

Biological Control Introductions in the Caroline and Marshall Islands¹

ILSE SCHREINER²

ABSTRACT

Numerous introductions of natural enemies of insects, weeds and other organisms have taken place in the Caroline and Marshall islands, especially since 1945. *Rodolia pumila* and several other species of coccinellids have been widely distributed for control of *Teerya* spp. and *Aspidiotus destructor*. Many of these species successfully established on the high islands of Micronesia. On atolls, sketchy information suggests that *R. pumila* established, dramatically reduced populations of fluted scales, and then became extinct. Periodic reintroductions seem necessary to maintain these predators on atolls. Other successful introductions include a variety of predators and parasites for control of *Oryctes rhinoceros* including a virus, several parasitic Hymenoptera directed against Aleyrodidae, predatory snails for control of giant African snail, and a variety of insects for the control of lantana and clidemia. Though many of the biological control agents are known to have established, little information is available as to their impact on target pests.

The Caroline and Marshall Islands consist of many small islands scattered across a huge expanse of the Pacific Ocean. To a large extent, the inhabitants still depend on traditional staple crops for their food. Because of a lack of equipment, materials and skills, local growers do not generally use pesticides. In this century, increased contact with the outside world has resulted in the introduction of a variety of serious new pests (Esaki 1952, Muniappan 1983, Schreiner and Nafus 1986). In order to enable island farmers to continue to farm successfully, it has been clear to the various occupying governments that biological control introductions were necessary. During the Japanese mandate prior to WWII, the Japanese are known to have introduced several coccinellid beetles (Esaki 1940, 1952, Beardsley 1955). The number of introductions increased considerably after the war during the American occupation. The Trust Territory entomologists were to a large extent concerned with obtaining and redistributing biological control agents around the area, an effort which continued until the late 1970s. In recent years, with the breakup of the Trust Territory into separate states, the responsibility for biological control has passed to the local agriculture departments. Because they have little entomological expertise, the pace of introductions has decreased in recent years, as requests for help are only generally made when problems are very serious.

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²College of Agriculture and Life Sciences, University of Guam, Mangilao, Guam 96923.

Although the biological control introductions occurring immediately postwar are documented in scattered literature, those occurring later generally are not. As I recently had an opportunity to examine the files of the Trust Territory entomologists, I felt that it was important to summarize the voluminous but scattered information on introductions and establishment, before it became unavailable. Additional information was also obtained from the records of the University of Guam entomologists and from the Department of Agriculture in Hawaii which has maintained records of shipments of parasites and predators from their department to this region.

A variety of organisms have been the targets of biological control introductions in the Micronesian area. These include insect pests of crops, arthropods of medical importance, two species of weeds as well as a snail and a rat.

AGRICULTURAL PESTS

Margarodid scales (*Icerya* spp.). Numerous outbreaks of the scales *Icerya aegyptiaca* (Douglas) and *I. seychellarum* (Westwood) have been reported from the islands of Micronesia in the last 40 years. The principal economic plant affected is breadfruit, which is one of the most important staple crops in Micronesia, and particularly important on the atolls. Several species of *Rodolia* ladybeetles have been introduced to the area to control *Icerya* species. *R. breviscula* Weise was collected in India and sent to Majuro (Marshall Islands) in 1948, but apparently did not establish. *R. cardinalis* (Mulsant) was introduced to Kwajalein and Likeap atolls (Marshall Islands) in 1958, but also did not establish.

The introduction of *R. pumila* Weise was more successful. This ladybeetle is thought to have been introduced into Micronesia by the Japanese (Beardsley 1955), probably from Taiwan. Little information is available as to where they did their releases, though an informant was found in the 1950s who recalled a red beetle being released by them in Losap (Mortlock Islands, Truk state) (Beardsley 1955). Over the next 30 years, the beetle was reared in Palau and numerous shipments of 20-300 beetles were sent primarily to various atolls in the region. Due to the isolation of these atolls, scanty information is available as to the success of these introductions. The releases and establishment of *R. pumila* were reviewed by Beardsley (1955) for the period up until 1954, and later information was obtained from the files of the Trust Territory entomologist. Many of the later reports concerning establishment are based on unconfirmed reports by the local administrations, and were not verified by an entomologist. A summary of all the introductions is listed in Table 1.

R. pumila was established on most of the high islands of Micronesia by the 1950s (Chapin 1965). *Icerya* spp. are no longer serious pests on these islands. The introduction of the beetle to the high island of Kosrae in 1977 was also successful. As margarodid scales are now uncommon on Kosrae (D. Nafus, pers. comm. 1986), the beetle appears to provide excellent con-

TABLE 1. Introductions of *Rodolia pumila* to the Caroline and Marshall Islands.

Release site	Source	Year	Establishment status
Yap State			
Ulithi	Saipan	1948	found in 1957, but serious scale outbreak reported in 1964 established, but serious scale outbreak reported in 1984
	Palau	1954	
	Palau	1964	
Fais	Palau	1954	not known
	Ulithi	1971	not known
Truk State			
Losap (Mortlocks)	?	pre WWII	yes (Beardsley 1955)
Pis (Truk)	Rota	1947	yes (Beardsley 1955)
Nama (Mortlocks)	Pis	1950	not known
		1954	yes (Beardsley 1955), then reported extinct
Nomwin	Palau	1964	not known
		1953	yes (Beardsley 1955)
Namoluk	Palau	1960	not known
Mortlocks	Palau	1964	not known
Pohnpei State			
Ngetik	Palau	1970	not known
Kosrae State			
Kosrae	Palau	1976	died in transit
	Palau	1977	yes, specimen collected in 1984
Marshall Islands			
Kwajalein	Guam	1949	yes, then disappeared (Beardsley 1955)
	Palau	1953	found in 1958
	Palau	1965	not known
	Palau	±1980s	not been seen in over a year in 1987 (R. West pers. comm.)
Ailinglaplap Jaluit	Guam	1949	reported yes (Beardsley 1955)
	Palau	1953	reported yes (Beardsley 1955)
		1954	no
	Palau	1958	no
	Palau	1961	yes, then typhoon removed them
Lae	Palau	1964	yes
	Palau	1953	not known
Majuro	Kwajalein	1963	no
	Palau?	1964	yes, but declined even before scales gone. Perhaps found in 1970
	Palau	1971	
	Palau	1972	yes
	Palau	1980s	not known
Rongelap	Palau	1972	reported yes, scale outbreak reported later
	Palau	1977	not known
Aur	Palau	1977	not known
	Palau	1977	not known

trol of fluted scales. On atolls, *R. pumila* appears to have been less successful. Because of the lack of follow-up in the region, it is difficult to determine why it has been necessary to send repeated shipments of this beetle to some atolls, despite their apparent successful establishment. Misidentifications of the pest species and lack of pre-shipment surveys for the predator may be causes. However, it is possible that the beetles were over-efficient on small islets, some of which have areas of only a few acres, and were unable to maintain their populations once they reduced the scales to very low levels. Typhoons may have compounded the problem of maintaining a viable population.

Aspidiotus destructor Signoret (Diaspididae) — the transparent scale. Another major focus of Trust Territory entomologists was control of the transparent scale and other diaspidid scales throughout the islands of Micronesia. The transparent scale seriously damages coconut, breadfruit and other important staple crops. A variety of coccinellids were introduced to Palau or to Saipan, mass reared by the Trust Territory entomologist, and then redistributed to the other islands. Although most of the species reared are known to be effective predators of the transparent scale, it appears from shipment records that they were not sent in specific response to reported problems. Instead, any beetle that appeared to be useful for control of scale insects was widely distributed around the region. As in the case of the *Rodolia* beetles, shipments of 100-300 beetles were sent to the islands and immediately released, with no attempt to mass rear them in their new home.

The transparent scale first became important in Pohnpei in 1939. At that time the coccinellid *Telsimia nitida* Chapin was sent there from Saipan (Esaki 1952). It was collected on Pohnpei in 1952, and was present throughout the larger islands of Micronesia in the 1950s (Chapin 1965). This tiny beetle was also released on Satawan (Mortlock Islands) in 1961, but was not found in 1964.

Pseudoscymnus anomalus Chapin was first noted in 1962 on Moen, Truk, feeding on *Aspidiotus*. It was sent to the Mortlocks that year where it was apparently successful. In 1964 it was found still present on some of the Mortlock islands. Beetles were collected on Pohnpei in 1965 and sent to the Mortlocks, presumably to be released on some of the other atolls than the sites of the original releases. *P. anomalus* was taken to Palau and Yap in 1962. In 1976 this beetle was found established on Yap and feeding on *A. destructor*, which it was said to be controlling. However, the scale was noted to be quite abundant in Yap in 1986 (D. Nafus, pers. comm. 1986). The beetle is also known to be established in Palau. *P. anomalus* was released in Kapingi-Marangi in 1987. A report by Demei, in the entomologist's files, notes that this species may be over-efficient on atolls and not able to persist there.

Azya trinitatis Marshall and *Cryptognatha nodiceps* Marshall were sent directly from Trinidad to Moen in 1960. They were alive and in good condition when they were released, but no information is available as to whether they established.

Rhizobius satelles (Blackburn), thought to be *Lindorus lophanthae* Blaisdell at the time, was introduced to Palau from Vanuatu in 1966. It established there and was then mass reared and sent to Yap, Truk (probably Moen) and the Mortlocks in 1968, and again to Truk and the Mortlocks in 1980. No information is available as to whether the beetles established on these islands.

The Trust Territory files record shipments of *Chilocorus nigritus* (F.) to the Mortlocks in 1971, Truk in 1974 and Pohnpei in 1980. I was not able to determine whether this beetle was purposefully introduced into Micronesia, though it was not here in the 1950s (Chapin 1965). It was apparently first recorded from Saipan in the Mariana Islands, and later also on Guam, though there are no records of it having been released in either location. It was reported as established on Palau in 1977. I observed this beetle to be common on Moen in 1984, and specimens were collected in Pohnpei in 1987. No information is available for the Mortlocks. A shipment of beetles collected in Pohnpei was sent to Kapingi-Marangi in 1987, but no information is available yet as to whether the beetles established.

Despite all of the shipments of scale predators to Moen over the years, that island still has a remarkably high density of various scales and mealybugs. Even *A. destructor* continues to be damaging.

Mealybugs (Pseudococcidae). *Cryptolaemus montrouzieri* Mulsant feeds on a variety of mealybugs. It was introduced to Palau by the Japanese (Esaki 1940) and was established by 1939, although it was not present in the other Caroline Islands or in the Marshall Islands at the end of WWII (Chapin 1965). Beetles were sent to Pohnpei, Truk, Yap, Majuro, Eauripik and Ifaluk in 1959. Shipments were sent to Yap, Truk and the Mortlock Islands in 1964. The beetle was reported to have established on Yap, but no information was available for the other locations.

***Oryctes rhinoceros* (L.) (Scarabaeidae) — the coconut rhinoceros beetle.** The coconut rhinoceros beetle was introduced to Palau probably around 1942 (Bryan 1949). Immediately after WWII an effort was mounted to find and mass rear parasites and predators of the beetle. The wasp *Scolia patricialis plebeja* Gribodo was imported from Malaysia, and several shipments in healthy condition were liberated in Palau in 1948 (Bryan 1949) but did not establish. *Megascolia procer* (Illiger), also from Malaysia, was imported to Palau in 1963 (Rao 1971). Clausen (1978) states that it may have established. *S. ruficornis* F. was collected in Zanzibar and released in Palau in 1948. This wasp was found to be established in 1953 (Gardner 1958, Owen 1961). However, it primarily parasitized beetle grubs in loose friable material such as sawdust, and not those breeding in coconut logs and other more solid objects. Therefore it is not a very effective parasite of *Oryctes*, which breeds primarily in fallen logs.

The predaceous histerid beetles *Placodes ebeninus* (Lewis) imported from Tanzania and *Pachylister chinensis* (Quensel) imported from Samoa, were also released, but did not appear to have established (Pemberton 1954).

Assassin bugs, *Platyeris laevicollis* Distant, were mass reared and released for several years, but at the end of that time there was no evidence that they had established, so the project was terminated in 1967.

In 1951, an attempt was made to control the beetles with milky spore disease, *Bacillus popilliae*, but this proved unsuccessful (Swan 1974).

Ultimately, control of the beetle was achieved with the *Oryctes* baculovirus, which was imported from Western Samoa. This was cultured and the infected beetles were distributed around Palau. Julia (unpublished) found that the virus had disappeared from the culture, but the virus was established in the beetle population on the island of Babeldoab. The virus culture was reobtained from Western Samoa in 1983, and infected beetles were distributed on the island of Peleliou and other places where beetle problems were evident.

***Brontispa mariana* Spaeth.** Several coconut feeding hispines in the genus *Brontispa* species are native to the Carolines. A parasitic wasp, *Tetrastichus brontispae* (Ferriere), was introduced to Saipan (Mariana islands) from Malaysia in 1948 to control *Brontispa mariana*, which, despite its name, was a newly introduced pest to the Mariana islands in 1931 (Lange 1955). *Brontispa mariana* has probably been present in Truk for a long time, but nevertheless was considered to be a serious pest. Shipments of *T. brontispae* were sent from Saipan to the islands of Moen and Etten (both in Truk lagoon) in 1950, and to Pulusuk atoll in 1969. The parasite was reported to be established in Etten, although there was no indication as to whether it was effective. No information was available for the other islands.

***Tarophagus proserpina* (Kirkaldy) (Delphacidae) — the taro planthopper.** The taro planthopper is an important pest of taro in the region. The egg-feeding mirid bug *Cyrtorhinus fulvus* Knight proved a highly effective predator when introduced to Hawaii from the Philippines (Clausen 1978). In 1947 it was introduced to Guam. According to Pemberton (1954), Langford collected bugs in Guam and sent them to Pohnpei in 1947 with good results. According to the records of the Hawaii Department of Agriculture, further shipments of *C. fulvus* were made from Hawaii to Pohnpei in 1955. Owen reported *C. fulvus* as being established in Pohnpei in 1959. He also reported it had established in Yap and Palau. Langford is thought to have made several unrecorded shipments of this mirid to other islands in Micronesia (Pemberton 1954), so it may have become established at that time.

According to Owen, there was evidence that the bug had been moved unintentionally to Kapingi-Marangi atoll. It may have been intentionally introduced to Ngetik and Nukuoro atolls. A letter was found in the entomologist's files requesting permission to do so, but no evidence that shipments were made could be found.

Other agricultural pests. Several other agricultural pests have been targets of biological control introductions. These are summarized in Table 2.

ARTHROPODS OF MEDICAL IMPORTANCE

Mosquitoes. Mosquito fish, *Gambusia affinis* (Baird and Girard), were introduced to the region for control of mosquitoes, probably to a number of islands, as a result of stocking by the U.S. Army during WWII. Several

TABLE 2. Summary of assorted biological control introductions for pests of minor crops.

Target pest	Biocontrol agent	Release site	Source and year	Success
<i>Saccharicoccus sacchari</i> (Cockerell)	<i>Hyperaspis trilineata</i> Mulsant	Palau	?Hawaii, 1963	not established
<i>Spodoptera</i> sp.	<i>Calosoma blaptoides</i> (Lapouge)	Palau	Hawaii, 1958	not known only 5 released
<i>Aleurodicus dispersus</i> Russell	<i>Encarsia haitiensis</i> (Dozier)	Palau	Guam, 1985	good control on Koror
	<i>Nephaspis oculatus</i> (Blatchley)	Pohnpei Kwajalein Palau	Guam, 1987 Hawaii, 1984 Guam, 1985	established not known not established
	<i>Nephaspis bicolor</i> (Gordon)	Kwajalein Kwajalein	Hawaii, 1984 Hawaii, 1984	possibly established possibly established but not seen recently
	<i>Delphastus pusillus</i> (LeConte)	Kwajalein	Hawaii, 1984	not known
<i>Aleurocanthus spiniferus</i> (Quaintance)	<i>Encarsia smithi</i> (Silvestri)	Kosrae	Guam, 1983	good control (Nafus 1987)
<i>Cosmopolites sordidus</i> (Germar)	<i>Dactylosternum hydrophiloides</i> Macleay	Palau	Malaysia, 1948	not known
	<i>Hololepta</i> spp.	Palau	Trinidad, 1953	not known

releases of mosquito fish from Guam were made in Truk in 1952 in ponds made from bombhole craters. They survived at least initially, but it is not known whether they became established on Truk (Bohart 1957). They are reported to be established in Pohnpei, Pulusuk and Jaluit (Maciolek 1984). No information is available as to their impact on mosquito populations.

"Mosquito fish" were introduced to Palau in 1976. Studies of the freshwater fish of Palau done several years later showed the presence of several exotic species, including the mosquito eating *Poecilia reticulata* Peters, but not *Gambusia* (Maciolek 1984).

Predatory mosquitoes, *Toxorhynchites brevipalpis* Theobald, were sent from Hawaii to Truk in 1951, but died before they could be released (Bohart 1957).

Latrodectus geometricus (Koch) — a black widow spider. The parasite *Eurytoma latrodecti* Fullaway was introduced to Kwajalein from Hawaii in the 1950s to control black widow spiders. The parasite was reported to have established (Pemberton 1954). It apparently was effective as Legner et al (1974a) observed reduced spider densities in 1972-1973.

***Musca sorbens* Weidemann and other filth breeding flies.** *Musca sorbens* and several other species of muscoid flies are considerable nuisances on many of the islands of Micronesia. In Kwajalein there has been a sizeable effort devoted to controlling this problem by a variety of methods, including biological control. Numerous insect parasites and predators were introduced in 1971-1972 (Legner et al 1974). They included the parasites *Tachinaephagus zealandicus* Ashmead, *Muscidifurax uniraptor* Kogan & Legner, *M. raptorellus* Kogan & Legner and *Spalangia endius* Walker (Legner et al 1974). In addition, a number of predaceous beetles were also introduced. These were the histerids *Hister nomas* Erichson, *Carcinops pumilo* Erichson, *Gnathoncus nanus* Scriba and *Magarinotus merdarius* (Hoffman), as well as the staphylinids *Pilonthus sordidus* Gravenhorst and *Aleochara* sp. Of these, *M. raptorellus*, *S. endius* and *C. pumilo* are known to have established. Legner (personal communication 1987) believes that these organisms contribute only a little to control of the flies, and that better biological control organisms might be sought in other parts of the world.

T. zealandicus and *M. uniraptor* were released in Palau in 1973. There are no records of establishment.

WEEDS

***Clidemia hirta* (L.) D. Don — Koster's curse.** *Clidemia hirta* was found to be a problem in Palau, particularly in forestry areas. To control it, two insects were imported from Hawaii in 1972. These were the thrips *Liothrips urichi* Karny and the moth *Ategumia ebulealis* (Guenée). *L. urichi* was found to be established by 1973, and effective primarily in sunny areas. There was no evidence that *A. ebulealis* established. In 1986, I passed through the forestry area, and found *Clidemia* to be quite rare along the roadside. However, I did not make any systematic assessment of the distribution of the weed.

***Lantana camara* L. — lantana.** Lantana is widely distributed in Micronesia. It has become a serious problem wherever cattle are pastured. The taxa present in Micronesia have not been investigated; however, several varieties are known to occur as weeds. Numerous introductions of insects have been made to the islands of Micronesia, particularly Pohnpei where lantana was found to be a serious weed immediately after WWII. A summary of the insects introduced is presented in Table 3.

Four insects were introduced to Pohnpei in 1948. In 1949, it was reported that *Teleonemia scrupulosa* (Stål) and *Ophiomyia lantanæ* (Froggatt) were recovered and a plume moth, probably *Lantanophaga pusillidactyla* (Walker), was collected (Bryan 1949). Gressitt (1954) reported that *Epinotia lantana* (Busck) had established, but according to Clarke (1976) this record appears to be an error. Gardner (1958) reports that only *T. scrupulosa* and *L. pusillidactyla* were established, and seemed to be exerting some control. *T. scrupulosa* was considered to be only partially effective in Pohnpei in 1967.

TABLE 3. Introduction of insects for the control of lantana in Micronesia.

Insect introduced	Source	Year
Pohnpei		
<i>Epinotia lantana</i> Busck (Tortricidae)	Hawaii	1948
<i>Lantanophaga pusillidactyla</i> (Walker) (Pterophoridae)	Hawaii	1948
<i>Teleonemia scrupulosa</i> (Stål) (Tingidae)	Hawaii	1948
<i>Ophiomyia lantanae</i> (Froggatt) (Agromyzidae)	Hawaii	1948
<i>Diastema tigris</i> Guenée (Noctuidae)	Hawaii	1955
<i>Pseudopyrausta acutangulalis</i> (Snellen) (Pyrilidae)	Hawaii	1955
<i>Neogalea esula</i> (Druce) (Noctuidae)	Hawaii	1955
<i>Hypena strigata</i> (F.) (Noctuidae)	Hawaii	1958
<i>Salbia haemorrhoidalis</i> Guenée (Pyrilidae)	Hawaii	1958
<i>Uroplata girardi</i> Pic (Chrysomelidae)	Hawaii	1963
Palau		
"lantana plume roller" probably		
<i>Lantanophaga pusillidactyla</i> (Walker) (Pterophoridae)	Pohnpei	1960
"lantana leafroller" probably		
<i>Salbia haemorrhoidalis</i> Guenée (Pyrilidae)	Pohnpei	1960
<i>Teleonemia scrupulosa</i> (Stål) (Tingidae)	Pohnpei	1960
<i>Uroplata girardi</i> Pic (Chrysomelidae)	Pohnpei	1974
<i>Plagiohammus spinipennis</i> (Thomson) (Cerambycidae)	Hawaii	1977
<i>Leptobyrza decora</i> Drake (Tingidae)	Hawaii	1977
Yap		
<i>Hypena strigata</i> (F.) (Noctuidae)	Hawaii	1958
<i>Salbia haemorrhoidalis</i> Guenée (Pyrilidae)	Hawaii	1962
<i>Teleonemia scrupulosa</i> (Stål) (Tingidae)	Palau	1962

Five Lepidoptera were introduced to Pohnpei between 1955 and 1958. No definite information is available as to whether any of these species established, but in 1960, insects identified as lantana leafroller (probably *Salbia haemorrhoidalis* Guenée) and lantana plume roller (probably *L. pusillidactyla*) were collected on Pohnpei and moved to Palau. The hispine beetle *Uroplata girardi* Pic was sent to Pohnpei from Hawaii in 1963, and was noted to be established in 1965. In 1986, lantana was no longer a common weed on Pohnpei (D. Nafus, pers. comm. 1987).

Several lantana insects have been moved from Pohnpei to Palau. The "lantana leafroller" and the "lantana plume roller" did not establish. *T. scrupulosa* established, but Demei noted that it was only effective in areas where purple colored flowers were common (much of Palau) but not where orange flowered varieties of lantana were common (the islands of Koror and Angaur). This tingid is known to differ in its preferences for the different color morphs of lantana, and in Australia red flowered varieties were most preferred and pink ones the least (Harley et al 1979). *U. girardi* was reported to be established in 1978 at which time it was being spread around Palau. The cerambycid *Plagiohammus spinipennis* (Thomson) from Hawaii did not establish and no information was available for *Leptobyrza decora* Drake, also introduced from Hawaii in 1977.

No information is available as to whether the two species of Lepidoptera introduced to Yap established, but they probably did not as lantana was surveyed there on several occasions for other lantana insects. *T. scrupulosa* became established. However, Yap has the orange flowered variety of lantana, and it was reported that the tingid was not very successful there. In 1986, lantana was common on Yap (D. Nafus pers. comm.).

No record of insects being sent to Truk for control of lantana were found. *T. scrupulosa* was reported as being there but only partially effective in 1967, and *U. girardi* was reported as established later that year. Lantana was still a very common weed on Truk in 1986 (D. Nafus pers. comm. 1986).

OTHER PESTS

***Achatina fulica* (Bowdich) — the giant African snail.** The giant African snail was introduced into Micronesia prior to WWII and was moved around the islands during and after that period. It was well established in Palau at the end of the war. A predatory snail, *Euglandina rosea* (Ferussac), was introduced to Palau from Hawaii in 1958. It established and by 1960 it was being moved to all the islands in that group. A shipment was sent to Pohnpei from Hawaii in 1960, but no information is available as to whether it established.

Two other species of predatory snail in the genus *Gonaxis* were also distributed around Micronesia. These were *G. kibweziensis* (E. A. Smith) and *G. quadrilateralis* (Preston). In the entomologist's monthly reports they are frequently referred to only as *Gonaxis* and it is not always certain which species was involved. Both species are apparently established on Palau. A shipment of *G. quadrilateralis* was sent to Truk in 1960 from Hawaii and one of *G. kibweziensis* was sent there in 1972, possibly from Saipan, followed by a shipment, recorded only as *Gonaxis*, in 1973, probably from Palau. A shipment of *Gonaxis* sp., probably *quadrilateralis*, was sent to Pohnpei in 1956. No information is available as to whether any predatory snails established in these locations. In general, shipments of about 200 snails were sent and immediately released, with no attempt to mass rear them on the island where they were introduced.

The land planarian *Platydemus manokwari* Beauchamp, which was accidentally imported to Guam, was reported in 1986 to have also spread to Palau. Few snails were observed by me when I visited there in 1986, and it is presumed that one or another of these predators has substantially reduced the snail populations.

***Rattus exulans micronesiensis* Tokuda — the Polynesian or roof rat.** The monitor lizard *Varanus indicus* (Daudin) was introduced by the Japanese to some Micronesian islands including Pohnpei for control of rats, which damaged coconut plantings (Storer 1962, Laird 1963). The source was Yap or Palau. Bates and Abbott (cited in Laird 1963) contrasted the size of *R. exulans* populations on Ella islet (Ifaluk) where there were few monitors with the scarcity of rats on islets where the monitors were more abundant. On Pohnpei, the lizards became established, but they did not appear to have much impact on the rats (Storer 1962).

Introducing monitor lizards was not without hazards, however. They are predators on crabs, birds and chickens among other things. In Kosrae, the Japanese are said to have introduced the monitors to control rats in the sugarcane plantings. However, the lizards not only established but flourished and grew to enormous sizes. According to Kosraens, the Japanese then brought bags and bags of the marine toad *Bufo marinus* (L.) to the island in the hopes that the lizards would eat them and be poisoned. Now the toads are also well established on the island and very abundant (B. Alokoa, pers. comm. 1987).

CONCLUSIONS

On most of these islands there are no trained personnel available for doing releases, or to mass rear beneficial organisms to increase the likelihood of establishment. No facilities are available for the handling of insects, as until recently even microscopes were not available anywhere for entomological work, except in Palau and Pohnpei. For most introductions, the original shipment was released immediately in the field. It was rare for even as many as 300 individuals of a given biological control agent to be released on any of these islands. Nevertheless, about 40% of the introductions are known to have established. In Palau, 26 organisms have been introduced, of which 9 are known to have established. In Kwajalein, 17 organisms were introduced, 6 successfully. In Pohnpei, 17 biocontrol agents were introduced of which 8 established. Four out of 12 introduced organisms are known to have established on Truk, and 3 out of 6 organisms introduced to Yap also did so. All three organisms known to have been introduced to Kosrae established, although unfortunately, one was the monitor lizard. One out of 3 biocontrol agents sent to Majuro is known to have established, but possibly only temporarily.

A possible reason for this relatively high success rate is that most of the biological control work in the Caroline and Marshall islands has consisted of the release of biological control agents which had already been successfully introduced elsewhere. The few biological control organisms not tested elsewhere have been released mostly in Palau and in Pohnpei. In Palau a variety of organisms were imported from Asia and elsewhere for control of coconut rhinoceros beetle. Only two actually became established, one being the virus which had already been successfully introduced to the islands of the South Pacific. Pohnpei received a number of shipments of insects to be used for controlling lantana at the time they were being multiplied for release in Hawaii. All the species which became established on Pohnpei were also species which became established in Hawaii.

Most of the agents introduced during the period of the Trust Territory were ladybeetles, and other fairly large predators. Little work has occurred with parasites. However, in the last 5 years, two minute parasites of whiteflies have been successfully established on islands in the Carolines, although the personnel making the releases had little experience handling such small animals, apart from a detailed letter of instructions accompanying the ship-

ments. It appears that there is considerable potential in this area. The transport of parasitic wasps to Pacific islands has been considered to be difficult (Stride, unpublished), but most of the high islands can now be reached in one day by flight. Transport is still a problem to many atolls, some of which can be reached only after a boat ride of several days.

Little information is available on the actual impact of these biocontrol agents. *Rodolia pumila* appeared to be a successful biological control agent for *Icerya* species on the high islands of Micronesia, but was not always persistent on the atolls. In the case of lantana, where there was a long-term effort to introduce organisms, control appears to have been successful in Pohnpei, where at least four herbivores successfully established, but not in Yap or Truk where only one or two organisms became established. In Palau, partial success was achieved with just two species establishing, possibly due to a difference in the taxa of lantana present on this island. The two white-fly parasites appear to be effective in Kosrae and Palau, and it is too early to tell in Pohnpei. There is insufficient information to make evaluations of most other species.

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