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Movement of New Insects into the Carolines and Marshalls in Recent Years

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Abstract—In 1986, surveys of crop insects were conducted in Palau, Yap, Chuuk, Pohnpei, Kosrae, and in 1989, in Jaluit and Majuro. In the Marshalls, 20 species of insects were found to have entered Majuro or Jaluit for the first time. Of these, ten species were new to the Marshalls, and the rest were already present on other atolls. Using 1975 as the base year, Majuro acquired 16 new records, corresponding to a rate of 1.1 new pests per year, and Jaluit had nine new records, or 0.6 new insects per year. These rates are lower than those for Guam, which got 2.5 new introductions per year during the 1980s. In the Carolines, between 1976 and 1986, Pohnpei acquired about 1.4 new insects per year, Yap 1.1, Palau 0.7, Kosrae 0.7, and Chuuk 0.6. Many of the new records in the Carolines were range extensions of insects already present. In both the Carolines and the Marshalls, scales, whiteflies, and other Homoptera accounted for most of the new introductions, but new species of moths, beetles, flies, and thrips were represented as well.

The movement of new insects into islands is a serious problem. In Hawaii between 20 and 30 new immigrants arrive every year (Beardsley 1979), and Guam may receive as many as 12–15 (Schreiner & Nafus 1986). In recent years new introductions to the Marshalls and Carolines have not been documented, particularly in the atolls, many of which have not been visited by an entomologist since the 1950s. In the early part of the 20th century, collecting in Micronesia was sporadic, but between 1936 and 1955 an intensive effort was made to determine the insect fauna. In 1936–40, the Japanese entomologist Esaki (1940, 1952) collected economically important insects and recorded many new pests. In the late 40s and early 50s, the United States Navy sponsored a survey of the invertebrate fauna. This and Esaki's surveys provided a baseline against which changes in the insect fauna of Micronesia can be measured. Unfortunately, the systematics of many groups has never been finished and published, so several groups remain unknown. During the 1950s through the late 1970s, the United States Trust Territory government maintained an entomology office, which was responsible for pest control and which kept track of changes in the fauna. In the 1980s, monitoring was sporadic and largely up to individual countries.

In 1986, under the auspices of the South Pacific Commission, I surveyed the insects of important crops in Palau, Yap, Chuuk, Pohnpei, and Kosrae. On

each of these islands I spent five to ten days visiting selected crops with local extension agents, and collecting associated insects. In 1989, I visted Jaluit and Majuro in the Marshalls on June 20–30, 1989. During this period, I also spent three hours on Likiep. All of these visits were too short to conduct thorough surveys, but I did find a large number of new records and am reporting rates of movements of crop pests into these islands based on these records. These rates are very conservative, and I am certain that there is much that I have not accounted for. In particular, despite the large number of scales found, there are undoubtedly many more, as I only sampled a few, agriculturally important hosts. Most of my sampling was restricted to the plants that the state or country wanted me to look at.

From Esaki's work, the Naval Survey, and other activities, the distribution of various economic insects on a variety of crops was determined (Bryan 1949, Pemberton 1954, Gressitt 1954). Following this through the late 1970s, various entomologists including J. Beardsley, R. Owen, J. Tenorio, O. Demei continued to catalogue pests on selected crops in the various islands in Micronesia, and several systematists published papers on their identification and distributions. A list of these insects, presumably compiled by O. Demei, was kept by The Office of the Chief Entomologist of the Trust Territories. It is dated 1973, but a few entries were made after that time. For the purposes of this paper, I am assuming that any insects not reported in the published literature, not listed by the Trust Territory Entomologists, or included in the collection of the Bishop Museum in Honolulu are new introductions. This may not always be correct as some species may have been present earlier but not collected, or were misidentified or otherwise overlooked. In addition, I have not been able to check all groups in the Bishop Museum in Honolulu, so I may have improperly included some species as new records when they are not. I apologize for any of these unintentional errors.

In have somewhat arbitrarily chosen 1975 as a base year for my calculations of the number of new species entering the various islands each year. 1975 corresponds to the year of publication of several key supplements to the *Insects of Micronesia* series, and is close to the last date entered on the copy of the Trust Territory list graciously provided to me by H. Adelbai.

For convenience, I have organized many of the new records around the main host plants. All new records are given in Table 1, along with their previous distribution records.

Coconut

One of the first new insect pests to be recorded in Micronesia was the coconut scale *Aspidiotus destructor* Signoret (Esaki 1940, 1952). This scale was first introduced to Yap from the Philippines in 1892. From there it spread to Palau in 1898 or 1899, and the Mariana Islands of Saipan in 1910, Guam 1911 (Vandenberg 1926), and later Rota and Tinian (Esaki 1952). Outbreaks in Yap in 1904–1907 and Saipan 1914–21, killed 70–80 percent of the coconuts and led to extensive biological control efforts (Nafus & Schreiner 1989).

Table 1. Movements of insects in the Carolines and Marshalls. Symbols are Pa (Palau or Belau), Y (Yap), C (Chuuk=Truk), Po (Pohnpei=Ponape), K (Kosrae=Kusiae), M (Majuro), J (Jaluit), L (Likiep), x (present before 1975), n (new since 1975).

Scientific Name	Common Name	Pa	Y	C	Po	K	M	J	L	References
Homoptera										
Aleurocanthus spiniferus (Quaintance) (Homoptera: Aleyrodidae)	orange spiny whitefly	·	n	x	n	n	·	·	·	Takahashi 1956, Nafus 1988 Schreiner & Nafus 1986
Aleurodicus dispersus Russell (Homoptera: Aleyrodidae)	spiralling whitefly	n	·	·	n	·	n	·	·	Schreiner & Nafus 1986
Aspidiotus destructor Signoret (Homoptera: Diaspididae)	coconut scale	x	x	x	x	·	n	·	·	Beardsley 1966
Asterolecanium sp. (Homoptera: Asterolecaniidae)	bamboo soft scale	x	·	n	·	·	·	·	·	Beardsley 1966
Ceroplastes rubens Maskell (Homoptera: Coccidae)	red wax scale	x	n	·	·	·	n	·	n	Beardsley 1966, 1975
Coccus hesperidum L. (Homoptera: Coccidae)	brown soft scale	x	x	x	·	·	x	n	·	Beardsley 1966
Coccus viridis (Green) (Homoptera: Coccidae)	green scale	x	x	x	x	n	·	·	·	Beardsley 1966
Dialeurodes citrifolii (Morgan) (Homoptera: Aleyrodidae)	cloudywinged whitefly	·	·	·	n	·	·	·	·	
Empoasca spp. (Homoptera: Cicadellidae)	green leafhopper	·	·	·	·	n	n	·	·	Linnavuori 1960, 1975
Eucalymnatus tessellatus (Signoret) (Homoptera: Coccidae)	tessellated scale	x	n	x	x	x	·	n	·	Beardsley 1966
Ferrisia virgata (Cockerell) (Homoptera: Pseudooccidae)	striped mealybug	x	x	x	x	·	x	n	·	Beardsley 1966
Heteropsylla cubana (Homoptera: Psyllidae)	leucaena psyllid	?	n	?	?	?	·	·	·	
Idiocerini (unidentified species) (Homoptera: Cicadellidae)	leaf hopper	n	·	·	·	·	·	·	·	
Lepidosaphes beckii (Newman) (Homoptera: Diaspididae)	purple scale	x	x	·	x	·	n	·	·	Beardsley 1966
Lepidosaphes gloverii (Packard) (Homoptera: Diaspididae)	glover scale	·	n	x	x	·	·	·	·	Beardsley 1966

Table 1. Continued.

Scientific Name	Common Name	Pa	Y	C	Po	K	M	J	L	References
Homoptera										
Lepidosaphes laterochitinosa Green (Homoptera: Diaspididae)	armored scale	x	n?	·	n?	·	·	·	·	Beardsley 1966
Parlatoria zizyphus (Lucas) (Homoptera: Diaspididae)	black parlatoria scale	x	·	n	x	·	·	·	·	Beardsley 1966
Pentalonia nigronervosa Coquerel (Homoptera: Aphididae)	banana aphid	x	x	x	x	n	n	·	·	Essig 1956
Phenacoccus madeirensis Green (Homoptera: Pseudococcidae)	mealybug	·	·	n	n	·	n	·	·	
Pinnaspis strachani (Cooley) (Homoptera: Diaspididae)	lesser snow scale	x	x	x	x	·	n	?	·	Beardsley 1966
Planococcus sp. (Homoptera: Pseudococcidae)	citrus mealybug	·	·	·	·	·	n	·	·	Beardsley 1966, 1975
Proutista moesta (Westwood) (Homoptera: Derbidae)	erect-winged blue plant-hopper	x	·	·	n	·	·	·	·	Fennah 1956
Pseudaulacaspis pentagona (T&T) (Homoptera: Diaspididae)	white peach scale	x	·	x	·	·	n	n?	·	Beardsley 1966
Pulvinaria psidii Maskell (Homoptera: Coccidae)	green shield scale	x	·	x	x	x	n	x	·	Beardsley 1966
Pulvinaria urbicola Cockerell (Homoptera: Coccidae)	urbicola soft scale	·	·	n	·	·	n	n	·	Beardsley 1966
Saissetia neglecta DeLotto (Homoptera: Coccidae)	Caribbean black scale	x	·	·	n	·	·	·	·	Beardsley 1966, 1975
Vinsonia stellifera Westwood (Homoptera: Coccidae)	stellate scale	x	n	·	x	n	·	·	·	Beardsley 1966
Hemiptera										
Brachyplatys insularis Ruckes or B. *pacificus* Dallas (Hemiptera: Plataspidae)	black island stink bug	x	n	x	n	n	n	n	·	Ruckes 1963, O.C.E.T.T.[1]
Coptosoma xanthogramma (White) (Hemiptera: Plataspidae)	black stink bug	·	·	·	·	n	·	·	·	
Physomerus grossipes (F.) (Hemiptera: Coreidae)	large spined-footed bug	n	·	·	·	·	·	·	·	Schreiner & Nafus 1986
Piezodorus hybneri (Gmelin) (Hemiptera: Pentatomidae)	shield bug	x	n	·	·	·	·	·	·	Ruckes 1963

Table 1. Continued.

Scientific Name	Common Name	Pa	Y	C	Po	K	M	J	L	References
Coleoptera										
Chaetocnema confinis Crotch (Coleoptera: Chrysomelidae)	sweetpotato flea beetle	·	·	·	·	·	n	·	·	
Cylas formicarius (Coleoptera: Curculionidae)	sweetpotato weevil	x	x	x	·	·	n	·	·	O.C.E.T.T.[1]
Metriona circumdata (Herbst) (Coleoptera: Chrysomelidae)	green tortoise beetle	x	n	x	n	·	n	·	·	Gressitt 1955 O.C.E.T.T.[1]
Lepidoptera										
Agonoxena pyrogramma Meyrick (Lepidoptera: Agonoxenidae)	coconut flat moth	·	·	n	n	x	·	·	·	Clark 1984
Badamia exclamationis F. (Lepidoptera: Hesperiidae)	migratory skipper	?	·	·	·	·	n?	·	·	Esaki 1940, Gressitt 1954
?*Brachycyttarus* sp. (Lepidoptera: Psychidae)	bagworm	·	·	·	·	·	n	n	·	
Chrysodeixis chalcites (Esper) (Lepidoptera: Noctuidae)	green garden looper	x	·	·	n	·	·	·	·	Gressitt 1954, Esguerra 1990
Lamprosema diemenalis (Guenée) (Lepidoptera: Pyralidae)	bean leaf-roller	·	·	·	n	·	n	n	·	Clarke 1976
Maruca testulalis (Geyer) (Lepidoptera: Pyralidae)	bean pod borer	n?	·	·	·	·	·	·	·	
Othreis fullonia (Clerck) (Lepidoptera: Noctuidae)	fruit piercing moth	x	·	·	n	n	·	·	·	Gressitt 1954, Denton et al. 1990
Penicillaria jocosatrix (Guenée) (Lepidoptera: Noctuidae)	mango shoot caterpillar	·	·	n	n	·	·	·	·	
Plutella xylostella (L.) (Lepidoptera: Yponomeutidae)	diamondback moth	n	·	·	·	·	·	·	·	

Table 1. Continued.

Scientific Name	Common Name	Pa	Y	C	Po	K	M	J	L	References
Thysanoptera										
Selenothrips rubrocinctus (Giard) (Thysanoptera: Thripidae)	redbanded thrips	n	n	n	x?	·	·	·	·	
Thrips palmi Karny (Thysanoptera: Thripidae)	melon thrips	n	·	·	·	·	·	·	·	
Diptera										
Liriomyza trifolii (Burgess) (Diptera: Agromyzidae)	serpentine leafminer	·	n	·	n	·	·	·	·	Schreiner & Nafus 1986

[1] The Office of the Chief Entomologist of the Trust Territories prepared a list dated 1973 which reports the pests of various crops on the islands groups of Chuuk, Palau, Yap, Pohnpei, Kosrae and the Marshalls.

The scale appeared in Pohnpei prior to 1938, probably from a separate introduction (Esaki 1940). It also appeared in Woleai Atoll sometime before 1940, the high islands in Chuuk (formerly Truk) by 1946 (Beardsley 1966), and the Mortlocks prior to 1960. The coconut scale has continued to spread, arriving in Kapingi-Marangi in 1985, and Majuro in the Marshalls around 1987. From Majuro it is being redistributed to other atolls in the Marshalls including Likiep in 1988, and possibly Wolei in 1989.

The infestation on these atolls was severe. On Majuro in June, 1989, the coconut scale was distributed throughout the main atoll island except for a few isolated points adjacent to the beaches. At Laura, the undersides of breadfruit leaves were often completely covered with coconut scale. Estimated populations of scales averaged about 50,000 scales per leaf. Many trees were in poor health and had dropped leaves, and some trees had died. In between the airport and Laura, populations were lower, averaging around 30,000 scales per leaf. This dropped to 2,700 in areas where the coccinellid *Chilocoris nigritus* was well established. *C. nigritus*, along with a second lady beetle, had been introduced earlier by Dr. Nelson Esguerra of the College of Micronesia in Pohnpei. A second lady beetle, possibly a species of *Pharellus*, was present and widely distributed, but it was unclear if it was having much impact on scale populations, or where it originated from. On one tree, the lady beetle averaged 5.8 beetles per leaf, but scale populations were still over 34,000 per leaf. In all areas parasitoid larvae and pupae were found inside the coconut scale. Parasitization rates were low, however, averaging less than two percent.

Infestations on coconut were generally less severe than on breadfruit. Populations ranged from over 2,000 scales per leaflet to slightly over 300 scales per leaflet.

Both *Chilocorus nigritus* and *Pharellus* were present on coconut, and I suspect that *C. nigritus* prefers coconut to breadfruit. Again it was most abundant where scale populations were highest.

On coconut the levels of parasitization were higher. An average of approximately 13 percent of the scales were parasitized and individual samples ranged up to 26 percent. In addition, a predatory mite was found under the scale cover. I was unable to rear the parasitoids during the visit, so I cannot provide identification. I suspect the parasitoids are contributing to the lower incidence of scales on coconut compared to the breadfruit, although host preferences of the scale or other factors may also be contributing.

Another coconut pest accidently introduced to Micronesia is the coconut rhinoceros beetle, *Oryctes rhinoceros* L., which was first reported in Palau in 1942 (Bryan 1949). It was thought to have come from Indonesia on Japanese shipping. The beetle caused serious damage to the coconuts, particularly right after WWII when there was abundant breeding material present. Extensive efforts were made to remove dead coconuts, and a biological control program was initiated (Gardner 1958, Schreiner 1989).

The weevils *Rhabdoscelus asperipennis* (Fairmaire) and *R. obscurus* (Boisduval) are both present in Palau, but when they entered and how widely they

are distributed in the Carolines is problematic. These species are closely related and difficult to distinguish. *R. obscurus* was first found on Guam in 1911 and later spread to other islands in the Marianas. Gressitt (1954) indicated that it was widespread but did not list any localities outside the Marianas. Julia (1983) states that *R. asperipennis* was widespread in the Carolines, but the 1973 Trust Territory list reported it only as on Palau. According to Julia, a thorough search in 1964 failed to uncover *R. obscurus* in Palau, whereas *R. asperipennis* was abundant and widespread. In 1983, *R. asperipennis* was uncommon and *R. obscurus* was found. Since the T.T. list records both species in Palau, I am assuming that *R. obscurus* was introduced sometime between 1966 and 1973, and I am not including it in the recent introductions, although problems with identification of these two species may invalidate this assumption.

Agonoxena pyrogramma Meyrick was reported from Guam by Fullaway (1912), but was not listed in Micronesia by Bryan (1949) or Pemberton (1954). Clarke (1984) looked for the moth in Micronesia in 1953, but only found it on Kosrae on nipa palm. In 1986, I reared it from coconut leaves on Pohnpei and found larvae which appeared to be this moth on Chuuk. In both cases the moths were abundant and widespread on the islands. It is possible they may have been overlooked in earlier surveys, but if it is as consistently conspicuous as on Guam, I doubt it. I suspect they are relatively new introductions.

Hemiberlesia palmae (Cockerell) was found on Chuuk. This scale was reported by Esaki (1940), but listed as questionable by Beardsley (1966) as specimens were not available for verification. D. Williams verified the record for Chuuk.

Citrus

Several pests, primarily scales, mealybugs, and whiteflies, associated with citrus have been moving about the Carolines and Marshalls. The orange spiny whitefly, *Aleurocanthus spiniferus* (Quaintance), a major pest of citrus in subtropical and tropical regions (Nakao & Funasaki 1979), has recently extended its range to several islands in Micronesia. It is native to Indomalay region, south China, and the Philippines. In 1919 it was found in southern Japan (Clausen 1978), and subsequently spread to the Chuuk and Guam by the late 1940s and early 1950s (Peterson 1955). Sometime before 1982, it became a major pest of lime and orange on Kosrae (Nafus 1988), Pohnpei (Schreiner & Nafus 1986), and Yap in the Caroline Islands.

Another whitefly, *Dialeurodes citrifolii* (Morgan), the cloudywinged whitefly, has recently entered Micronesia, probably from Hawaii, where it has been established since 1966 (Paulson and Kumashiro 1985). I found it on the undersides of citrus leaves around Kolonia, Pohnpei, in 1986. It was not present elsewhere on Pohnpei or in Micronesia. The whitefly was intermixed with populations of the orange spiny whitefly and several species of scales. Because it is transparent, it is easily overlooked and could easily be moved on plant material from island

to island. On Palau, I did find a few nymphs of a similar whitefly on one lime tree outside Koror, but I could not identify this species as no pupae were found.

Three scales, *Lepidosaphes gloverii* (Packard), *Parlatoria zizyphus* (Lucas), and *Ceroplastes rubens* Maskell, and one mealybug *Planococcus* sp. have extended their Micronesian ranges. Beardsley (1966) reported *L. gloverii* from Chuuk, Pohnpei, and the Marianas. I found it in Yap as well. The black parlatoria scale was previously found only on Pohnpei, but I now report it from Chuuk as well. On Pohnpei it is abundant on various types of citrus in the Kolonia area. On Chuuk it was infesting two citrus trees on Moen near the Governor's house. Beardsley (1966, 1975) originally listed the pink wax scale from the Marianas, Palau, and Kwajalein. I found it on citrus in northern Yap and on breadfruit on Majuro and Likiep. It was parasitized, but I did not have time to rear any of the species. *Planococcus citri* (Risso) was reported as widely distributed in Micronesia by Beardsley (1966), but recent studies (Cox 1981) have shown this is a species complex rather than a single species. In most cases, *P. pacificus* Cox is likely to be the species of mealybug present (Williams & Watson 1988), although *P. citri* is known to be on Guam. In the Marshalls, a species of *Planococcus* (as *citri*) was reported from Kwajalein on *Aralia* leaves. I found a *Planococcus* species on citrus on Jaluit. It appeared to be *pacificus*, but this needs verification.

Phyllocnistis citrella Stainton, the citrus leaf miner, was found in Guam and Saipan about 1927 (Gressitt 1954). Bryan (1949) recorded it from Palau but not elsewhere in the Carolines or Marshalls. In 1986, I found it on lime in northern Yap. It was abundant and causing partial defoliation.

Othreis fullonia (Clerk) is also an important pest of citrus in Micronesia. It has been in the Marianas for a long time, and has an endemic parasitoid fauna associated with the eggs. In the Carolines and Marshalls, it was either uncommon or absent. Gressitt (1954) reported it from Palau, where it was evidently uncommon, but it was not reported elsewhere in Micronesia until relatively recently. In Kosrae, Muniappan found it damaging citrus in 1982, and he and his coworkers recently found it in Pohnpei as well (Denton et al. 1990). These probably represent relatively new introductions as native *Telenomus* egg parasites are not known to be associated with the moth on these islands.

Sweet Potato

Several insects attacking sweet potato have extended their distributions within or entered the region. Many of the insects attacking sweet potato also eat other species of *Ipomoea* including beach morning glory, and various weedy species. These alternate hosts are common around airports and often residences on most islands. The sweetpotato weevil, *Cylas formicarius* (F.), is a widespread pest in Micronesia but was not known from the Marshall Islands. On Majuro I found it infesting beach morning glory in Rita.

Metriona circumdata (Herbst), the green tortoise beetle, was also present along with the sweetpotato flea beetle *Chaetocnema confinis* Crotch. The green tortoise beetle is an Asian species, which feeds on the leaves of sweet potato in

both the adult and larval stages. It is thought to have entered Guam from the Philippines in 1945 (Gressitt 1955), and from there it spread to Chuuk and Palau soon after. I found it in Yap in 1984, Pohnpei in 1986, and Majuro in the Marshalls in 1989. I did not see it in Jaluit or Likiep. It is obviously moving eastwards towards Hawaii and the U.S. The sweet potato flea beetle has been moving in the other direction, outwards from Hawaii. I found it in Majuro, but not Jaluit or Likiep. It was found on Guam in 1986, and by 1988–9 was present on Saipan, Tinian and Rota. The adults feed on the leaves, chewing tunnel-like tracks, and the larvae tunnel in the roots. It is a serious pest of sweet potatoes in the southern United States.

Physomerus grossipes (F.), the large spined-footed bug, was first found in Guam in the 1960s (Schreiner & Nafus 1986). In 1986, I collected it in Palau. This bug feeds on the vines of sweet potato and morning glory. It can occur in great numbers on vines growing up trellises or other supports, but does not occur to any great extent on vines on the ground. Thus, it is not a serious problem.

Beans

On beans several insects had new distribution records. *Brachyplatys insularis* Ruckes is a species endemic to the Marianas islands, and neither it nor any other species of *Brachyplatys* were found elsewhere at the time of the Naval faunal survey (Ruckes 1963). Between the mid 1950s and 1973, a *Brachyplatys* species listed as *B. pacificus* on the 1973 T.T. list appeared in Palau and Chuuk. I found a *Brachyplatys* species on all of the high islands of Micronesia and in the Marshalls in Jaluit and Majuro. *B. pacificus* and *B. insularis* are closely related and difficult to distinguish. Ruckes felt the Marianas records of *B. pacificus* were probably *B. insularis*, and it is possible that the other Micronesian records are all one species. T. J. Henry examined specimens of *Brachyplatys* from the Marianas, Kosrae, Pohnpei, Yap, and Palau. He felt these were all one species, but tentatively identified them as *B. subaenus* (Westwood). He is re-examining the identification of the species, and a final determination should be available shortly. Another platispid which recently entered Micronesia and is extending its range is *Coptosoma xanthogramma* (White). It is frequently found on both long beans (*Vigna* sp.) and pole beans (*Phaseolus* sp.), although it is not abundant. It was first recorded from the Marianas in 1968, and by 1984, was present in Kosrae. I suspect it is much more widely distributed. *Piezodorus hybneri* (Gmelin), originally reported from Palau and the Marianas (Guam, Saipan), was also found in Yap, and Bjork collected it from Tinian in the Marianas in 1985. The green garden looper *Chrysodeixis chalcites* (Esper) may also be extending its distribution. Gressitt (1954) originally listed it from the Marianas and Palau, but Esguerra (1990) also indicates that it is now in Pohnpei. This species has a very wide host range. It is common on various cucurbits in addition to beans. Other new records of species on beans includes *Empoasca* sp. in the Marshalls, *Maruca testulalis* (Geyer) in Palau, *Liriomyza trifolii* (Burgess) in Yap and Pohnpei, and *Lamprosema diemenalis* (Gue-

née) on Pohnpei, Jaluit, and Majuro. *L. diemenalis* was defoliating soybeans on Majuro and Pohnpei, but was rarely present on other species of beans.

Mango

Coccus viridis (Green), *Penicillaria jocosatrix* Guenée, *Selenothrips rubrocinctus* (Giard), *Vinsonia stellifera* Westwood all showed range extensions within or into Micronesia. *V. stellifera* was extremely abundant on mango in Kosrae, but only on certain trees. In some cases, on trees growing next to each other, one tree would have several scales per leaf and the other tree none. On Palau an unidentified species of leafhopper in the subfamily Idocerini was abundant on mango at the Agricultural Experiment Station. This species is not listed by Linnavuori (1960, 1975), and is assumed to be a new introduction although it is still unidentified.

Banana

Cosmopolites sordidus (Germar) was common in Guam in 1939, but Esaki (1940) did not find it in any of the other islands at that time. Since then it has spread to Palau, Yap, Chuuk, and Pohnpei. On Pohnpei it is localized. I found extensive damage to one banana plantation.

Pentalonia nigronervosa Coquerel has been widely distributed in the Carolines for a long time, and in the Marshalls on Lib and Arno, but it was not reported from Kosrae or Majuro (Essig 1956). I found it in low numbers in both locations. In neither case were numbers high enough to be damaging, but the main threat associated with this aphid is that it is a vector of bunchy top. Bunch top is a fatal viral disease which is not present in either the Carolines or the Marshalls, but is present in the Marianas, Hawaii and Philippines. Because of the presence of this aphid and the current cultural practices, this disease would spread rapidly and be seriously damaging in both island groups.

Other Hosts

The spiralling whitefly, *Aleurodicus dispersus* Russell, originated in Central America, and was accidentally introduced into Hawaii in the late 1970s. Since then, it has been spreading westward into the Pacific and southeast Asia. In 1981 the whitefly reached Guam and became a problem on several species of plants. By 1985 it was established in Palau and Pohnpei. It also established in the Marshalls in Kwajalein and Majuro. In all of these areas, natural enemies have been deliberately or accidentally introduced, and have at least partially controlled the whitefly. Several other Homoptera, including *Lepidosaphes laterochitinosa* Green on Guava, *Pulvinaria urbicola* Cockerell on peppers, breadfruit, and plumeria, *Phenacoccus madeirensis* Green on tomato, *Empoasca* sp. on eggplant, and *Asterolecanium bambusae* (Boisduval) on bamboo have new distribution records (Table 1). *Proutista moesta* (Westwood) was collected on Pohnpei. This species

was reported on Palau and in the Marianas previously (Fennah 1956, Gressitt 1954). In Palau, I found populations of *Thrips palmi* Karny, *Badamia exclamationis* F. and *Plutella xylostella* (L.). *B. exclamationis* probably has been there for many years and is not a new introduction, as Esaki (1940) says it is widespread in Micronesia, but it was not recorded on the 1973 Trust Territory list of pests on *Terminalia* on Palau. I also found it on Majuro. Gressitt (1954) indicates that it was present in the Marshalls on Likiep, but does not report it from other atolls. I suspect this is a new record for Majuro, but it is natural dispersal. This butterfly is a strong flier and is noted for its migratory habits (Common & Waterhouse 1982).

Taxonomic Affinity of Species Moving

The majority of new records were Homoptera, principally scales and mealybugs and whiteflies (Table 2). These groups are sedentary, and would not be easily recognized as an insect by most Micronesians. They could also be easily overlooked by quarantine officials if they have not had sufficient training in entomology, a common problem in Micronesia. For the more active Homoptera, there were far fewer new distribution records. Only six new distributions, two for the aphid *Pentalonia nigronervosa*, one for the psyllid *Heteropsylla cubana*, two for species of *Empoasca*, one for *P. moesta*, and one for an unidentified species of leafhopper were found in these groups.

The second most common group was the Lepidoptera with a total of 15 new records involving nine species. Most of these are medium-sized to small nocturnal moths. I suspect movement has been on aircraft, except for *O. fullonia*, *P. xylostella*, and *B. exclamationis*. *O. fullonia* and *B. exclamationis* are strong fliers and have probably dispersed naturally. *P. xylostella* probably entered through commerce or was brought in on illegally imported plants from Asia. In Micronesia, aircraft are no longer treated to prevent insect movements. I am certain this has enhanced the movements of several species in recent times.

Hemiptera, Coleoptera, Thysanoptera, and Diptera had fewer new records. In the Hemiptera, two species extended their ranges and two other species were recorded from the Carolines for the first time. *P. grossipes* is an Asian species which has recently been recorded from Guam as well. It may have entered Palau

Table 2. Number of new records in the Carolines and Marshalls by order of insect.

Order	Marshalls	Carolines	Total
Homoptera	19	23	42
Lepidoptera	6	12	18
Coleoptera	3	3	6
Hemiptera	0	6	6
Thysanoptera	0	4	4
Diptera	0	2	2

from either the Philippines or from Guam. The other species all attack legumes, which are common plants in beach or disturbed areas, including near airport runways. Three species of Coleoptera had new distribution records. One of these, *C. confinis*, is new to the region. It is an American species which established in Hawaii in 1983 (Lai 1985) and has recently spread to Guam. I suspect that it is present in the Carolines as well, but it entered the region after my survey in 1986. The other two species have long been established in Micronesia and are gradually extending their range. In all three cases, the beetles feed on hosts which are common near beaches or disturbed areas and are present near airport runways. I suspect they are moving in aircraft cargo holds. Only two species of thrips and one of Diptera have extended their ranges. I suspect these moved on plant material, either imported foods or flowers. *Thrips palmi* is present in orchid flowers (Waterhouse & Norris 1987) and probably moved that way.

Rates of Movement

Of the 47 species with new distributions, 16 of these are new to both the Carolines and the Marshalls. Within the Carolines I found 48 new distribution records involving 33 species. I am sure this is well under the amount that actually took place. Of these 33 species, 14 were new to the Carolines, and the rest were range extensions of insects already present. Pohnpei had the largest number of new insects, acquiring about 1.4 new insects per year on agriculturally important crops (Table 3). Yap had fewer new introductions, averaging around one species per year, and Chuuk, Palau, and Kosrae had the fewest.

In Majuro and Jaluit in the Marshalls, we see a similar picture. In the Marshalls there were 25 new distribution records involving 20 species. Half of these were new to the Marshalls, and the remainder already present within the Marshalls on other atolls. Majuro had 16 new records, of which nine were new to the Marshalls and seven were species present on at least one other atoll. Jaluit had nine new insects, four of which were new to the Marshalls, but three of these were also found in Majuro. Thus, of the nine, only one was not recorded elsewhere

Table 3. Number and rate of new introductions of insects into the Caroline and Marshall Islands after 1975. Rates are based on surveys in 1986 in the Carolines and 1989 in the Marshalls.

Location	Number of new introductions	Number per Year
Pohnpei (Carolines)	15	1.4
Majuro (Marshalls)	16	1.1
Yap (Carolines)	11	1.0
Palau (Carolines)	8	0.7
Kosrae (Carolines)	8	0.7
Chuuk (Carolines)	7	0.6
Jaluit (Marshalls)	9	0.6

in the Marshalls. The other eight were present in either Majuro, Kwajalein or both. Majuro acquired about 1.1 insect pests per year, and Jaluit had 0.6 per year.

Possible Origins

Air traffic in Micronesia has grown steadily since 1950, and is probably the most important link in the movement of new pests into the region. Kwajalein and Majuro have air connections from Hawaii, Guam, and other Pacific destinations such as Nauru. Majuro serves as the hub for connections with other Marshallese atolls. Jaluit has air connections only within the Marshalls. All of the high islands in the Carolines have jet aircraft landing daily, although Kosrae was only served by small planes until 1986. In the eastern Carolines, air traffic island hops between Hawaii and Guam with stops in Majuro, Kwajalein, Kosrae, Pohnpei, and Chuuk. In the western Carolines, flights originate and terminate in Guam and the Philippines, with stops in Palau and Yap. There are no direct flights between the eastern and western Carolines, although passenger traffic between them without quarantine inspection in Guam is possible.

Without detailed studies, it is not possible to determine origin of the majority of the new introductions with certainty, so the following comments are speculative and largely based on prior distributions. I am discussing the Marshalls, the eastern Carolines, and the western Carolines as separate groups. In part this is done because of the air traffic patterns.

Recent distribution records suggest Kwajalein and Majuro are the focal point for most new introductions in the Marshalls. From there, such as in the case of the coconut scale, they spread to other atolls. Judging from the case in Jaluit, this is the pattern for the majority of the insects, although a few insects such as *Eucalymnatus tessellatus* (Signoret) have made it to atolls without direct air service to points outside the region. Within the Marshalls, there is no quarantine or aircraft disinsection.

In the eastern Carolines the general pattern of movement is influx from Guam or Hawaii, followed by inter-island redistribution. Most introductions seem to be on plant material moved between islands, as the majority of new introductions are scales and mealybugs. Quarantine officials from the islands indicated that they knew there was considerable smuggling of plant materials. At least one-third of the new introductions are from Guam or Hawaii. The remainder are range expansions of prior introductions within the Carolines, or additional re-introductions from Guam or Hawaii. In the western Carolines, the flow of insects is from Guam and the Philippines. Palau is probably receiving about 25 to 40% of its new insects from the Philippines or other Asian points, and the remainder from Guam or other Caroline Islands. After Hawaii and Guam, Palau is the most important entry point into Micronesia for new species. Its diversity of agricultural pests is similar to that of Guam, and is much higher than any of the other islands in the Carolines. A number of important pests such *Oryctes rhinoceros* (L.) and *Segestes unicolor* Redtenbacher occur in Palau, but are absent

from the rest of Micronesia. Yap has had a rather high rate of new introductions in recent years. Most of these insects are scales or other Homoptera. Guam and Palau are probably the main source, although a few species may be coming from the eastern Carolines.

The movement of new pests into the newly emerging countries in Micronesia is a serious problem. In the past, most of these islands have enjoyed a relatively pest free environment, but this is changing rapidly. The new pests reported in this paper, and others which will arrive in the future, will exact a heavy toll on these nations by forcing new expenditures for pesticides or other methods of pest control, increasing pollution, and increasing crop losses. In some cases it may no longer be possible to grow certain crops economically. I feel that the two main problems are the undetected movement of live plant material, and movement of insects in the cargo holds of aircraft. Of the two, movement of plant material is probably the more important. Quarantine cannot guarantee that new pests will be prevented from establishing, but it can significantly slow their movement to new areas. Efforts to strengthen quarantine on each island or island group need to be made. This should include quarantine within islands in a particular country.

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References

Beardsley, J. W. 1966. Homoptera: Coccoidea. Insects of Micronesia 6: 377–562.

Beardsley, J. W. 1975. Homoptera: Coccoidea, suppl. Insects of Micronesia 9: 657–681.

Beardsley, J. W. 1979. New immigrant insects to Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23: 35–44.

Bryan, E. H. 1949. Economic Insects of Micronesia. Report of the Insect Control Committee for Micronesia. 1947–8. Washington, D.C., Natl. Res. Counc., 29 p.

Clarke, J. F. 1976. Microlepidoptera: Tortricoidea. Insects of Micronesia 9: 1–144.

Clarke, J. F. 1984. Microlepidoptera: Gelechioidea. Insects of Micronesia 9: 145–155.

Common, I. F. & D. Waterhouse. 1982. Butterflies of Australia. Angus and Robertson Publishers, London. 434 pp.

Cox, J. 1981. Identification of *Planococcus citri* (Homoptera: Pseudococcidae) and a description of a new species. Systematic Entomology 6: 47–53.

Clausen, C. P. 1978. Introduced Parasites and Predators of Arthropod Pests and Weeds: a World Review. U.S. Dep. Agric. Handb. 480.

Denton, G., R. Muniappan, M. Maurtani & T. S. Lali. 1990. The distribution and biological control of the fruit piercing moth, *Othreis fullonia* in Micronesia. Abstract 5, 2nd ADAP Crop Protection Conf. May 29–30, Univ. Guam, Guam.

Esguerra, N. 1990. Control of the leaf-footed plant bug on cucumber by nontrellising. Abstract 16, 2nd ADAP Crop Protection Conf. May 29–30, Univ. Guam, Guam.

Esaki, T. 1940. A preliminary report on the entomological survey of the Micronesian Islands under the Japanese mandate, with special reference to the insects of economic importance. Proc. 6th Int. Cong. of Entomol. 6: 407–415.

Esaki, T. 1952. Notes and records on some important pests of Micronesia mostly introduced during the period under Japanese mandate. Proc. 9th Int. Cong. Entomol. 1: 813–818.

Essig, E. O. 1956. Homoptera: Aphididae. Insects of Micronesia 6: 15–37.

Fennah, R. G. 1956. Homoptera: Fulgoroidea. Insects of Micronesia 6: 39–176.

Fullaway, D. T. 1912. Entomological notes. Guam Agr. Exp. Sta. Rpt. 1911: 26–35.

Gardner, T. R. 1958. Biological control of insect and plant pests in the Trust Territory and Guam. Proc. 10th Int. Cong. Entomol. (1956) 4: 465–469.

Gressitt, J. 1954. Introduction. Insects of Micronesia 1: 1–257.

Gressitt, J. 1955. Coleoptera: Chrysomelidae. Insects of Micronesia 17: 1–60.

Julia, J. F. 1983. *Oryctes* and *Rhabdoscelus* problems in the Republic of Palau. South Pacific Comm. Doc. 1806. 19 p.

Lai, P. Y. 1985. Notes and exhibitions. Proc. Hawaiian Entomol. Soc. 25: 16.

Linnavuori, R. 1960. Homoptera: Cicadellidae. Insects of Microinesia 6: 231–344.

Linnavuori, R. 1975. Homoptera: Cicadellidae, Suppl. Insects of Micronesia 6: 611–632.

Nafus, D. 1988. Establishment of *Encarsia smithi* on Kosrae for control of orange spiny whitefly, *Aleurocanthus spiniferus*. Proc. Hawaii Entomol. Soc. 28: 229–231.

Nafus, D. & I. Schreiner. 1989. History of biological control in the Mariana Islands. Micronesica 22: 65–106.

Nako, H. K. & G. Y. Funasaki. 1979. Introductions for biological control in Hawaii: 1975 & 1976. Proc. Hawaii Entomol. Soc. 13: 125–128.

Paulson, G. & B. Kumashiro. 1985. Hawaiian Aleyrodidae. Proc. Hawaii. Entomol. Soc. 25: 103–124.

Pemberton, C. E. 1954. Invertebrate consultants committee for Pacific. Report for 1949–54. Pacif. Sci. Bd. Natl. Acad. Sci., Natl. Res. Counc., 56 p.

Peterson, G. D. 1955. Biological control of the orange spiny whitefly in Guam. J. Econ. Entomol. 48: 681–683.

Ruckes, H. 1963. Heteroptera: Pentatomoidea. Insects of Micronesia 7: 307–356.

Schreiner, I. 1989. Biological control introductions in the Caroline and Marshall Islands. Proc. Hawaii. Entomol. Soc. 29: 57–69.

Schreiner, I. & D. Nafus. 1986. Accidental introductions of insect pests to Guam, 1945–1985. Proc. Hawaii. Entomol. Soc. 27: 45–52.

Takahashi, R. 1956. Homoptera: Aleyrodidae. Insects of Micronesia 6: 1–13.

Vandenberg, S.R. 1926. Report of the Entomologist. Guam Agr. Exp. Sta. Rpt. 1925, 17–20.

Waterhouse, D. & K. Norris. 1987. Biological Control: Pacific Prospects. Inkata Press, Melbourne. 454 pp.

William, D. & G. Watson. 1988. The Scale Insects of the Tropical South Pacific Region, Part 2: The Mealybugs (Pseudococcidae). C.A.B. International Institute of Entomology, London. 260 pp.