on Aitutaki.

The host-parasite relationships determined through our rearing studies are summarized in Table 2.

Cockroach parasites

To help control the American cockroach, *Periplaneta americana* (Linnaeus) (Blattodea: Blattidae), the parasite *Ampulex compressa* (Fabricius) was introduced from Hawaii between 1955 and 1958 (Table 1). Given [1960a] reported that by 1956 the cockroach population had declined and *A. compressa* was established. In 1952 *Evania appendigaster* and *Tetrastichus hagenowii* Ratzeburg were also considered for introduction [Given 1960a]. Although we made no attempt to rear parasites from cockroach eggs, the evaniid *Szepligetella sericea* has been collected on Rarotonga, Aitutaki, Mitiaro, Mangaia, and Manuae, and *Evania appendigaster* on Rarotonga (as early as June 1909), Aitutaki and Manuae (DSIR). Krauss (1961) also found *E. appendigaster* on Aitutaki.

Termite parasites

After studying the termite (Isoptera) problem in the Northern Cook Islands, Given (1960b) suggested that parasites [apparently those listed by Thompson (1944:101)] be considered for introduction, but there are no records of any being released.

Green vegetable bug parasites

Given [1960a] reported that in 1944 the egg parasite *Trissolcus basalis* (Wollaston) (as *Microphanurus*), family Scelionidae, was suggested for introduction to the Cook Islands to control the green vegetable bug, *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae). In April 1950, a consignment of *Trissolcus* sp. was sent to Mangaia, possibly from New Caledonia (Table 1). Only 4 surviving adults were liberated, probably an inadequate number for establishment (Rao *et al.* 1971), and to our knowledge, the parasite has not been recovered on Mangaia.

Planthopper parasites

The citrus flatid, *Colgar peracutum* (Walker) (or *C. rufostigmatum* Distant) (Hemiptera: Flatidae), was common on citrus in Rarotonga and Aitutaki during our survey. Like Simmonds (1971), we found no evidence of parasitism.

The taro planthopper, *Tarophagus prosperpina* (Kirkaldy) (Delphacidae), was reported (as *Megamelus*) to have a dryinid parasite in the Cook Islands [Dumbleton 1953]. On Rarotonga we found dryinid larvae attached to the abdomen of the delphacid *Delphacodes muirella* Metcalf on sweet potato, *Ipomoea batatas* (DSIR).

Aphid parasites

Dumbleton [1953] noted parasitism of aphids on taro and the black citrus aphid, *Toxoptera aurantii* (Boyer de Fonscolombe) (Hemiptera: Aphididae). In October 1955 W. Cottier reared *Aphelinus* sp. (DSIR) from the brown citrus aphid, *T. citricidus* (Kirkaldy) on oranges *(Citrus sinensis)* in Rarotonga. Valentine [1975] noted that the parasite *Aphelinus ?gossypii* Timberlake was established in aphid colonies on cucumbers, *Cucumis sativus*. We found this parasite on Rarotonga associated with *Aphis gossypii* Glover on taro and with *Toxoptera* sp. on sweet orange, *Citrus sinensis* (Table 2).

Whitefly parasites

Dumbleton [1953] reported that the citrus whitefly, *Orchamoplatus mammaeferus* (Quaintance & Baker) (Hemiptera: Aleyrodidae) [*Aleuroplatus (Orchamus) samoanus* Laing is a junior synonym], was increasing in importance in the Cook Islands, frequently occurring in large numbers on the underside of citrus leaves (Fig. 3). No parasites of this pest are known to occur in the Cooks (Dumbleton [1953]; Simmonds 1971; Valentine [1975]; our rearing studies). Furthermore, Russell (1958) observed no parasitized individuals among some hundreds of specimens she examined from the Pacific, and Mound and Halsey (1978) recorded no natural enemies for this species. Given [1960a], however, reported that an unidentified disease, probably fungal, attacked the citrus whitefly in the Cooks, often leaving no living individuals. In November 1978, Valentine (pers. comm.) introduced *Encarsia* sp. and *Prospaltella* sp., aphelinid parasites of a related *Orchamoplatus* from Australia; these were released at the Totokoitu Research Station, Rarotonga, for control of the citrus whitefly. Interestingly, Simmonds (1971) found no citrus whitefly on Mauke.

Scale insect parasites

Chaff scales, *Parlatoria* spp. (Hemiptera: Diaspididae), on citrus have been the primary target for biological control in recent years (Table 1). On *Citrus sinensis* we found that *P. cinerea* Doane & Hadden accounted for 94% of the armoured scale infestation on the bark and 60% on the stems; *P. pergandii* Comstock made up most of the remaining population, but other species including *P. citri* McKenzie were also found (Deitz and Walker 1976). Most orchards were heavily infested regardless of treatment and in many cases treated orchards had higher infestations than untreated orchards. Simmonds (1971) found evidence of parasitism on *Parlatoria* and suggested that further parasites and predators be introduced. These introductions were reducing the numbers of *Parlatoria* by 1973 (Simmonds 1974). About 1972, Mr Bullingham's citrus orchard at Titikaveka, Raro-

Table 1. Parasite introductions to the Cook Islands. Information based on: a, Lever 1938 a, b; b, Dumbleton [1953]; c, Dumbleton 1957; d, Given [1960a] e, Simmonds 1971; f, Rao *et al.* 1971; g, Valentine [1975], pers. comm.; h, Sankaran 1974 a-c, 1975, pers. comm.; i, our findings; j, R. L. Hill pers comm. (* = voucher specimens held at DSIR)

PEST · Parasite	INTRODUCTION DETAILS: Liberation Origin	Liberation Site	Liberation Date	KNOWN TO BE ESTABLISHED
FRUIT FLY, *Dacus melanotus*				
Braconidae:				
Opius tryoni (origin Australia) or *O. humilis* (origin Africa) (d,e,g)	via Honolulu	Rarotonga	1927	
Eulophidae:				
Melittobia sp. (formerly *Aceratoneuromyia*) (f)	Fiji	Cook Is	1938	
Syntomosphyrum indicum Silvestri (c)	Fiji	Cook Is	1937-8	
Syntomosphyrum sp. (a,d,e,g)	Fiji (Suva)	Rarotonga	1938	
Tetrastichus giffardianus Silvestri (c,d,e,f,g)	Africa (f) (via Suva)	Rarotonga	1936-8	
Tetrastichus sp. (d,e,f,g)	Honolulu	Rarotonga	1927	
Tetrastichus sp. (a,d,e,g)	Suva	Rarotonga	1937-8	
Chalcididae:				
Dirhinus ?giffardii Silvestri (c,f)	Fiji	Cook Is	1937-8	
Dirhinus sp. (a,d,e,g)	India (a) (via Honolulu & Suva)	Rarotonga	1937-8	
AMERICAN COCKROACH, *Periplaneta americana*				
Evaniidae:				
Ampulex compressa (c,f)	Hawaii	Cook Is (Rarotonga)	1955	yes (f)
Ampulex [*?compressa*] (d,e)	Honolulu	Rarotonga	1955	yes (d)
Ampulex [*?compressa*] (d)		Rarotonga	1958	yes (d)
GREEN VEGETABLE BUG, *Nezara viridula*				
Scelionidae:				
Trissolcus [*?basalis*] (d,e)	Egypt (f), via ?New Caledonia	Mangaia	1950	
APHIDS, MEALYBUGS, SCALE INSECTS				
Aphelinidae:				
Aphelinus sp. (d)	[?N.Z.]	Rarotonga	1928	
			1929	
			1941	yes (d), no (f)
MEALYBUG, "*Pseudococcus* sp."				
Aphelinidae: prob. *Coccophagus gurneyi* Compere (d,e,f)	[?Australia or California, via N.Z.]	Rarotonga	1934	
PURPLE SCALE, *Lepidosaphes beckii*				
Aphelinidae:				
Aphytis "x" (d,e,f)	California	Aitutaki	1954	?yes(f)
CHAFF SCALES, *Paralatoria cinerea* & *P. pergandii*				
Aphelinidae:				
Aphytis hispanicus (g,h)	Ghana (via CIBC Bangalore,h)	Rarotonga	1973-74	yes (g,h,i)
**Aspidiotiphagus citrinus* (g,h)	Ghana (via CIBC Bangalore,h)	Rarotonga	1973-74	yes (g,i)
CITRUS WHITEFLY, *Orchamoplatus mammaeferus*				
Aphelinidae:				
Encarsia sp. (g)	Australia	Rarotonga	1978	
Prospaltella sp. (g)	Australia	Rarotonga	1978	
DIAMONDBACK MOTH, *Plutella xylostella*				
Ichneumonidae:				
Diadegma cerophaga (g)	N.Z.	Rarotonga	1974-75	
Thyraella collaris (g)	N.Z.	Rarotonga	1974-75	yes (g)
Trichogrammatidae:				
Trichogramma spp. (including *evanescens* Westwood) (g)	N.Z.	Rarotonga	1974-75	
ARMYWORM, *Mythimna* sp. (formerly *Leucania* sp.)				
Braconidae:				
**Aparteles ruficrus* (Haliday) (j)	N.Z.	Rarotonga	1976	
ARMYWORM AND CUTWORM MOTHS				
Trichogrammatidae:				
Trichogramma australicum Girault (g)	N.Z.	Rarotonga	1974	
T. dendrolimi Mats. (g)	N.Z.	Rarotonga	1974	
T. evanescens Westwood (g)	N.Z.	Rarotonga	1974	
T. euproctidis (Girault) (g)	N.Z.	Rarotonga	1974	
Trichogramma sp. (g)	N.Z.	Rarotonga	1974	
GREEN LOOPER, *Chrysodeixis eriosoma*				
Encrytidae:				
Litomastix sp. (g)	N.Z.	Rarotonga	[1974]	yes (i)

Table 2. Summary of hymenopterous parasites reared, Cook Islands, October 1975. (* = new parasite records for the Cook Islands)

PARASITE	HOST	PLANT	ISLAND
ICHNEUMONIDAE			
**Diplazon laetatorius* (Fabricius)	*Allograpta amphotera* or *Isichiodon scutellaris* (Diptera: Syrphidae)	*Citrus sinensis*, *Citrullus lanatus*, *Cucumis* sp.	Rarotonga, Aitutaki
SCELIONIDAE			
*nr. *Telenomus* sp.	*Spodoptera litura* (Lepidoptera: Noctuidae)	unidentified	Rarotonga
CYNIPIDAE			
Eucoilinae: unidenfied species	*Liriomyza brassicae* (Diptera: Agromyzidae)	*Brassica* sp.	Rarotonga
ENCYRTIDAE			
**Microterys flavus* Howard	*Kilifia acuminata* (Signoret) or *Coccus viridis* (Green) (Hemiptera: Coccidae)	*Plumeria rubra*	Rarotonga
THYSANIDAE			
**Thysanus ?flavopalliatus* (Ashmead)	*Parlatoria cinerea* (Hemiptera: Diaspididae)	*Citrus sinensis*	Rarotonga
	Kilifia acuminata (Signoret) or *Coccus viridis* (Green) (Hemiptera:Coccidae)	*Plumeria rubra*	Rarotonga
EULOPHIDAE			
**Hemiptarsenus ?semialbiclava*	*Liriomyza brassicae* (Diptera: Agromyzidae)	*Brassica oleracea*	Rarotonga, Aitutaki
APHELINIDAE			
Aphelinus ?gossypii	*Toxoptera* sp. (Hemiptera: Aphididae)	*Citrus sinensis*	Rarotonga
	Aphis gossypii (Hemiptera: Aphididae)	*Colocasia* sp.	Rarotonga
Aphelinus sp.	*Aphis gossypii* (Hemiptera: Aphididae)	*Colocasia* sp.	Rarotonga
Aphytis ?hispanicus	*Parlatoria cinerea* or *P. pergandii* or both (Hemiptera: Diaspididae)	*Citrus sinensis*	Rarotonga, Aitutaki
Aphytis sp(p).	Unidentified (Hemiptera: Diaspididae)	*Musa* cultivar	Aitutaki
Aspidiotiphagus citrinus	*Parlatoria cinerea* or *P. pergandii* or both (Hemiptera: Diaspididae)	*Citrus sinensis*	Rarotonga, Aitutaki
	Diaspis bromeliae (Kerner) (Hemiptera: Diaspididae)	*Ananas comosus*	Aitutaki
	Parasaissetia nigra (Nietner) (Hemiptera: Coccidae)	*Hibiscus* sp.	Aitutaki
Aneristus sp.	*Kilifia acuminata* (Signoret) or *Coccus viridis* (Green) (Hemiptera: Coccidae)	*Plumeria rubra*	Rarotonga
	Coccus viridis (Green) (Hemiptera: Coccidae)	*Coffea liberica*	Rarotonga
	Coccus viridis (Green) (Hemiptera: Coccidae)	*Gardenia* sp.	Rarotonga, Aitutaki
DRYINIDAE			
unidentified	*Delphacodes muirella* (Hemiptera: Delphacidae)	*Ipomoea batatas*	Rarotonga

tonga, was set aside for the establishment of parasites and predators: *Aspidiotiphagus citrinus* (Craw) was released between January and March 1974 and *Aphytis hispanicus* Mercet between January and September 1974 (Sankaran 1974a, b, c). In November 1974, Valentine [1975] recovered both parasites on Rarotonga, and in early 1975, Sankaran also reported that *A. hispanicus* had been recovered from *Parlatoria* on Rarotonga. We found these parasites were widespread on both Rarotonga and Aitutaki by October 1975. Valentine [1975] noted that inadequate, erratic, and poorly timed pesticide applications can disrupt the natural enemy complex resulting in a resurgence of the scale population. Recent observations suggest that this is the situation in the Cooks (Valentine [1975]; Deitz and Walker 1976).

The purple scale, *Lepidosaphes beckii* (Newman) (Hemiptera: Diaspididae) has also had much attention. Dumbleton [1953] reported it having a hymenopterous parasite. In 1954 a parasite, *Aphytis* "x", was introduced from California to Aitutaki [Given 1960a], probably liberated during Cottier's visit. Given [1960a] found heavy parasitism of purple scale on neglected citrus and mango, *Mangifera indica,* during his visit. Simmonds (1971), also finding purple scale with parasite holes, speculated that these may have resulted from the liberation of *Aphytis* in 1954, and Rao *et al.* (1971) stated that *Aphytis* had probably established although no reliable determination had been made. We reared no purple scale but did recover *Aphytis* sp(p). from several scale insects (Table 2).

The pineapple scale, *Diaspis bromeliae* (Kerner) is parasitized by *Aspidiotiphagus citrinus* on Aitutaki (Table 2). Simmonds (1971) also reported a parasite of "*?Diaspis bromeliae*" on pineapple, *Ananas comosus,* in Mangaia. *Aphytis ?hispanicus* occurs in association with Boisduval's scale, *Diaspis boisduvalii* Signoret, on pineapple (DSIR).

Dumbleton [1953], noted a parasite on *Pinnaspis strachani* (Cooley) (Hemiptera: Diaspididae) on dadap, *Erythrina subumbrans,* and Valentine [1975] reported that on citrus *Parasaissetia ?nigra* (Nietner) (as *Saissetia*), family Coccidae, seemed to be parasitized by a *?Coccophagus* sp. In November 1978, Valentine (pers. comm.) recorded *Aneristus* sp. (Aphelinidae) and *Encyrtus* sp. (Encyrtidae) from *Saisettia* sp. on citrus (DSIR).

Parasites of Lepidoptera

The flower moths, *Eurhodope ardescens* Meyrick (as *Cryptoblabes plagioleuca* Turner) (Pyralidae) and *Prays* sp. nr. *parilis* Meyrick, (Yponomeutidae) have no known natural enemies in the Cook Islands (Dumbleton [1953]; Given [1960a]; Simmonds 1971; Valentine [1975]).

Simmonds (1971) reared *?Telenomus* sp. from eggs masses of *Spodoptera litura* (Fabricius) (Noctuidae). A parasite near *Telenomus* sp. was also recovered from *Spodoptera* eggs by P. T. Joseph on Rarotonga in October 1970 (DSIR). On Aitutaki we also observed a chelonine braconid apparently parasitizing *Spodoptera* egg masses on two occasions in October 1975, but attempts to rear the *Spodoptera* larvae failed. Valentine [1975] introduced *Trichogramma* spp. for the control of armyworm and cutworm moths (Table 1).

The diamondback moth, *Plutella xylostella* (Linnaeus) (Yponomeutidae), badly infests cabbage crops in the Cooks. Neither Simmonds (1971), nor Valentine [1975] observed parasites during their visits. In 1974 Valentine [1975] liberated the ichneumonid parasites *Diadegma cerophaga* (Gravenhorst) and *Thyraeella collaris* (Gravenhorst) (Table 1). The latter was recovered from the diamondback moth on Rarotonga in November 1978 by E. W. Valentine (DSIR), but *D. cerophaga* has not been recovered.

In 1974 *Litomastix* sp. was released to control the green looper, *Chrysodeixis eriosoma* (Doubleday) (Noctuidae), formerly known as *Plusia chalcites* (Esper), and was recovered from *C. eriosoma* on Rarotonga in April 1977 by P. A. Maddison (UNDP) (Table 1).

Fruitfly parasites

For the control of the fruit fly, *Dacus melanotus* (Diptera: Tephritidae), braconids,

eulophids, and chalcids were introduced from 1929 to 1938 (Table 1). Given [1960a] found no definite evidence of the establishment of parasites, but neither did he find much evidence of the pest between September and November 1960. He did collect 2 species of parasitic Hymenoptera searching infected fruit, which, together with the other Hymenoptera he collected, were unfortunately lost after his return to New Zealand [Given 1960a]. Although we reared no parasites from a large sample of infested fruit in 1975, we recovered an *Opius* sp. and a dirhinine chalcid from the field. As voucher specimens of early introductions are not available, we are unable to determine whether these were the parasites introduced prior to 1938.

Leafminer parasites

We reared the eulophid, *Hemiptarsenus ?semialbiclava* (Girault), and an unidentified cynipid from the serpentine leafminer, *Liriomyza brassicae* (Riley), on cabbage (Table 2).

PREDATORS

The earliest introductions of predators to the Cook Islands were made from 1937 to 1940 when the histerid beetle *Plaesius javanus* Marseul was introduced from Fiji to control the banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae). Since 1939 coccinellids have been introduced to control mealybugs, purple scale, and more recently chaff scales (Table 3). Other predators were suggested, but not introduced (Given [1960a]): a coniopterygid (Neuroptera) and *Typhlodromus* sp. (predacious mite), both suggested as controls for citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), and *Catoblema dubia* Butler, a noctuid predator suggested as a control for scale insects.

Table 3. Predator introductions to the Cook Islands. Information based on: a, Lever 1938a,b; b, Dumbleton [1953]; c, Dumbleton 1957; d, Given [1960a]; e, Krauss 1961; f, Simmonds 1971; g, Rao *et al.* 1971; h, Sankaran 1974 a-c, pers. comm.; i, Valentine [1975], pers. comm.; j, our findings. (* = vouchers specimens held at DSIR)

PEST	INTRODUCTION DETAILS			KNOWN TO BE ESTABLISHED
Predator	Origin	Liberation Site	Date	
BANANA WEEVIL, *Cosmopolites sordidus*				
Histeridae:				
Plaesius javanus (a,g)	Fiji	Cook Is	1937	yes (b,d,g,j)
**P. javanus* (b,c,f,g)	Java (via Fiji)	Cook Is	1938-40	
P. [*?javanus*] (d)	(Fiji,Suva)	Rarotonga	1938	
P. [*?javanus*] (d)	(Fiji,Suva)	[?Rarotonga]	1940	
PURPLE SCALE, *Lepidosaphes beckii*				
Coccinellidae:				
Chilocus bipustulatus (d,g)	California	Aitutaki	1954	?yes (d,g)
MEALYBUGS, "*Pseudococcus* spp."				
Coccinellidae:				
Cryptolaemus montrouzieri (c)	N.Z.	Cook Is	1939	yes (c,e,j)
CHAFF SCALES, *Parlatoria cinerea* & *P. pergandii*				
Coccinellidae:				
**Sticholotis madegassa* (i)	Reunion (via CIBC Bangalore,h)	Rarotonga	1973	yes (f,h,j)
**Lindorus ?lophanthae* (i)	Australia (via Reunion & CIBC Bangalor, h)	Rarotonga	1973	yes (f,j)
Chilocorus schioedtei (i)	CIBC Bangalore	Rarotonga	1973	
Rodolia pumila (i)	New Caledonia	Rarotonga	1974	

Odonata

The following species have been collected from the Cook Islands: *Ischnura aurora* (Brauer), Rarotonga; *Agriocnemis exsudans* Selys-Longchamps, Rarotonga; *Pantala flavescens* (Fabricius), Rarotonga; *Anax guttas* (Burmeister), Rarotonga; *Diplacodes bipunctata* (Brauer), Rarotonga (DSIR).

Orthoptera: Tettigoniidae

Phisis ?holdhausi Karny (Fig. 4), a large (30 mm), green, longhorn grasshopper with spectacular interlocking spines on the forelegs is apparently predacious (Buxton *in* Chopard 1929). L. M. Pitkin (pers. comm.), who identified our 3 Rarotongan specimens from citrus (DSIR), was uncertain whether *P. holdhausi* is a distinct species or a form of *P. pallida* (Walker).

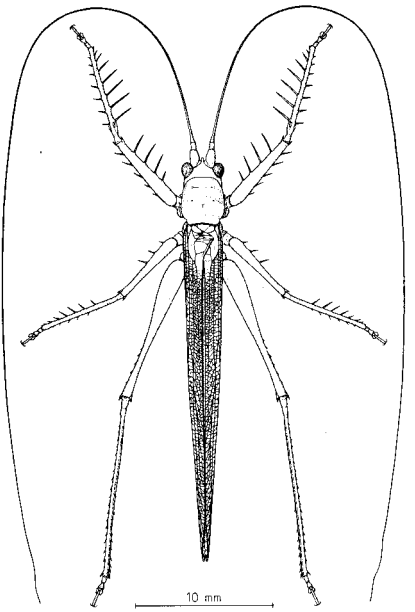


Fig. 4. *Phisis ?holdhausi* Karny, dorsal aspect, female.

Hemiptera

Although no introductions of predacious Hemiptera to the Cook Islands are recorded, the following species have been collected: ANTHOCORIDAE: *Amphiareus constrictus* (Stål), Rarotonga, Aitutaki, *Buchananiella soldalis* (White), Rarotonga, and *Lasiochilus* sp., Rarotonga; NABIDAE: *Alloeorhynchus* sp., Rarotonga, and *Nabis capsiformis* Germar, Rarotonga, Aitutaki; PENTATOMIDAE: *Oechalia schellembergii* (Guérin-Méneville), Aitutaki, and *Platynopus melacanthus* (Boisduval), Rarotonga, Aitutaki; and REDUVIIDAE: *Empicoris minutus* Usinger or *E. rubromaculatus* (Blackburn), Rarotonga, *Oncocephalus pacificus* Kirkaldy, Rarotonga, and *Peregrinator biannulipes* (Montrouzier and Signoret), Rarotonga (DSIR).

Thysanoptera

Karynothrips melaleucus (Bagnall) and *Aleurodothrips fasciapennis* (Franklin) were collected (Maddison pers. comm.) in November 1975, at Titikaveka, Rarotonga, on grapefruit *(Citrus paradisi)* and mango respectively. Zimmerman (1948) noted that both these thrips are evidently predators in Hawaii.

Neuroptera: Chrysopidae

The following chrysopids have been found in the Cook Islands: *Chrysopa basalis* Walker, Rarotonga, Aitutaki; *C. oceanica* Walker, Rarotonga; *C. ramburi* Schneider, Aitutaki; and *C. otalatis* Banks, Rarotonga (UNDP, DSIR). The common species *C. basalis* was found in association with citrus orchards and trees. Valentine (pers. comm.) recently observed chrysopid larvae apparently feeding on immature *Orchamoplatus mammaeferus* on Rarotonga.

In the early 1950's enquiries were made regarding the possibility of using a coniopterygid to control citrus rust mite [Given 1960a], but there are no records of any introductions.

Coleoptera: Histeridae and Coccinellidae

The histerid beetle, *Plaesius javanus,* was introduced into the Cook Islands from Fiji (1937-40) to control banana weevil, *Cosmopolites sordidus* (Table 3). Given [1960a] and Rao *et al.* (1971) noted that although well established on Rarotonga, *Plaesius* did not effectively control *Cosmopolites.* Voucher specimens (DSIR) from a shipment of *"Plaesius javanus"* from Suva to the Cook Islands (1940) show that actually 2 species were introduced: *P. javanus* and *Hyposolenus laevigatus* (Marseul), a similar histerid also described from Java. Recent collections indicate that both species still occur in the Cook Islands (DSIR). Jepson (1914) recorded only *P. javanus* as being introduced into Fiji from Java; we have seen no voucher specimens of this introduction, but both species were probably introduced to Fiji at that time.

The coccinellid *Chilocorus bipustulatus* (Linnaeus) was introduced in 1954 to control purple scale (Table 3). Given [1960a] and Rao *et al.* (1971) suggested it was then well established on Aitutaki although no reliable determinations were made. Krauss (1961) reported 4 other coccinellids from Aitutaki but not *C. bipustulatus.* Simmonds (1971) found no records of recovery, and the DSIR and UNDP collections have no specimens of *C. bipustulatus* from the Cook Islands. Records at the Totokoitu Research Station, Rarotonga, state that 6 specimens of *C. schioedtei* Mulsant were released at Rarotonga in August 1973 (Table 3).

The coccinellid *Cryptolaemus montrouzieri* Mulsant, introduced in 1939 to control mealybugs (Table 3), is widely established (DSIR collection). Specimens of *C. montrouzieri* were collected in the Cook Islands in 1935 (Given [1960a], Rao *et al.* 1971) establishing its presence prior to the 1939 release.

Sticholotis madegassa (Weise) and *Lindorus ?lophanthae* Blaisdell were liberated on Rarotonga in 1973 (Table 3). Sankaran (1975) noted that a coccinellid, probably *S. madegassa,* had been recovered on citrus trees. We found *S. madegassa* in the orchard at Titikaveka set aside for the establishment of parasite and predators and in an adjacent orchard (DSIR); in April 1977 a specimen was recovered by P. A. Maddison on a leaf of *Acalypha hispida* at Avarua, the opposite side of the island (UNDP). *L. ?lophanthae* was not found in any citrus orchard, but 1 specimen was recovered from sweet potato leaves, *Ipomoea batatas,* at Totokoitu, Rarotonga, in 1975 (DSIR).

According to Simmonds (1971), *Rodolia cardinalis* (Mulsant) was said to have been introduced to control *Icerya seychellarum* (Westwood) (Hemiptera: Margarodidae) in the Cook Islands. Although we have found no definite record of its introduction, this coccinellid has established on Aitutaki (Krauss, 1961 and UNDP collection) and in low numbers on Rarotonga (1 specimen, 1974, DSIR: another 1937, C. E. Clarke collection, Auckland Institute and Museum). Records at the Totokoitu Research Station, Rarotonga, state that in March 1974, Balbernie released *Rodolia pumila* Weise on Rarotonga (Table 3).

Because of the seriousness of citrus rust mite, *Phyllocoptruta oleivora*, Simmonds (1971) urged that consideration be given to the introduction of *Stethorus* spp. (Coccinellidae) and predacious mites. Yet Simmonds (1971) and Valentine [1975] held little prospect for effective biological control as previous efforts elsewhere had proven unsuccessful. Although there are no records of *Stethorus* species being introduced, we collected 3 specimens of *Stethorus* sp. (DSIR) from citrus trees on Rarotonga. Simmonds (1971) speculated that there could be some degree of natural control of citrus rust mite by a parasitic fungus.

Dumbleton [1953] recorded *Coccinella repanda* Thunberg (as *transversalis* Fabricius) and *Scymnodes lividigaster* Mulsant (as *Platyomus*) associated with black citrus aphid, *Toxoptera*

aurantii. We found these coccinellids and other predators associated with colonies of the aphid *T. citricidus* on *Citrus sinensis* in Rarotonga: COCCINELLIDAE: *Scymnodes lividigaster, Coccinella repanda, Coelophora inaequalis* (Fabricius); CHRYSOPIDAE: *Chrysopa basalis;* SYRPHIDAE: a larva, either *Allograpta amphotera* (Bezzi) or *Ischiodon scutellare* (Fabricius); (and FORMICIDAE: *Pheidole fervens* Fr. Smith, an ant which feeds on aphid honeydew). Valentine [1975] found a similar range of predators associated with citrus aphids on Rarotonga. Krauss (1961) listed *Coccinella repanda* and *Scymnodes* sp. from Aitutaki. P. A. Maddison recently collected *C. repanda* feeding on *Icerya* sp. on Aitutaki, and *Coelophora inaequalis* feeding on aphids on Atiu (UNDP).

Other coccinellids known to occur in the Cook Islands are *Harmonia arcuata* (Fabricius), Aitutaki and Rarotonga, and *"Scymnus" ?sedatus* Broun, Aitutaki (DSIR, UNDP). Two other unidentified species have been found on Aitutaki (UNDP).

Diptera: Syrphidae

Krauss (1961) listed the syrphid *Ischiodon scutellaris* (as *Xanthogramma*) from Aitutaki. We reared, from pupae, adult syrphids which have been identified as *I. scutellaris* and *Allograpta amphotera* and also observed unidentified syrphid larvae feeding on citrus aphids.

Hymenoptera: Formicidae, Sphecidae and Vespidae

Ants (Formicidae) are among the insects whose status as predators is not easily determined, some being herbivores or general feeders. Krauss (1961) listed 2 species of ants from Aitutaki, and Taylor (1967) listed 20 species from the Cook Islands. Presently a total of 31 species are known (islands listed are new records): *Anochetus graeffei* Mayr; *Anoplolepis longipes* (Jerdon); *Cardiocondyla emeryi* Forel; *C. nuda* (Mayr); *Hypoponera eduardi* (Forel), Rarotonga; *H. punctatissima* (Roger), Rarotonga; *Leptogenys falcigera* Roger, Aitutaki; *Monomorium floricola* (Jerdon), Aitutaki; *M. minutum* Mayr, Aitutaki; *M. pharaonis* (Linnaeus), Rarotonga; *M. talpa* Emery, Rarotonga; *Paratrechina (Nylanderia) bourbonica* (Forel), Rarotonga, Aitutaki; *P. (N.) vaga* (Forel); *Pheidole fervens* Fr. Smith; *P. megacephala* (Fabricius); *P. oceanica* Mayr; *P. umbonata* Mayr, Rarotonga; *Plagiolepsis alluaudi* Emery, Rarotonga; *Ponera tenuis* (Emery), Rarotonga, Aitutaki; *Rogeria sublevinodis* Emery, Rarotonga; *Solenopsis geminata* (Fabricius), Mangaia; *Strumigenys godeffroyi* Mayr, Rarotonga; *S. rogeri* Emery, Rarotonga; *Tapinoma melanocephalum* (Fabricius); *T. minutum* Mayr, Rarotonga, Aitutaki; *Technomyrmex albipes* (Fr. Smith), Aitutaki; *Tetramorium guineense* (Fabricius), Rarotonga; *T. pacificum* Mayr; *T. simillimum* (Fr. Smith); and *T. tonganum* Mayr, Rarotonga (all DSIR identified by Taylor); and also *Triglyphothrix striatidens* (Emery) (Taylor, 1967).

Krauss (1961) listed a number of predatory wasps from Aitutaki: SPHECIDAE: *Pison hospes* Smith and *Sceliphron caementarium* (Drury); VESPIDAE: *Pachodynerus nasidens* (Latreille), *Pachymenes bicinctus* (Fabricius), *Polistes olivaceus* (De Geer), and *Rygchium rufipes* (Fabricius). He also reported *"Polistes macaensis* (Fabricius)?" which is now considered to be a junior synonym of *P. olivaceus* (P. A. Maddison, pers. comm.). Nevertheless specimens in the DSIR collection indicate that a second species of *Polistes* occurs in the Cooks. DSIR also holds specimens of a sphecid, *Tachysphex* sp., from Aitutaki and Rarotonga.

Araneae

Marples (1960) listed 31 species (13 families) of spiders from the Cook Islands: Rarotonga, 13 species; Pukapuka, 8; Aitutaki, 24; Mangaia, 10; Rakahanga, 4; Manihiki, 3; and Penrhyn, 1. The Cook Island spiders in the collections of Entomology Division have not been identified.

CONCLUSIONS

Need for voucher specimens and permanent records of all introductions became obvious during the preparation of this review. Without a series of preserved specimens of the insects actually introduced it is often impossible for future workers to determine whether they have established (Yoshimoto 1978). Some of the Cook Island introductions (Tables 1 and 3) were only identified to the generic level, others may have been incorrectly identified, and it is likely that additional specimens were liberated with no record at all. Few of the parasites (Table 1) are definitely known to have established, partly because of the lack of voucher specimens. The introduced predators (Table 3) are better represented by voucher specimens, and thus it is easier to determine if species have established. The voucher specimens of *Plaesius javanus* show that actually 2 predacious beetles were introduced under that name. It would be helpful if voucher specimens of all future introductions to the Cook Islands were deposited with the UNDP/FAO-SPEC collection at DSIR, Auckland.

The full range of natural enemies now present in the Cook Islands can be determined only through intensive survey and rearing. Even in our brief study we reared hymenopterous parasites from field collected pests which are apparently new records for the Cooks (Table 2).

Furthermore, a review of previous work on entomophagous insects in the Cook Islands shows that several aspects have been largely neglected. No attempts have been made to acquire quantitative data on entomophagous species present or to determine their effectiveness on pest populations. Also, the disruptive effect of pesticides on the natural enemy complex needs examination, particularly with respect to the control of *Parlatoria* spp. on citrus. In this connection it is essential that the untreated orchard set aside for the establishment and monitoring of introduced parasites and predators be retained. Clearly, much additional study is needed to realize the maximum benefit from natural enemies in protecting the crops of the Cook Islands.

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Corrigendum

New Zealand Entomologist 6(4), 1978, page 381, bottom line. Correspondence regarding the late Dr J. S. Armstrong's paper should be addressed it: PHILIP S. CORBET, Department of Zoology, University of Canterbury, CHRISTCHURCH, New Zealand.