Fluted Scales and Their Biological Control in United States Administered Micronesia

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I. Introduction

Several serious outbreaks of fluted scale insects (*Icerya* spp.) on islets in scattered atolls in the Caroline and Marshall groups came to my attention during the two years (1952-1954) in which I served as an entomologist for the U. S. Trust Territory of the Pacific Islands. Previous outbreaks of these scales are known to have occurred on various islands in Micronesia both before and after World War II. Fluted scales constitute one of the few relatively serious insect problems which presently confront the inhabitants of these islands.

Although a number of entomologists, both Japanese and American, have concerned themselves with fluted scales in Micronesia, detailed information dealing with their work is not readily available. Records concerning the distribution of these scales and the predators (*Rodolia* spp.) introduced for their control are incomplete and often contradictory. This paper is an attempt to assemble the available information pertaining to these scales and their biological control in the U. S. administered islands of Micronesia.

In addition to the references cited, unpublished reports and correspondence of entomologists who have worked in the area since the war have served as sources of information. I am indebted to Dr. E. A. Chapin, Professor Teiso Esaki, Dr. Harold Morrison, Dr. C. E. Pemberton, and to Mr. Kay Sakimura for supplying determinations and other information not available in the literature.

II. Economic Importance of Fluted Scales in Micronesia

The principal economic plant seriously affected by outbreaks of fluted scales in this area is the breadfruit tree, *Artocarpus incisus* (Thunberg) L. f. Breadfruit is a staple food in nearly all of Micronesia, and on many islands is, next to coconut, the most important crop. Inhabitants of the low coral atolls are particularly dependent upon this food because of the very limited agricultural potential of their lands. On some islands, principally those in the vicinity of Truk in the central Carolines, the natives insure a year-round supply of breadfruit by collecting the excess fruit when in season, pounding it into a paste-like mass, and storing this product in rock-lined pits in the soil. This material, after it has been washed and cooked, serves as food during seasons when the trees are not in fruit. In addition to food, the breadfruit tree supplies Micronesian peoples with the principal wood used for the construction of the canoes upon which they depend for local transportation and for fishing.

When present on breadfruit, fluted scales usually are concentrated on the undersurfaces of the leaves along the midribs and larger veins. They may also inhabit the surfaces of developing fruits. On a few occasions very heavy infestations have been found responsible for the death of mature trees (Oakley, 1953; Pemberton, 1954). More frequently, trees which are badly attacked suffer partial defoliation and a general loss of vigor. A black sooty mold, which grows upon honeydew secreted by fluted scales, frequently covers the upper surfaces of all but the youngest leaves of heavily infested trees. This mold may be partially responsible for the debilitation of infested trees as it must interfere to some extent with photosynthesis.

Wherever outbreaks of these scales have been encountered natives have complained of substantial reductions in the size of breadfruit crops. Inhabitants of scale-infested islets have attributed crop reductions of up to 50 per cent and more to these insects. Such reports are not always completely reliable, however.

Even on islets where no control measures have been attempted breadfruit losses due to fluted scales may vary considerably from year to year as a result of fluctuations of scale populations. The occurrence of such fluctuations may explain why, occasionally, there have been conflicting reports concerning the seriousness of fluted scales at a particular locality. It has been noted that where *Rodolia* beetles are absent other predators, such as green lacewings, periodically may become plentiful enough to reduce scale populations greatly. Such reductions, however, are not permanent, and severe scale infestations may again develop when these predators are themselves decimated by starvation, parasites, etc.

Climatic conditions, as well as biological factors, apparently affect fluted scale populations. Extended periods of dry weather seem to favor the development of heavy infestations. Natives of several atolls have reported that the heaviest scale populations usually develop during and immediately following such dry periods.

Nomwin in the central Carolines is a good example of a Micronesian atoll, heavily dependent upon breadfruit, which has been invaded by fluted scales. Severe infestations of *Icerya aegyptiaca* (Douglas) were first reported at Nomwin in 1946 (Oakley, 1946), but the scale was probably present there several years earlier. When I visited the atoll in February, 1954, *I. aegyptiaca* was very abundant on breadfruit and a number of other hosts. The village chiefs complained that breadfruit crops had been considerably below normal for several years and that the resulting scarcity of this food was imposing a serious hardship upon the people. On Nomwin, as well as other remote islets visited, I found it impossible to evaluate satisfactorily the overall effect of fluted scale infestations upon the natives' economy because of the very brief periods which I was able to spend in these places. There seems little doubt, however, that continued crop losses of this nature, particularly if combined with scarcities of other foods, can prove very serious to these people.

Several food plants other than breadfruit are subject to attack by fluted scales in Micronesia. Except for citrus, which is sometimes badly damaged, infestations on these crops generally have been found to be less severe

than on breadfruit and have been considered to be of relatively minor importance.

III. Distribution of Fluted Scales in Micronesia

Three species of the genus *Icerya* Signoret, all widely distributed pests, and one other closely related monophlebine scale, *Steatococcus samaraius* Morrison, comprise the economically important fluted scales known to occur in Micronesia. The Egyptian fluted scale, *Icerya aegyptiaca* (Douglas), is the predominant species in these islands and is the one which most frequently is found damaging breadfruit. This scale occurs in Formosa (Kuwana, 1922) and possibly gained entry into Micronesia from there.

Certain wild hosts of *Icerya aegytiaca,* chiefly *Scaevola frutescens* (Mill.), *Macaranga* sp., *Glochidion* sp., and *Allophylus* sp., are widespread in Micronesia. Some widely cultivated ornamentals, particularly *Acalypha wilkesiana* Muell.—Arg., roses, *Pseuderanthemum* sp., and *Codiaeum variegatum* (L.) Bl., as well as several common weeds such as *Jatropha gossypifolia* L., and *Cassia mimosoides* L. are also commonly infested by this scale.

Lime and other citrus trees are sometimes badly attacked by *Icerya aegyptiaca* in the Caroline and Marshall Islands. On some islands bananas, taro [*Colocasia esculenta* (L.) Schott and *Alocasia macrorrhiza* (L.) Schott], pandanus, and even young coconut palms have been found infested with this scale.

There is little available information on the status of *Icerya aegytiaca* during the Japanese administration of the islands. First definitely collected in Micronesia at Saipan by Esaki in February, 1936, (Takahashi, 1936), it was probably established on some islands several years earlier. Kuwana (1922) mentions (in a footnote) that *Icerya aegyptiaca* was often taken on plants from the Marshall Islands intercepted by quarantine inspectors at Yokohama. This indicates that it may have become established in the Marshalls during the early years of the Japanese occupation, or possibly even before. Specimens collected on Professor Esaki's Micronesian expeditions provide the only authenticated early records for this species. In addition to Saipan, he collected *I. aegyptiaca* at Jabor, Jaluit Atoll (in November, 1937); Wena or Moen Island, Truk (in July, 1939); and Koror, Palau Islands (in November, 1939) (Takahashi, 1939, 1941).

I found no references to prewar outbreaks of *Icerya aegyptiaca* in Micronesia. However, records of infestations of *I. purchasi* Maskell on Saipan, Tinian, and the Palau Islands prior to 1928 (Sakimura, 1935) are questionable (Takahashi, 1939; Esaki, 1940), and it is probable that the species actually involved in these outbreaks was *I. aegyptiaca.*

Natives tell of a serious outbreak of "white bugs," presumably the Egyptian fluted scale, which occurred on breadfruit on the volcanic islands of the Truk group a few years prior to World War II. A similar outbreak is said to have taken place at Losap Atoll southeast of Truk at about the same time. It seems probable that other unrecorded prewar or wartime outbreaks of this scale occurred in Micronesia.

Since the United States assumed trusteeship of these islands a number of outbreaks of *Icerya aegyptiaca* have come to light. In 1946, Townes and Oakley encountered heavy infestations of this species at Pis Islet, Truk; Nomwin Islet, Nomwin Atoll; Fassarai and Mogmog Islets, Ulithi Atoll; Jabor Islet, Jaluit Atoll; Bikadjela Islet, Alinglapalap Atoll; and Likiep Islet, Likiep Atoll (Townes, 1946; Oakley, 1946, 1953). Subsequent American investigators (K. L. Maehler, R. P. Owen, D. B. Langford, and J. W. Beardsley) have reported heavy infestations of *I. aegyptiaca* from the following localities: Elemat, Lam, and Potangeras Islets, Ulithi Atoll (1948); Falalop Islet, Ulithi Atoll (1954); Fais Island (1954); Nomwin, Fananu, and Igup Islets, Nomwin Atoll (1954); East Fayu Island (1952); Nama Island (1949); Kwajalein and Eru Islets, Kwajalein Atoll (1948, 1953); Lae Islet, Lae Atoll (1953); Bikadjela Islet, Alinglapalap Atoll (1949); Pinglap and Jabor Islets, Jaluit Atoll (1953); Majuro and Uliga Islets, Majuro Atoll (1948); and Likiep Islet, Likiep Atoll (1950). In addition, there have been recent unconfirmed reports of fluted scale infestations, most probably due to this species, from Elin and Setoanelap Islets, Nomwin Atoll; Ruac Islet, Truk; Jaluit Islet, Jaluit Atoll; Kili Island; Ebeje Islet, Kwajalein Atoll; and from several unspecified islets in Likiep Atoll.

Since 1946 *Icerya aegyptiaca* has been found present but not a serious pest on the following Micronesian islands: Anatahan, Saipan, Tinian, Agiguan, Rota, Guam, Yap Islands (Ruul, Tomil), Palau Islands (Babelthuap, Koror, Malakal, Ngerkabesang, Peleliu), Truk Islands (Tonoas or Dublon, Wena or Moen, Etten, and Ton), and Ponape. With the exception of the uninhabited islands of Agiguan and Anatahan, *Rodolia* beetles have been found associated with fluted scales in all these localities.

The Seychelles fluted scale, *Icerya seychellarum* (Westwood), has been found on a few islands in western Micronesia. First collected on Angaur Island in the Palau group in 1936 (Takahashi, 1936), it has been taken since the war at Yap (Ruul I.) and in Ulithi Atoll (on Fassarai, Mogmog, and Falalop Islets). Severe infestations of *Icerya seychellarum* were discovered on breadfruit at Falalop and Mogmog Islets, Ulithi, in 1948, and again on Falalop Islet in 1954. At Falalop I found many breadfruit trees attacked by both *I. seychellarum* and *I. aegyptiaca*. Where such mixed populations occurred *I. seychellarum* was generally more plentiful and this species was judged to be a more serious pest than *I. aegyptiaca* on that islet. *I. seychellarum* was also taken on *Casuarina equisetifolia* L. and *Eugenia* sp. at Falalop.

At Yap I have taken small numbers of *Icerya seychellarum* on citrus, but it is not a serious problem there. *Rodolia pumila* Weise, which occurs in both the Yap and Palau groups, may control the Seychelles scale in those islands. There are, however, no recorded observations of any species of *Rodolia* attacking *I. seychellarum* in Micronesia.

The notorious cottony cushion scale, *Icerya purchasi* Maskell, occurs in Micronesia on Guam where it was first reported in 1911 (Fullaway, 1913). Until controlled, this scale was a serious pest of citrus and various ornamentals there (Swezey, 1940). It is not recorded as attacking breadfruit. The cottony cushion scale has also been reported from Saipan,

Tinian, and the Palau Islands (Sakimura, 1935), but, as was previously discussed, these records are thought to represent misidentifications of *Icerya aegyptiaca*. *I. purchasi* apparently has never been taken in Micronesia except on Guam.

Steatococcus samaraius Morrison, a fluted scale originally described from New Guinea (Morrison, 1927), is known in Micronesia only from the Palau Islands. This species has been taken on banana leaves, young coconut trees, and a wide variety of weeds, ornamentals, and native trees and shrubs. Although occasionally plentiful on some ornamentals such as *Acalypha* spp., roses, *Casuarina equisetifolia,* and *Erythrina* sp., the writer never found it more than a minor agricultural pest. In the Palau Islands this species is apparently held in check by natural enemies, particularly *Rodolia pumila.*

IV. Fluted Scale Enemies and Biological Control in Micronesia

In addition to predators purposely introduced for the control of fluted scales, several others have been found attacking these pests in Micronesia. Adults and larvae of one or more species of green lacewings (*Chrysopa* spp.) have been observed feeding upon fluted scales in several localities. D. B. Langford reported *Icerya aegyptiaca* populations at Likiep in the Marshall Islands materially reduced by *Chrysopa* in 1948. The writer has noticed similar reductions of this scale by green lacewings at Fais Island and at Lae Atoll. Large numbers of *Chrysopa* cocoons were found among the remains of dead scales on the under surfaces of breadfruit leaves on these islands. On both it was apparent that very large fluted scale populations had developed before the lacewings became plentiful enough to affect control. At Fais many *Chrysopa* cocoons were found to have been parasitized by a small wasp, possibly *Isodromus* sp.

The coccinellid beetles *Harmonia arcuata* (Fab.) and *Coelophora inaequalis* (Fab.) were found feeding upon *Icerya aegyptiaca* at Likiep by Langford, and *H. arcuata* recently was found attacking this species in Jaluit Atoll. Another coccinellid, *Cryptolaemus montrouzieri* Mulsant, is known to attack *I. aegyptiaca* occasionally in the Mariana Islands and *Steatococcus samaraius* in the Palaus. *Scymnus* sp. has been reported to be a fairly efficient enemy of *Icerya purchasi* on Guam (Fullaway, 1913).

Entomogenous fungi may also play an important part in the natural control of fluted scales, particularly during wet weather. There is very little information available regarding such fungi in Micronesia, however. D. B. Langford, in 1948, reported finding *Icerya seychellarum* at Ulithi Atoll greatly reduced by a fungus disease. In the Palau Islands the writer has seen infestations of *Steatococcus samaraius* which had been largely destroyed by an undetermined entomogenous fungus.

Among the enemies of fluted scales now found in Micronesia only introduced coccinellid beetles of the genus *Rodolia* Mulsant have proven efficient enough to reduce and maintain scale populations at levels where they are of no economic significance. Three species of *Rodolia* have been introduced into Micronesa to combat outbreaks of these pests. The famous Vedalia beetle, *Rodolia cardinalis* (Mulsant), was established on Guam from colonies sent from Hawaii in 1926, and soon brought the cottony cushion scale under control there (Vandenberg, 1927). Insofar as I have

been able to ascertain, *R. cardinalis* does not occur elsewhere in Micronesia.

Japanese entomologists are reported to have introduced *Rodolia cardinalis* to Saipan and the Palau Islands from Formosa in 1928 (Sakimura, 1935). Mr. Sakimura recently informed me that the *Rodolia* which he collected in Saipan and Palau in 1934, were not typical *cardinalis* but were an immaculate form also known to him from Formosa. Professor Esaki in a recent correspondence expressed the view that the *Rodolia* introduced into Micronesia by the Japanese was probably not *R. cardinalis*. It appears probable that the species introduced in 1928 was actually *R. pumila* Weise. This is an immaculate form, about the same size as *R. cardinalis,* which has been found in Micronesia as well as in Formosa and China. Possibly, shipments of this species were sent from Formosa misidentified as an immaculate form of *R. cardinalis*. I have been unable to find detailed records of these introductions, however.

The first Micronesian specimens to be determined as *Rodolia pumila* were found feeding upon *Icerya aegyptiaca* on Rota Island in 1947 (Pemberton, 1948). Specimens collected by Esaki in the Palau Islands in 1936 and on Rota in 1937, also appear to belong to this species. Since the war *R. pumila* has been taken on Saipan, Tinian, Rota, Guam, Yap, Palau (Angaur, Peleliu, Koror, Ngerkabesang, Malakal, and Babelthuap Islands), Truk (Wena, Tonoas, and Ton Islands), and Ponape. Some of these islands possibly were colonized by accidental introductions of *R. pumila* from Saipan, Palau, or elsewhere. Sakimura (1935) mentions that *Rodolia* from Saipan apparently found their way unaided to the nearby island of Tinian. However, the Japanese probably spread this predator purposely to several islands to combat outbreaks of fluted scales.

Although no published reports concerning movements of *Rodolia* within Micronesia by the Japanese were found, a few credible accounts of such movements have been received from islanders. Trukese natives have reported that the Japanese imported "small red beetles" which controlled an outbreak of fluted scales in the Truk Islands shortly before World War II. An outbreak at Losap Atoll was said to have been controlled by a similar Japanese introduction. Although *Rodolia* have not been collected at Losap by Americans there is evidence that a species, probably *R. pumila,* is established there. Langford has reported that in 1950 natives of Nama found *Rodolia* feeding on a colony of fluted scales (probably *Icerya aegyptiaca*) at Losap and transferred the beetles to Nama where, at that time, *I. aegyptiaca* was severely damaging breadfruit.

Since the end of World War II, U. S. entomologists have attempted to establish *Rodolia pumila* on a number of Micronesian islands. The available information concerning these introductions is summarized in table I.

Only the introductions to Pis Islet, Truk; Nama Island; and Fananu and Igup Islets, Nomwin Atoll are known to have resulted in establishment. Although *Rodolia pumila* was reported by Langford to be established on Kwajalein Islet, Kwajalein Atoll in 1950, I was unable to find it in October, 1953, even though *Icerya aegyptiaca* was abundant there. The liberal use of DDT sprays and fogs by the U. S. Navy for the control of flies and mosquitoes has apparently either exterminated or greatly

reduced *Rodolia* populations on Kwajalein. Due to the infrequent intervals at which they are visited by U. S. administrative personnel, it may be several years before definite information is obtained on the status of *Rodolia* on some of the islets where releases have been made.

Observations indicate that, with the exception of Kwajalein Islet, *Icerya aegyptiaca* is no longer a serious problem on any of the islands where *Rodolia pumila* is known to have become established. *R. pumila* is also known to control *Steatococcus samaraius* in the Palau Islands, and may be largely responsible for the scarcity of *Icerya seychellarum* in both Yap and Palau.

A colony of *Rodolia,* tentatively determined by E. A. Chapin as *R. fumida* Mulsant, was sent from Bangalore, India, to Guam in February, 1948. Twelve adults of this *Rodolia* were liberated on Guam and the remainder of the shipment, an unspecified number, were released on Uliga and Majuro Islets, Majuro Atoll (Pemberton, 1954). Reports indicate that this *Rodolia* may have become established in Majuro Atoll. However, no specimens have been collected on either Guam or Majuro since the releases were made. In September, 1953, neither *Rodolia* nor *Icerya* could be found at Majuro although both the islets where the beetles were released were searched.

Esaki (1940, b) states that *Icerya aegyptiaca* was controlled wherever then known in Micronesia, except at Jaluit, by *Rodolia koebelei* Oliff. To my knowledge, there are no records of this species having been introduced into Micronesia. Professor Esaki has indicated that the *Rodolia* to which he referred was the immaculate red or red-orange form which has subsequently been determined to be *Rodolia pumila* Weise.

V. Conclusion and Recommendations

There is definite need for a survey of all the inhabited islets in the atolls of Micronesia to determine accurately the present distribution of fluted scales and other pests. Thorough insect surveys of most of these atolls have never been made, and many have not been visited by entomologists for a number of years. Consequently, information concerning the present status of fluted scales is unavailable for many islets. Some may now harbor populations of these pests which are not yet physically obvious or economically significant. In such places the scales will likely remain undetected or unreported until they become a serious problem. It is also possible that heavy infestations may exist unknown to U. S. authorities on some of the minor inhabited islets which are visited infrequently by Trust Territory field parties.

Fluted scales, particularly *Icerya aegyptiaca,* probably will spread eventually to most of the islets of Micronesia. Frequent small boat traffic between islets and atolls affords ample opportunity for the dispersal of such pests. Fruits such as bananas, breadfruit and coconuts are often transported on these boats and travellers usually carry food for inter-island trips wrapped with breadfruit, banana, or taro leaves in baskets woven from green coconut fronds. On one occasion the writer found breadfruit leaves infested with *Icerya aegyptiaca* used to wrap food being carried between islands. Such leaves, if later discarded on an islet free of fluted scales, could easily result in establishment of these pests.

Table 1. **Liberations of *Rodolia pumila* Weise in Micronesia since World War II.**

Locality Released	Date of Release	Number Released	Source of Colony	Released by	Establishment
Pis Islet, Truk	May 1947	34 adults	Rota	D. B. Langford	Confirmed Mar. 1949, Feb. 1954.
Potangeras Islet, Ulithi Atoll	June 1948	200 larvae and pupae	Saipan	D. B. Langford	Unconfirmed, reported in 1950 by U. S. Coast Guard officer.
Kwajalein Islet, Kwajalein Atoll	Oct. 1949	Approx. 100	Guam	D. B. Langford	Confirmed April 1950. Status now doubtful.
Bikadjela Islet, Alinglapalap Atoll	Oct. 1949	Approx. 100	Guam	D. B. Langford	Unconfirmed, reported 1950 by natives.
Nama Island	Mar. 1949	22 adults and 9 pupae	Pis Islet, Truk	D. B. Langford	Confirmed December 1950.
Pinglap Islet, Jaluit Atoll	Sept. 1953	15 adults and 30 larvae	Koror, Palau Is.	J. W. Beardsley	Unconfirmed, reported August 1954 by missionary.
Kwajalein Islet, Kwajalein Atoll	Oct. 1953	10 adults	Koror, Palau Is.	J. W. Beardsley	Negative reports.
Eru Islet, Kwajalein Atoll	Oct. 1953	15 adults	Koror, Palau Is.	J. W. Beardsley	Negative reports.
Lae Islet, Lae Atoll	Oct. 1953	14 adults and 10 larvae	Koror, Palau Is.	J. W. Beardsley	No reports.
Nomwin Islet, Nomwin Atoll	Feb. 1954	Approx. 100 adults	Koror, Palau Is.	J. W. Beardsley	Unconfirmed, scale reported absent Dec. 1954 by agriculturist.
Fananu and Igup Islets, Nomwin Atoll	Feb. 1954	Approx. 200 adults	Koror, Palau Is.	J. W. Beardsley	Confirmed December 1954.
Elin Islet, Nomwin Atoll	Feb. 1954	40 adults	Koror, Palau Is.	Nomwin native	Unconfirmed, scale reported absent December 1954 by natives.
Fais Island	Apr. 1954	60 adults and 50 pupae	Koror, Palau Is.	J. W. Beardsley	No reports.
Falalop Islet, Ulithi Atoll	Apr. 1954	10 adults and 15 pupae	Koror, Palau Is.	J. W. Beardsley	No reports.

Successes already achieved with biological control of fluted scales make this method an obvious first choice for use against both existing and future outbreaks of these pests in Micronesia. The relative ease with which *Rodolia* spp. can be secured and transported, combined with their efficiency as predators, indicates that it should be possible to utilize these coccinellids successfully on the majority of Micronesian islets. Once the distribution of fluted scales in Micronesia is accurately known a concerted effort should be made to establish enemies, such as *Rodolia pumila,* wherever these scales occur. Certainly, the time and expense required to achieve satisfactory biological control of fluted scales is minor when weighed against the lasting benefits such control brings to the inhabitants of these remote islands.

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