The Biology of the Mariana Coconut Beetle, Brontispa mariana Spaeth, on Saipan, and the Introduction of Parasites from Malaya and Java for its Control[1]

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(Presented by Mr. Van Zwaluwenburg at the meeting of April 11, 1949)

The Mariana coconut beetle, *Brontispa mariana* Spaeth, is a serious pest of the coconut palm, *Cocos nucifera,* on certain of the islands of Micronesia, particularly Saipan and Rota in the Mariana group. As a result of the depredations of this beetle a former copra and coconut oil industry of sizeable proportions has been almost completely eliminated. Esaki (1940) states that it was first discovered on Saipan in 1931 and during 1935 and 1936 caused such severe damage that in 1936 about 70 per cent of the plantations were burned over. In view of its wide distribution in the Carolines on coconuts there is considerable evidence to indicate that it was brought to Saipan on coconut seedlings for planting stock. Swezey (1940) mentions the fact that in 1936 a Japanese boat reversed the order of its route so as not to go from Saipan to Guam and increase the possibility of introducing it to Guam.

The reports of Townes and Oakley (1946) based on their survey for the United States Commercial Company pointed out the severe damage caused by the beetle on Saipan and Rota and suggested either eradication of the coconut trees or the introduction of natural enemies. The few remaining larger coconut trees on Tinian and a limited number on Saipan were cut and destroyed prior to the initiation of this investigation. The recommendations for this research were contained in the reply of Knowles A. Ryerson, chairman of the Pacific Science Board, to Admiral Chester W. Nimitz, dated 7 July 1947. During the period 19 November 1947 to 6 February 1948 a search was made for parasites associated with externally-feeding hispid beetles in the Philippines, Malaya, and Java, and, as a result, two parasites were introduced to Saipan and Rota.

SYSTEMATIC POSITION.—The Mariana coconut beetle, *Brontispa mariana* Spaeth, belongs to the subfamily Hispinae of the beetle family Chrysomelidae. It was named by Spaeth (1937) from specimens collected on coconut palm on Saipan in July 1936. Spaeth placed it close to *B. limbatus* Waterhouse in general coloration and size. Chujo (1937) described it as a new genus and species, *Planispa castaneipennis* Chujo,

[1] These investigations undertaken as a project of the Pacific Science Board under the direction of the Insect Control Committee for Micronesia, at the request of the United States Navy. Collecting was done on a survey made under the auspices of the Insect Control Committee for Micronesia of the Pacific Science Board, National Research Council, with financial assistance from the Office of Naval Research.

[2] On loan to the Pacific Science Board of the National Research Council as Field Associate in Entomology, 1 October 1947 to 1 May 1948.

from specimens collected on Saipan. The genus *Brontispa* was erected by Sharp (1903).[3] Weise (1911) lists the related genera as *Leucispa* Chapuis, South Australia; *Octodonta* Chapuis, Malaya; *Plesispa* Chapuis, Malaya and Java; *Oxycephala* Guerin, New Guinea, Aru Islands, New South Wales, and Solomon Islands; and *Xiphispa* Chapuis, New Guinea and Madagascar.

DISTRIBUTION OF THE GENUS BRONTISPA.—The center of distribution of the genus *Brontispa* is in the Austro-Malayan region. Most of the species occur in the Pacific Ocean between 20° north and south of the equator, and 100° to 180° east longitude. The known distribution summarized chiefly from Maulik (1938) is as follows: Philippine Islands, *depressa* Baly, *angulosa* Uhmann, *banguiensis* Uhmann, and *surigaoana* Uhmann; Marianas, *mariana* Spaeth; Carolines, *mariana* Spaeth, *chalybeipennis* Zacher, and *namorikia* Maulik; New Guinea, *longissima longipennis* Gestro, and *linearis* Spaeth; Solomons, *longissima froggatti* Sharp; Java, *longissima javana* Weise, *longissima celebensis* Gestro, and *affinis* Uhmann; Celebes, *longissima celebensis* Gestro; Aru Island, *longissima longissima* Gestro; Lord Howe Island, *longissima castanea* Lea; Witu Islands, *longissima simmondsi* Maulik; Ceram, *longissima reicherti* Uhmann; Mauritius, *gleadowi* Weise; and Rodriguez Island, *limbatus* Waterhouse.

DISTRIBUTION OF BRONTISPA MARIANA SPAETH.—The Mariana coconut beetle has a wide distribution in the Mariana and Caroline Islands of Micronesia. The known distribution is as follows:[4] Marianas: Rota (Esaki, 1940; Townes and Oakley, 1946); Saipan (Esaki, 1940; Swezey, 1940; Townes and Oakley, 1946); Carolines: Truk (Moen, Tol, Fefan, Udet Islets); Yap; Woleai (Utagal Islet); Nukuoro (Shenukdei Islet); Ulithi (Fassarai and Mogmog Islets); Hall Islands (Nomwin); and Ponape? (Oakley, 1946).

The present writer was able to verify the occurrence of *Brontispa mariana* on Saipan and Rota. A survey of Tinian indicated that the few remaining seedling coconut trees were not infested. Specimens supposedly this species from Anatahan were determined by L. L. Buchanan as a *Sessinia* sp. in the family Oedemeridae. *Brontispa mariana* is not the sole representative of this genus in the Carolines as *B. chalybeipennis* Zacher, according to Esaki (1940), is reported from Ponape, Kusaie, and the Marshalls, a *Brontispa* species from the Palau Islands is reported by Oakley (1946), and *Brontispa namorikia* recently described by Maulik is reported from Kusaie.[5]

DESCRIPTION OF THE STAGES.—EGG: The eggs of *Brontispa mariana* are capsular, elongate-spheroid, flattened, dark brown in color, and are laid singly or end to end in groups up to six in number. In size the

[3] Sharp, Proc. Linn. Soc. N. S. Wales 1903(1904), p. 924.

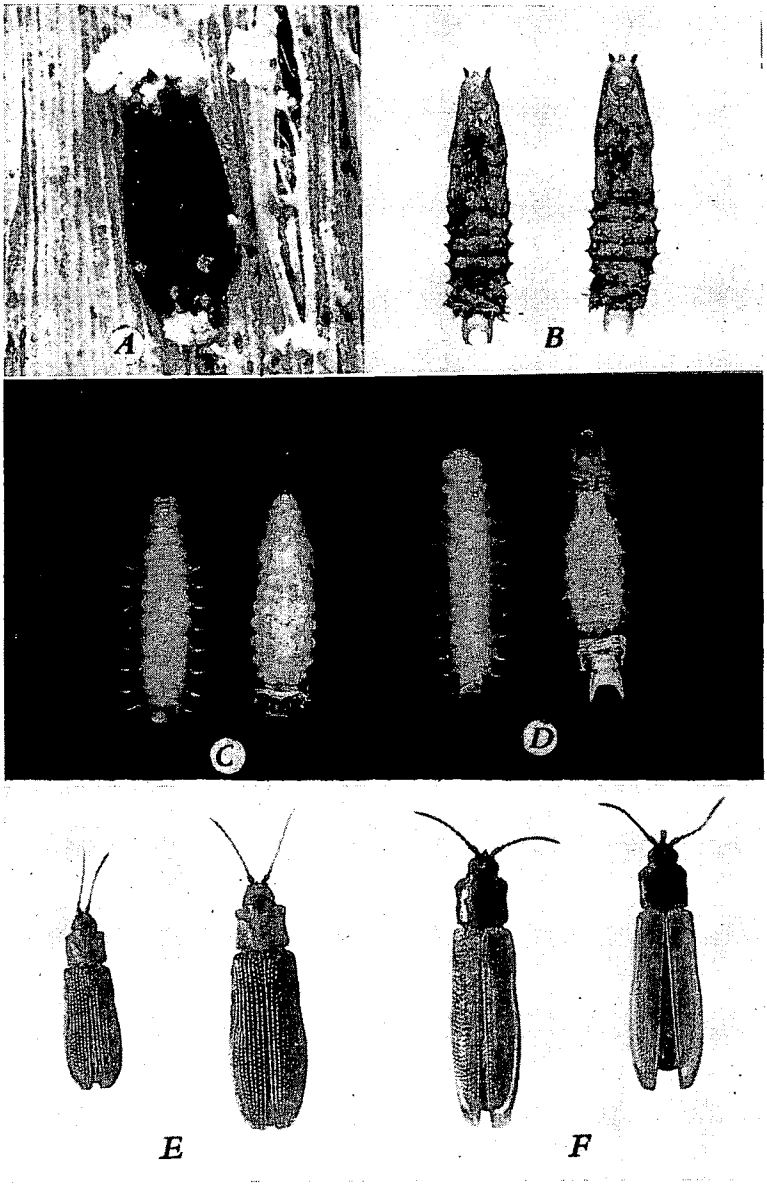
[4] Records without author references supplied by C. F. W. Muesebeck, from the United States National Museum collection.

[5] Record according to E. C. Zimmerman of the Hawaiian Sugar Planters' Experiment Station. See Maulik, S. 1946. A new species of *Brontispa* from the Pacific. Ann. Mag. Nat. Hist., 13(11):498-502.

width varies from 0.70 mm. to 0.93 mm., with an average width of 0.80 mm., and the length varies from 1.48 mm. to 1.80 mm. with an average of 1.60 mm. The surface of the egg has shallow, hexagonal reticulations. The egg is shown in plate 1A.

LARVA: The larvae molt three times and have four larval instars. With the exception of size, and minor differences, the larval instars are similar. The first instar larva lacks the dorsal row of teeth on the posterior processes, and the lateral abdominal processes are broader. In the second instar teeth occur on the posterior processes, and in the third instar the lateral abdominal processes become less lobe-like and resemble those present in the fourth instar. The approximate length of the larvae at different stages in their growth is as follows: at hatching from the egg, 2-3 mm.; first molt, 4 mm.; second molt, 5-5.5 mm.; third molt, 7-8 mm.; and the mature larva, 9-11 mm. A description of the fourth larval instar is as follows (see plate 1D): the larva is flattened dorso-ventrally, and has a characteristic, chitinized pair of hooks, and a pair of fleshy protuberances from each of the abdominal segments—one from each side, located laterally. The larva is 7 to 8 mm. long at the time of molting, attaining a length of 9 to 11 mm., and is a yellowish white in color. The head is broad, concolorous with the body; the antennae are short, three-segmented, with two terminal palp-like projections; the eyes are made up of a ring of five ocelli; and the labrum is broad and entire. The mouth parts are located ventrally; the maxillary palpi are short and three-segmented, and the labial palpi are short, and two-segmented; and the mandibles are well developed, stout basally, with two terminal teeth, and hollowed terminally to serve as chisels for use in scooping out portions of leaf surface. Three pairs of thoracic legs are present, with a single, well developed claw on each leg, and flap-like structure opposite each claw. One pair of well developed, laterally placed, tubular spiracles is present on the second thoracic segment, one pair of spiracles each on abdominal segments 1 to 7, and a pair located dorsally near the base of the posterior hooks on abdominal segment 8. The abdominal segments have a laterally placed, fleshy protuberance from each of segments 1 to 8, and a posterior forceps-like process from segment 8. The posterior processes have a dorsal row of teeth. A measurement of the head capsules of 1,090 larvae substantiated the fact that four instars are present. Upon plotting the frequency distribution of the head capsule widths it was possible to segregate four classes corresponding to the four instars as follows: width of head capsule at time of hatching up to first molt (first instar), 19-26 units (one unit in these measurements equals 0.025 mm.); second instar, 27-36 units; third instar, 37-46 units; and fourth instar, 47-63 units.

PUPA: The pupa is elongate, flattened, widening slightly posteriorly, and has a characteristic posteriorly located forceps-like structure similar to that of the larva. The cast skin of the fourth instar larva usually remains attached at the posterior end of the pupa, but is easily removed to show the pupal processes. The pupa is yellowish white in color with



A. Egg of *Brontispa mariana* Spaeth, × 20.
B. Pupae of *Plesispa reichei* Chap., parasitized by *Tetrastichus brontispae* (Ferrière), × 3.
C. Mature larva and pupa of *Plesispa nipae* Maulik, × 3.
D. Mature larva and pupa of *Brontispa mariana*, × 3.
E. Male, left, female, right, of *Plesispa nipae*, × about 3.
F. Female, left, male, right, *Brontispa mariana*, × about 3.

brownish posterior hooks, and the male pupa is 8 to 9 mm. long, and the female pupa 9 to 10.5 mm. long. The average width of the pupa of both sexes is 2 mm. The head has two characteristic, downwardly projecting, hook-like structures arising anterior to the eyes, and a conspicuous frontal process which in the male is long, and terminates bluntly in front and in the female is short and sub-acute apically. The antennae are free, and long. Rudimentary mouthparts are present. The wings and legs are partly free and distinctly visible. Dorsally the abdomen has segments 2 to 7 with sparsely distributed, dark spicules, and ventrally segments 4 to 7 have a medial row of six spicules; and laterally on each segment is a tubercle with a few terminal hairs. The posterior forceps are smooth, unlike those of the fourth instar larva. The pupa is shown in plate 1D.

ADULT: The adult beetle is uniform dark brown in color, glossy, and greatly flattened dorso-ventrally (see plate 1F). The females range from 8.5 to 10.5 mm. long, with an average of 8.6 mm. (exclusive of antennae), and are approximately 2 mm. wide, and the males range from 6.75 to 9 mm. long, averaging 7.5 mm. long, and are 2 mm. wide. The antennae are sub-filiform, stout, 11-segmented, and 1.8 to 2.3 mm. long; the scape is over twice as long as segment 2; and segments 7 to 11 are closely joined, and almost club-like. The head is flattened with the mouthparts arising ventrally, and the front is produced into characteristic interantennal processes which in the males are almost half as long as the head and terminate abruptly, and in the females are one-fourth the length of the head, and terminate less abruptly; the head is deeply grooved lengthwise through the center and the grooves extend into the interantennal processes; the eyes are large, and black in color; and the head is sparsely punctate above. The thorax is sub-rectangular with the apical angles broadly expanded, particularly in the females, and with a slight projection; the posterior angles have a short spine; and the dorsal surface is sparsely and deeply punctate at the edges with considerable impunctate area medially. The elytra are elongate, and slightly expanded apically, with eight rows of sub-quadrangular depressions running longitudinally; the lateral margins are upturned; and the interstices are not raised into costae. The legs are short with trochanters present, and the femora are enlarged; the tibiae are set distally with several short, heavy-set spines; and the tarsal segments are greatly flattened, have two terminal claws, and are covered ventrally with a thick pubescence.

LIFE HISTORY.—The Mariana coconut beetle belongs to a group of leaf-feeding hispid beetles which feed externally on the buds and new growth of palms and other plants. The beetle under discussion feeds in the buds of the coconut palm, *Cocos nucifera*, where as both larvae and adults it feeds inter- and intra-pinnately, scraping off the leaf surfaces and causing characteristic, darkened blemishes which persist during the interval of time the leaf remains on the tree. The damage is shown in figure 1.

In the laboratory on Saipan it was found that the life history could be studied satisfactorily by confining all stages in small Stender dishes.

Larvae were fed small pieces of coconut leaves, changing the food daily, and a small piece of white blotting paper was placed on the bottoms of the dishes to absorb excessive moisture.

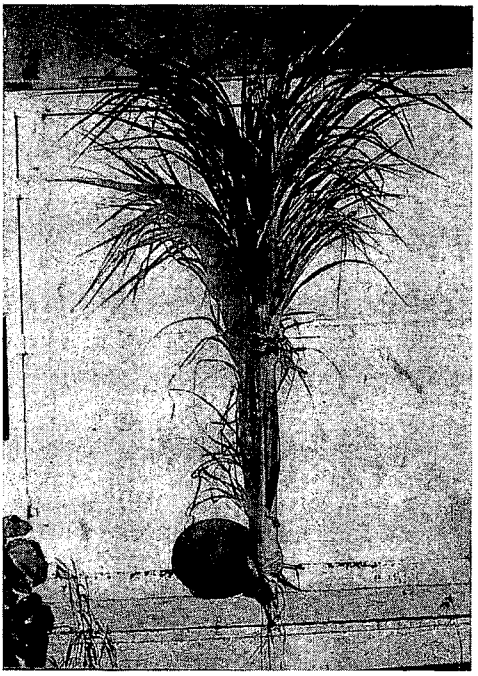


Figure 1.—Center foliage of a coconut tree showing discoloration and fraying of the leaflets caused by larvae and adults of *Brontispa mariana*. The foliage was tied and removed in this manner for later study in the laboratory.

The eggs are laid between the leaflets on the upper or lower surfaces of the folded leaflets in the buds of the trees. They are light brown in color when first laid later changing to dark brown. Adults seem to prefer oviposition sites which are located intra-pinnately about 3 mm. above the midrib of the leaflets, but can lay eggs any place on the new growth. There was some indication that the females selected areas for egg laying near leaf areas which had already been fed on by beetles and where fermentation processes were in progress. The egg is lightly glued to the leaf surface, and the female beetle places a blob of frass or chewed-up leaf epidermis at the ends of each egg or group of eggs. Eggs may be laid singly or end to end in groups of from 2 to 6. Records were kept in the laboratory of the number of eggs laid at any one time and a summary of 395 laboratory records is as follows: 269 instances of one egg, or 68.1 per cent; 92 instances of 2 eggs, or 23.3 per cent; 25 instances of 3 eggs, or 6.3 per cent; 7 instances of 4 eggs, or 1.7 per cent; and 1 instance each of 5 and 6 eggs, or 0.3 per cent respectively. The duration

of the egg stage under Saipan laboratory conditions was six days, although an occasional egg would hatch in five days.

The larvae emerge through a slit at one end of the egg capsule. The slit is usually made laterally at a zone corresponding to the upper, tough portion of the egg, and the soft, underneath portion. In one instance it was noted that an interval of 30 minutes elapsed from the time the larva first started to emerge until it was free of the egg. It was observed that in certain instances the posterior hooks of the small larvae were used to enable them to separate the egg and thereby emerge. The small larva upon emerging from the egg usually proceeds to devour a portion of the egg shell before feeding on plant material. The larvae soon feed on coconut leaves eating long strips between the fibers. The larvae often feed together in large numbers and the entire surface of the leaf may become scarred and discolored. Larvae can feed between or within the leaflets.

In the laboratory the mean number of days for the larval period was 22.72 days with means for each instar as follows: first instar, 4.86 days; second instar, 3.38 days; third instar, 5.05 days; and fourth instar, 9.43 days. The variation in number of days for the duration of each of the instars was as follows: first instar, 3 to 8 days; second instar, 2 to 7 days; third instar, 2 to 8 days; and fourth instar, 6 to 16 days. Several days before pupation the larvae usually remain quiescent. The pupal period varied from 3 to 6 days with a mean of 5.14 days. Of a total of thirty-three individual rearings only seven were successfully completed. These varied from 30 to 36 days with a mean of 32.71 days. An average of all records, complete and incomplete, raised this figure to a mean of 33.68 days for the life cycle of the beetle from egg to adult in the laboratory at a mean temperature of 85° F.

Adults live for several months. One female started laying eggs on October 24, 1947, and died on December 22, having laid 113 eggs or an average of 1.88 eggs per day for the sixty-day period. Another female in 33 days laid 106 eggs or an average of 3.21 eggs per day.

Of 642 adults examined during this study, 343 were females and 299 were males, or a proportion of 1 male to 1.15 females, or a sex ratio of 0.58.

Generations of the beetle in the field were not definitely determined, although on the basis of the laboratory rearings, taking into consideration the maximum and minimum developmental periods, it would be assumed that 3 to 9 cycles occur a year. It was noticed that there was definitely a cyclic development of the beetles in individual trees so that there would be a preponderance of certain stages. Continuous generations occurred, and the longer life of the adults resulted in an accumulation of hundreds of them in a single tree.

HABITS AND INJURY.—The larvae and adults are positively thigmotropic and under most conditions negatively phototropic. Adults prefer not to fly, but under certain conditions fly to neighboring trees and spread the infestation. In the laboratory adults were observed to fly to the screen ventilator openings. Larvae in the laboratory were con-

tent to remain on folded leaflets as long as the food supply was adequate. Adults were observed to prefer to feed on the inside of the folded leaflets, feeding longitudinally between the fibers as in the case of the larvae and consumed strips 2 to 55 mm. long at a time. As is true for the larvae, the adults are semi-gregarious, congregating at the bases of the leaflets in large numbers. Mating is infrequently observed and apparently occurs chiefly at night. This was interesting in that it was noticed that *Brontispa depressa* in the Philippines mated frequently during the day. The adults have the interesting ability to move in any direction. The larvae are sluggish and prefer the darkened, interfolded leaves.

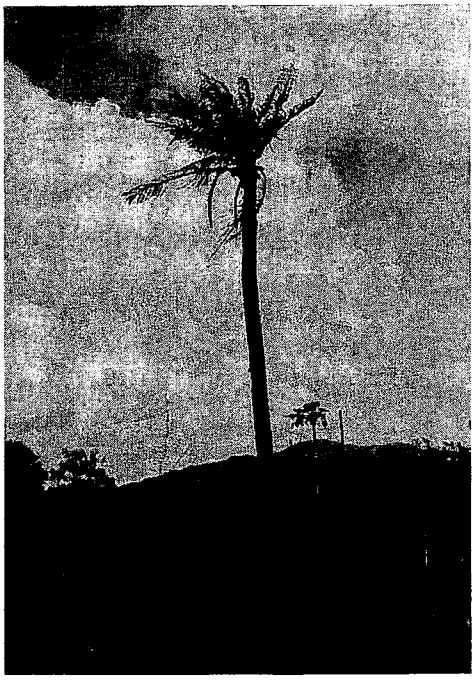


Figure 2.—Coconut tree on Saipan badly damaged by *Brontispa mariana.*

It was apparent on Saipan that the Mariana coconut beetle causes a slow decline of the trees resulting in a reduction in the yield of coconuts and an occasional death of a tree. A badly injured tree is shown in figure 2. A survey on Saipan conducted during October and November, 1947, indicated that only thirty-two per cent of the palms were bearing nuts, and most of these were not bearing sizeable clusters. The only other primary insect causing noticeable injury to coconut palms on Saipan during this survey was the red coconut scale, *Furcaspis oceanica* Lindinger.

HOST PLANTS.—The only known host plant of *Brontispa mariana* in the field is the coconut palm. In the laboratory it was found that both larvae and adults had a decided aversion for Chinese betel nut, *Areca catechu,* the only other common palm growing on Saipan, although in one instance a mature larva was able to complete its development on this plant. In one instance in the field on Saipan it was observed that a betel nut palm growing adjacent to an infested coconut palm was not infested with the beetle. A palmate-leaved palm, probably a *Eupritchardia* species, growing in the Agricultural Station on Saipan was infested in the laboratory and adults were reared from eggs laid on this plant.

SEASONAL ABUNDANCE IN RELATION TO CLIMATIC FACTORS.—Most species of hispid beetles feeding on the coconut palm cause more damage during dry periods than during periods of greater rainfall. This is due primarily to the more rapid rate of growth of the leaves during intervals of adequate rainfall. For this reason it would be expected that the Mariana coconut beetle would cause greater damage during dry seasons than during wet seasons. Rainfall would also probably restrict the migration of beetles, and tend to increase parasitic fungi. On the other hand the activities of parasites would be increased during dry periods. When the writer arrived on Saipan in October, 1947, there was severe and widespread damage to coconuts caused by the Mariana coconut beetle. It is interesting to note that from January to June, 1947, Saipan suffered an extended drought. During the period August to December, 1946, only 17.67 inches fell, and the annual rainfall on Saipan for 1947 at Tanapag was only 48.18 inches and over 30 per cent of this fell in October. In view of the importance of climatic factors to damage caused by this beetle the monthly mean average temperature and the monthly rainfall for 1947 and the first six months of 1948 are shown in the following tabulation:

Month	Mean Average Temperature °F.		Rainfall in Inches	
	1947	1948	1947	1948
January	79.7	79.8	2.45	4.47
February	80.2	78.2	1.12	1.48
March	81.0	78.9	1.40	3.68
April	81.0	80.1	1.26	4.52
May	81.8	81.3	1.90	2.53
June	82.4	82.3	1.21	3.22
July	82.0		7.80	
August	82.7		4.93	
September	81.8		5.49	
October	81.4		15.20	
November	82.2		4.00	
December	81.2		1.42	

Ordinarily there is a wet and dry season on Saipan, although it may not be marked, as rain may fall heavily during any month, and also there is a considerable variation depending upon where the observations are made. The wet season is usually from July to November and

the dry season from January to May. The mean average monthly temperature varies but little and so no great differences in rate of development of the beetle would be expected. Usually, however, it is warmer and there is a higher humidity from June to October or November. The humidity is usually high, with an average of 82 per cent relative humidity. Figures obtained at Tanapag for 1945 indicated an average relative humidity of 77.4 per cent, and for eight months in 1947, 80 per cent. With an average mean total developmental period of 33.86 days from egg to adult, assuming that the first eggs are laid in from 7 to 10 days, and assuming an average length of life of the beetle as 60 days, there would be an average of approximately five to six generations a year of *Brontispa mariana* on Saipan. Inasmuch as the average temperature for the laboratory was 85° F., which is higher than outdoor temperatures, and allowing for other variations, it is possible the number of generations could vary from over 3 to almost 9.

NATURAL ENEMIES.—No published records of parasites of the Mariana coconut beetle appear to be available. Oakley (1946) mentioned the occurrence of the earwig, *Chelisoches morio* (L.) in association with colonies of the beetle on every island he visited. An outstanding example of the biological control of a hispid beetle was reported by Taylor (1937). He reported the status of parasites introduced to control a leaf-mining hispid, *Promecotheca reichei* Baly in Fiji. Taylor mentioned the fact that the parasites attacking leaf-mining hispids do not ordinarily attack the externally-feeding species. For this reason the present investigation deals with parasites associated with externally-feeding hispids as it was thought that these would have the best possibility of selecting *Brontispa mariana.* Some selected references dealing with parasites associated with hispids feeding externally are tabulated below:

1923.[6] Corbett mentioned the occurrence of a chalcidoid egg parasite of *Plesispa reichei* Chap.

1929. Dammerman reported a parasite in Sumatra and the Malay peninsula destroying up to 60 per cent of the eggs of *Plesispa reichei* Chap.

1931. Ferrière described *Haeckeliania brontispae* from Java and Celebes.

1933. Ferrière reported *Pleurotropis detrimentosus* Gahan from larvae of *Plesispa reichei* Chap. in Java, and *Trichogrammatoidea nana* Zehnt. from the eggs of *Brontispa froggatti* (*B. longissima*) in the Solomon Islands.

1933. Ferrière described *Tetrastichodes plesispae* from *Plesispa reichei* in Java, and *Tetrastichodes brontispae* from Java and Dutch New Guinea, reared from *Brontispa longissima.*

1933. Risbec reported *Chelisoches morio* (L.) as a predator of *Brontispa froggatti* (*B. longissima*) in New Hebrides.

1934. Lever reported a small, gamasid mite, *Celaenopsis* sp. in association with the adult of *Brontispa froggatti* (*B. longissima*).

[6] References refer to those listed by author and date in "Literature cited" at the end of this paper.

1935. Awibowo reported the introduction of *Tetrastichodes brontispae* Ferrière to Celebes for the control of *Brontispa froggatti* var. *celebensis* (*B. longissima celebensis*) in March 1933. He listed the parasites of *B. longissima* in Java as follows: egg parasites, *Haeckeliania brontispae* Ferrière, 17 per cent parasitism, and *Ooencyrtus* sp., 10 per cent parasitism; and pupal parasite, *Tetrastichodes brontispae* Ferr., 60 to 90 per cent parasitism. He listed the parasites of *Plesispa reichei* Chapuis, as follows: egg parasite, *Ooencyrtus* sp., 23 per cent parasitism; larval parasites, *Pleurotropis detrimentosus* Gahan, 15 per cent parasitism, and *Tetrastichodes plesispae* Ferr., 10 per cent parasitism; and pupal parasite, *Tetrastichodes plesispae* Ferr., 60 to 90 per cent parasitism.

1936. Lever reported the control of *Brontispa longissima* in Celebes by *Tetrastichodes brontispae* from Java.

1937. Lever introduced *Tetrastichodes brontispae* from Java to the Solomon Islands to control *Brontispa froggatti* (*B. longissima*). Parasites were introduced during August and September, 1936, on Banika Island in the Russell group.

1941. O'Connor reported the importation to New Guinea of *Tetrastichus brontispae* (Ferrière) from the British Solomon Islands in 1939. He reported the presence of several natural enemies of *Brontispa longissima* in New Guinea as follows: a trichogrammatid egg parasite, a rare eulophid, a bacterial disease, and two mites, one an *Anoplocelaeno* sp.

1941. Johns reported that the parasites *Tetrastichus brontispae* and *Trichogrammatoidea nana* Zehnt. have become established in the Solomons, but have not given effective control.

The only natural insect enemy observed on Saipan and Rota prior to the introduction of other parasites was the earwig, *Chelisoches morio* (L.). On October 16, 1947, a mature earwig was caged with a mature *Brontispa mariana* larva. The earwig was immediately attracted to the larva, proceeded to feel it all over with its antennae, started chewing in several places, and finally began feeding on the dorsal part of the body just behind the head. In fifty-two minutes the larva was completely consumed. This earwig was found to be very abundant in practically all coconut trees examined, but played no observable role in reducing numbers of the beetles. The hypopi of tyroglyphid mites were commonly attached to the undersides of the elytra of beetles on Saipan, but there was no indication that they caused injury to the beetles. A fungus disease of the adult beetles was found on Rota on October 18, 1947. It was determined as a *Metarrhizium* species,[7] and was considered as secondary and of minor importance at this particular time. That fungus diseases could play a part in the control of hispid beetles is indicated by the work of Reyes (1932) on *Promecotheca cumingi*.

FIELD SEARCH FOR PARASITES.—A week was spent in the vicinity of Los Baños, Luzon, Philippine Islands, searching for parasites. Two exter-

[7] Determined by Dr. E. A. Steinhaus.

nally-feeding hispid beetles were found as follows: *Brontispa depressa* Baly[8] on *Arenga pinnata,* at Los Baños (October 22, 24, 1947) and San Pablo (October 25); and *Plesispa reichei* Chapuis on coconut at San Pablo (October 23), Los Baños (October 24), and on *Arenga pinnata* at San Pablo (October 25). No evidence of the presence of parasites was found, and there was no later emergence of parasites from caged material.[9] An infestation of the coconut leaf-mining hispid, *Promecotheca cumingi* Baly, was observed near San Pablo, and of 100 eggs examined 78 showed the presence of parasitism.

In Malaya, headquarters were established at Kuala Lumpur, Selangor, Federation of Malaya. Parasites were found associated with *Plesispa reichei* Chapuis, *Plesispa nipae* Maulik, and *Wallaceana palmarum* (Gestro), and two of the parasites were shipped to Saipan or taken there personally by the writer. *Plesispa reichei* was found attacking young coconut trees at numerous localities, but was also found selecting *Crytostachys lakka, Oreodoxa regia, Nipa fruticans,* and an *Arenga* species. An egg parasite of this beetle, *Ooencyrtus podontiae* Gahan[10] was found at the following localities: on coconut at Kuala Lumpur, collected December 18, 1947, one egg of 9 collected was parasitized; on coconut at Klang, collected December 24, 1947, two eggs of 8 collected were parasitized, and at the same locality on December 26, 2 of 14 eggs were parasitized; on coconut at Serdang, collected December 23, 1947, one of 10 eggs was parasitized; and on *Crystostachys lakka,* at Kuala Lumpur, collected December 18, 1947, one of 2 eggs collected was parasitized and the parasite emerged January 1, 1948. One egg of *Plesispa reichei* collected on coconut at Kuala Lumpur on December 18, 1947, was found on January 14, 1948, to have four emergence holes and one adult recovered was determined as *Haeckeliania brontispae* Ferrière. In the laboratory it was found possible to rear *Tetrastichus brontispae* (Ferrière) from pupae of *Plesispa reichei* (see plate 1B). Adults of this parasite from Java readily selected one- to two-day-old pupae of this beetle. No field collections of this parasite from *Plesispa reichei* were made.

Plesispa nipae Maulik in Malaya was found attacking *Nipa fruticans* at Kuala Selangor, Kapar, and Klang, and this hispid was attacked by several parasites (see plate 1C and 1E for larva, pupa and adults). The commonest parasite, particularly in the Klang area, was an egg parasite, *Haeckeliania brontispae* Ferrière, which parasitized an average of 60 per cent of the eggs during December 1947 and January 1948. The fact that the eggs of this beetle are laid side by side in groups and are concentrated in certain localized areas on the plants may explain in part the high degree of egg parasitism. The eggs of *Plesispa reichei,* for example, are more widely scattered on the plants, and it was difficult to collect large numbers of parasitized eggs in the field. The eulophid parasite, *Tetrastichus brontispae* (Ferrière), was collected occasionally from *Plesispa nipae* larvae and pupae, and the records are as follows:

[8] Hispid beetles in this paper determined by H. S. Barber, G. E. Bryant and S. Maulik.
[9] Letter to writer from Dr. C. M. Cendaña dated December 31, 1947.
[10] Parasites in this paper determined by A. B. Gahan.

at Kapar on the Kuala Selangor Road (January 6, 1948), one pupa of 8 collected was parasitized, and 2 pupae died, and a second collection at the same locality (January 19, 1948) gave a count of 43 parasitized pupae of 75 pupae collected, and 2 parasitized larvae were found; on the road to Kuala Selangor (January 1, 1948), one pupa of 8 collected was parasitized; and at Klang (December 26, 1947) one parasitized pupa was collected. Two other parasites of *Plesispa nipae* were reared as follows: an *Achrysocharis* species (probably the same as the one from *Wallaceana palmarum*) was reared from a larva collected January 1, 1948, on the road to Kuala Selangor; and a *Tetrastichus* species (not *brontispae*) was reared from a pupa collected at Kapar, January 6, 1948.

The hispid, *Wallaceana palmarum* (Gestro), was collected in Malaya on *Nipa fruticans, Areca catechu, Eugeissona triste, Metroxylon sagus,* an unidentified palm in the Klang area with persistent leaf bases, and an unidentified spiny palm at Ulu Langat. This beetle occurs in association with *Plesispa nipae* on *Nipa fruticans,* but its preferred host seems to be *Areca catechu* where the larvae and adults feed on the new central growth and on the protected bases of the leaf stalks. An *Achrysocharis* sp. was found to be a larval parasite in one small area at Ulu Langat, in collections made from December 27, 1947, to January 13, 1948. Of 44 mature larvae collected December 27, 1947, eight larvae were parasitized, and from 6 to 32 parasites emerged from a single larva with a proportion of sexes of one male to 7 females. At this time a larva of a predaceous beetle was found feeding on the pupae of the *Achrysocharis* species.

Five additional unidentified species of externally-feeding hispids were collected in Malaya, and with one exception there was no indication of parasites. On February 1, 1948, at a locality 7 miles south of Klang, adults, eggs, and larvae of a *Wallaceana* species[11] were collected on *Zalacca conferta.* One mature larva was discolored and swollen, and had parasite emergence holes not unlike the condition observed for the *Achrysocharis* species attacking the larvae of *Wallaceana palmarum.*

Parasites were found more abundantly in Malaya on palms where vines held the leaves together, making ideal conditions for the beetles. This condition is shown in figure 3.

No search for the parasites of *Brontispa longissima javana* Weise and *B. longissima celebensis* Gestro in Java was necessary as the parasites were well known and at least two species had been reared in the laboratory of the Instituut voor Plantenziekten at Buitenzorg. The eulophid *Tetrastichus brontispae* (Ferrière)[12] had been previously shipped to Celebes from Java, and a breeding program was initiated to breed this parasite for introduction to Saipan and Rota. The egg parasite, *Haeckeliania brontispae* Ferrière,[13] was also secured in Java in limited numbers.

[11] Determined as *Wallaceana phoenicia* Mik. (Maulik, 1949).

[12] *Tetrastichodes* Ashm., which is used commonly for this species is synonymous with *Tetrastichus* Hal. according to A. B. Gahan in Proc. U. S. Nat. Mus., 1916, p. 168; Burks, in Proc. U. S. Nat. Mus., 93:510, also treats it as a synonym.

[13] The original spelling by Girault was *Haeckeliania,* but recent authors have been using *Haeckeliana* which is incorrect as it refers to a genus in the Protozoa. (See Neave, Nomenclator Zoologicus, 2(D-L):544.)

Eighteen collections of *Brontispa longissima* in the vicinity of Buitenzorg, Java, collected from December 31, 1947, to January 28, 1948, involving 1,769 larvae and 640 pupae gave no determinable parasitism of

Figure 3.—A leaf of *Nipa fruticans* growing near Klang in Malaya encircled by a climbing vine. This condition creates an excellent habitat for *Plesispa nipae* with resultant increase in parasite activity.

the larvae and an average of 16 per cent pupal parasitism by *Tetrastichus brontispae*. Of 1,002 adult beetles collected, 830 were the subspecies *javana* and 172 were *celebensis*. There was a wide range in the percentage of parasitism in a single tree, in fact it varied from no parasitism to 100 per cent parasitism of the pupae. The fact that these collections were made during the rainy season probably accounts for the low average per cent parasitism. In these collections it was not determined if mature larvae were parasitized prior to pupation.

Records in the Buitenzorg collection indicate that the egg parasite of *Plesispa reichei* is *Ooencyrtus corbetti* Ferrière (Buitenzorg, Java, 28-VI-32, and XII-35) and the egg parasite of *Brontispa longissima* is *Ooencyrtus podontiae* Gahan (V-31, and 1932, det. Muesebeck), the same egg parasite found in Malaya. An *Ooencyrtus* species egg parasite is also recorded from the hispid, *Botryonopa marginata* (Medan, Sumatra, 1935, det. Gahan).

PROPAGATION OF TETRASTICHUS BRONTISPAE (FERRIERE).—This eulophid parasite is almost black in color with greenish reflections, and antennae and legs are yellowish to brown, and it ranges in size from 0.8 mm. long to 1.4 mm. long. The duration of the life history was from 16 to 20 days during this study, and from 8 to 20 parasites emerged from a single pupa. The females select mature larvae or one- to two-day-old pupae, and in 5 days the pupa begins to clear and the parasite larvae can be seen moving inside. The beetle pupa begins to extend and becomes translucent, and toward the end of the developmental period the black parasite pupae can be seen inside. In emerging, holes are cut through the pupae and the adults crawl out. An occasional parasitized beetle larva does not pupate, and in this case the parasites emerge through the larva, but usually parasites emerge through the pupae.

In Malaya little attempt was made to breed *Tetrastichus brontispae*. Adults of this species emerging in Malaya from parasitized pupae of *Brontispa longissima* were found to select one-day-old pupae of *Plesispa reichei*. Parasites emerging from *Plesispa reichei* on Saipan from such a rearing were exposed to *Brontispa mariana* pupae, and adults were reared. These observations indicated that this parasite was not too selective within the genera *Brontispa* and *Plesispa*, a fact which was of considerable importance in its transfer to *Brontispa mariana*.

In Java *Tetrastichus brontispae* was propagated by exposing one- to two-day-old pupae to the parasites in glass tubes using about 15 *Brontispa* pupae to 15 to 25 adult female parasites. A 50:50 mixture of honey or sugar and water was used to feed the parasites, which was placed as small droplets on a piece of coconut leaf inside each tube. To maintain a high humidity a small piece of moistened absorbent paper was placed in each tube. A low wattage incandescent lamp placed in proximity to the rearing tubes was found to stimulate parasite activity and egg laying. An exposure period of 24 hours was given, after which the pupae were removed. In 5 to 6 days the degree of parasitism could be noted. Natural mortality varied from 10 to 25 per cent. Pupae were found to be more easily handled than larvae in the breeding work. A total of 572 para-

sitized pupae were secured in Java and later shipments were made directly to Saipan from Buitenzorg.

Parasites from Java emerging on February 9, 1948, on Saipan were caged with pupae of *Brontispa mariana* and on February 27 the first parasites emerged. The parasites were reared by methods similar to those already described. Fifteen exposures of pupae were made and the last parasites emerged in the laboratory on Saipan on April 2, 1948. In the laboratory on Saipan at an average mean temperature of 85° F. the developmental period for *Tetrastichus brontispae* varied from 16 to 19 days with an average of 17.75 days. That shorter periods of exposure would be possible was indicated when 3 two-day-old pupae were exposed for one hour with 20 female parasites, and on March 1 parasites emerged from all the pupae. On Saipan the parasites were found to oviposit in both the dorsal and ventral areas of the pupae, but they seemed to prefer intersegmental areas as oviposition sites. Parasites to be released were fed and mated before they were released.

Figure 4.—Adult female of *Haeckeliania brontispae* from Malaya, × 29.

PROPAGATION OF HAECKELIANIA BRONTISPAE FERRIERE.—This small trichogrammatid egg parasite, ranging in size from 0.5 mm. to 0.93 mm. long, is dark brown and the wings are pale fuscous with a terminal clear band (see figure 4). Usually one parasite emerges from a single egg, but apparently races of this insect occur where several usually emerge from a single egg. Newly laid eggs are preferred as oviposition sites. Host eggs include those of *Brontispa longissima, Plesispa nipae,* and *Plesispa reichei.* Specimens from Java were found to select and complete their development in eggs of *Brontispa mariana,* and Malayan specimens were found to oviposit and complete their development in eggs exposed in the laboratory. One female was observed on Saipan to oviposit for a period of four minutes in one egg of the coconut beetle. Certain females were found to oviposit a second time in the same egg. In mating the male climbs on the back of the female and brings his

abdomen underneath to engage the female, and in this position the male may be carried about by the female. Adults fed readily on a 50:50 mixture of honey and water. One female from Malaya was observed to live in the laboratory on Saipan for a period of 14 days.

No attempt was made to propagate large numbers of this egg parasite, as eggs collected in Malaya were 60 per cent parasitized. Certain rearings were made however in the laboratory on Saipan using eggs of *Brontispa mariana* and these are given in the following tabulation:

Date Exposed	Number of Eggs Exposed	Number of Parasites	Date Emerged	Number Emerged
February 8	40	25	February 26	2
February 9	4	25	March 1	1
February 10	31	25	March 1	1
February 12	14	10	March 5	1
February 14*	15	5	March 8-10	12
February 15*	15	5	March 16	2
February 16	8	15	March 10	1
March 9	40	6	March 27-29	5

* Parasites from Java, the rest from Malaya.

The developmental period of these rearings varied from 16 to 30 days with an average of 21.4 days. If the two rearings of the Java parasite are excluded it is observed that the average developmental period from egg to adult is 19.6 days, whereas it averages 27 days for the Java strain. The eggs were usually exposed to the parasites for a 24-hour period, although in the case of the February 9 rearing, the 4 eggs were exposed to 25 parasites for one hour. One-day-old eggs were found to be more readily selected by the parasites. In these rearings only a 15 per cent recovery of parasites was obtained as of a total of 167 eggs exposed only 25 parasites emerged. It was observed that a number of parasites dried up inside the eggs and failed to emerge, and on numerous occasions tyroglyphid mites were found inside the eggs.

INTRODUCTION OF PARASITES TO SAIPAN AND ROTA.—Two parasites were successfully introduced to Saipan and Rota, namely the larval and pupal parasite, *Tetrastichus brontispae* (Ferrière), and the egg parasite, *Haeckeliania brontispae* Ferrière, which were both introduced from Malaya and Java. The first shipment of parasites was made from Malaya in Janury 1948 by plane, and as a result, 125 egg parasites and 75 *Tetrastichus* were liberated by D. B. Langford and R. Reif on Saipan. A third parasite, *Achrysocharis* sp., from *Wallaceana palmarum,* did not survive. A shipment of 572 parasitized pupae obtained in Java containing *Tetrastichus* was taken by plane to Saipan by the writer, along with 2,400 parasitized *Plesispa nipae* eggs containing *Haeckeliania,* a few *Haeckeliania* from Java on *Brontispa longissima,* and a few larvae and pupae of *Plesispa nipae* parasitized by the Malayan strain of *Tetrastichus.* The first *Tetrastichus* parasites from this shipment were liberated on Saipan on February 7, 1948, and approximately 1,000 parasites were reared from pupae of *Brontispae mariana* in the Saipan laboratory. One- and two-day-old pupae of *Brontispa mariana* were readily selected in the laboratory

by both the Java and Malayan strains of *Tetrastichus*. Two later shipments of *Tetrastichus* were received on Saipan from Java, and the parasites were liberated and used in the laboratory rearings. One was received March 10, 1948, and the second was received by D. B. Langford and liberated on Saipan from April 23 to 30, 1948. A total of 5,285 *Tetrastichus* parasites were liberated during the period January 16 to April 30, 1948, of which 250 were released on Rota. A total of 25 liberations were made on Saipan and an attempt was made to place them in the more important coconut growing areas on the island. Each liberation was made in from 1 to 5 trees. An attempt was made to place the parasites in trees showing a preponderance of mature larvae and pupae. A total of 332 *Haeckeliania* egg parasites were released during the period January 14 to March 29, 1948. Of this number 50 were released at one locality on Rota. A total of only 14 egg parasites of the Java strain were released, and only 8 of the Malayan strain which had been reared from *Brontispa mariana* eggs on Saipan. Ten liberations of egg parasites were made.

ESTABLISHMENT OF PARASITES.—Observations were made of a young coconut tree at Magicienne Bay on Saipan where parasites were liberated February 7, 1948, to record the establishment of *Tetrastichus brontispae,* and the following tabulation indicates the results obtained:

Date of Observation	Number of Pupae Collected	Per cent Parasitism
February 14	4	100.0
February 28	8	12.5
March 3	3	33.3
March 11	4	100.0
March 19	1	100.0

It was apparent from these initial observations, even though the numbers involved are not statistically significant, that this parasite had already completed two generations in the field on *Brontispa mariana.* The egg parasite was not recovered in the field although on March 19 at Magicienne Bay 2 eggs of 6 examined yielded dead egg parasites when examined under the microscope, and one egg was found with a round emergence hole similar to *Haeckeliania.* Recent observations indicate that the larval and pupal parasite, *Tetrastichus brontispae* is established on Saipan and Rota and is effectively controlling *Brontispa mariana* with an overall parasitism on Saipan by November 1948 of 60 per cent. The egg parasite, *Haeckeliania brontispae,* has not been recovered and it is assumed that it did not become established.

SUMMARY.—The Mariana coconut beetle, *Brontispa mariana* Spaeth, was first found on Saipan about 1931, and since this time has almost completely eliminated a sizeable copra and coconut oil industry. The United States Navy requested the Pacific Science Board to investigate the possibilities of controlling this insect so that the industry could be restored for the benefit of the natives. The genus *Brontispa* is widely

distributed in the Austro-Malayan area, and *B. mariana* is found in the Mariana and Caroline Islands. Detailed descriptions of the egg, larva, pupa and adult are given. This beetle is an externally-feeding hispid beetle attacking both as larvae and as adults the central unfolded leaves, causing dark blemishes which persist and reduce the general health of the tree. The tree usually fails slowly, produces only a few, if any, coconuts and may finally die. Details of the life history are presented and the mean average number of days for development from egg to adult was found to be 33.68 days with an adult life of several months. Continuous generations occur and it was estimated that there are from 3 to 9 generations a year, with an average of 5 to 6 generations. The only known host in the field is the coconut palm, although beetles were able to complete their development on a *Eupritchardia* species. Prior to the introduction of parasites the only known enemies were the earwig, *Chelisoches morio* (L.) and a fungus disease, *Metarrhizium* sp. A review is presented of the literature dealing with parasites affecting externally-feeding hispid beetles. A search for parasites in the Philippines, Malaya and Java resulted in the introduction of the larval and pupal parasite *Tetrastichus brontispae* (Ferrière), and the egg parasite, *Haeckeliania brontispae* Ferrière both of which were introduced from Malaya and Java. Other parasites collected in Malaya were a larval parasite of *Wallaceana palmarum* and *Plesispa nipae,* an *Achrysocharis* sp., a *Tetrastichus* sp. from pupae of *Plesispa nipae,* and an egg parasite of *Plesispa reichei, Ooencyrtus podontiae* Gahan. A total of 5,285 adult parasites of *Tetrastichus brontispae* were liberated on Saipan and Rota, of which 1,000 specimens were reared from *Brontispa mariana* on Saipan and the others were brought directly from Malaya or Java. About 332 adults of the egg parasite, mostly brought directly from Malaya, were liberated on Saipan and Rota. Parasites were released on Saipan and Rota during the period January 16, 1948, to April 30, 1948. Field observations made up to March 19, 1948, indicated that at this time the *Tetrastichus* parasite had completed two generations in the field on *Brontispa mariana* on Saipan. Recent observations indicate that *Tetrastichus* is well established in all of the major coconut-growing areas on Saipan, and on Rota, and by November 1948 on Saipan had an overall parasitism of larvae and pupae of *Brontispa* of 60 per cent.

ACKNOWLEDGEMENTS.—The writer is indebted to a number of individuals and groups for assistance during the course of these investigations. H. J. Coolidge and other members of the Pacific Science Board have given encouragement throughout the investigations and have handled the multitudinous details connected with field travel. The Insect Control Committee for Micronesia, C. E. Pemberton, Harry S. Smith, and C. P. Clausen, have made valuable suggestions during the investigations. The United States Navy by furnishing transportation, equipment and personnel assistance, is responsible for the success obtained in securing the parasites. I am particularly indebted to Admiral C. H. Wright, formerly Deputy High Commissioner, Trust Territory of the Pacific Islands, and his staff, Commander R. A. Wilhelm and his staff,

Captain G. L. Compo and his staff, D. B. Langford, staff entomologist, Frank Brown of the Agricultural Station on Saipan, and Lieutenant H. S. Phipps. Certain individuals or institutions assisted in securing beetles or parasites in the field, particularly C. M. Cendaña of the Philippine College of Agriculture, H. T. Pagden and R. J. A. W. Lever of the Malayan Department of Agriculture, and J. van der Vecht of the Institute of Plant Diseases and Pests, Buitenzorg, Java.

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