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Pests of *Cycas micronesica* leaf, stem, and male reproductive tissues with notes on current threat status

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Abstract—*Cycas micronesica* is endemic to the West Caroline and Mariana Island groups. We have been conducting a survey of the pests of this native cycad on Guam. We report insect pests that were observed feeding on *C. micronesica* plants in habitat, or that emerged from cycad tissues that we harvested in habitat. We focus on leaf, stem, or male strobili consumers.

Introduction

Cycas micronesica K.D. Hill is the only native gymnosperm from the Mariana Islands. It is endemic to Guam and surrounding islands (Hill & Stevenson 2006), and can be found in numerous habitats (Figure 1A–D). We have been monitoring phenology of the species in several habitats throughout the island since 2002. Our surveys during the course of these phenology measurements revealed that some insects cause severe damage to this important biological resource.

Very few insects have been reported on this species (Table 1). We report the previously unreported pests observed feeding on stem, leaf, or male cone tissues of *C. micronesica.* We describe each species under the heading of plant organ on which each insect causes the greatest damage. However, when more than one plant organ is consumed by a species, we also mention each species as a minor consumer under the heading of these other organs.

Leaf Feeders

Cycad leaf miner: *Erechthias* sp. (Lepidoptera: Tineidae). Det. G.S. Robinson, Natural History Museum, London.

The larvae of this moth species mine into *C. micronesica* leaflets and cause distinctive blotching (Figure 1E). Pupation takes place inside the leaflet blotches, and numerous adults (Figure 1F) emerge from the blotches. This insect is currently a major threat to Guam's cycad population.

Direct damage of photosynthetic tissue negatively impacts daily carbon relations. However, indirect damage by this leaf miner in the form of early leaf senescence may be more detrimental to long-term plant health than direct loss of photosynthetic tissue. The dynamics of leaf turnover determine various components of whole plant photosynthesis, and these processes are regulated to

Table 1. List of insects previously reported on Cycas micronesica.

Name of the insect	Order	Family	Reference
Lallemandana phalerata (Stal)	Hemiptera	Cercopidae	Lallemand, 1942
Ugyops samoaensis Muir	Hemiptrea	Delphacidae	Beller, 1948
Ceropalastes rubens Maskell	Hemiptera	Coccidae	Townes, 1946
Ceroplastes floridensis Comstock	Hemiptera	Coccidae	Beardsley, 1966
Aonidiella comperei McKenzie	Hemiptera	Diaspididae	Beardsley, 1966
Lepidosaphes carolinensis Beardsley	Hemiptera	Diaspididae	Beardsley, 1966
Parlatoria proteus (Curtis)	Hemiptera	Diaspididae	Beardsley, 1966
Lepidosaphes rubrovittatus Cockerell	Hemiptera	Diaspididae	Beardsley, 1975
Dorcatomiella guamensis Blair	Hemiptera	Anobiidae	Beller, 1948
Alciphron glaucus (Fabricius)	Hemiptera	Pentatomidae	Usinger, 1946
Cycasia oculata Malloch	Diptera	Tephretidae	Beller, 1948
Euglenes bifossicollis Blair	Coleoptera	Euglenidae	Blair, 1942
Mordellistena castanea (Boheman)	Coleoptera	Mordellidae	Beller, 1948
Carpophilus mutilatus Erichson	Coleoptera	Nitidulidae	Gillogly, 1962
Phytorus lineolatus Weise	Coleoptera	Chrysomelidae	Beller, 1948
Anaballus amplicollis (Fairmaire)	Coleoptera	Curculionidae	Zimmerman, 1942

maximize carbon gain while efficiently using available resources (Hikosaka 2005). Species with large, sclerophyllous leaves, such as cycads, generally have lengthy leaf life span and lower photosynthetic capacity than species with short leaf life span (Chabot & Hicks 1982). For these species, longer leaf life spans compensate for the relatively lower photosynthetic capacity by permitting carbon gain to occur over an extended time frame, thereby securing a positive net carbon economy on a per-leaf basis.

These factors apply to leaf physiology dynamics of Guam's cycad (Marler 2004). Indeed, photosynthetic capacity of 11-month-old *Cycas micronesica* leaves was maintained to within 85% of that for recently matured leaves (Marler 1999). In contrast, a rapid decline in photosynthetic capacity begins immediately after full leaf expansion for many species. For example, Kitajima et al. (2002) reported photosynthetic capacity for *Cecropia longipes* leaves declined more than 50% by 74 days after full leaf expansion. For these reasons, leaf herbivore damage for species with long-lived leaves may be more detrimental to overall carbon relations than similar leaf herbivore damage for species with short-lived leaves (Chabot & Hicks 1982).

Older leaf cohorts are preferentially targeted by this moth species (Figure 1G). For some reason, younger leaf cohorts exhibiting no signs of damage coexist on plants with epidemic levels of damage to older cohorts. This disparity in timing of predation whereby the older leaf cohorts are targeted is less detrimental in terms of leaf carbon dynamics than if the younger leaf cohorts were targeted (Chabot & Hicks 1982).

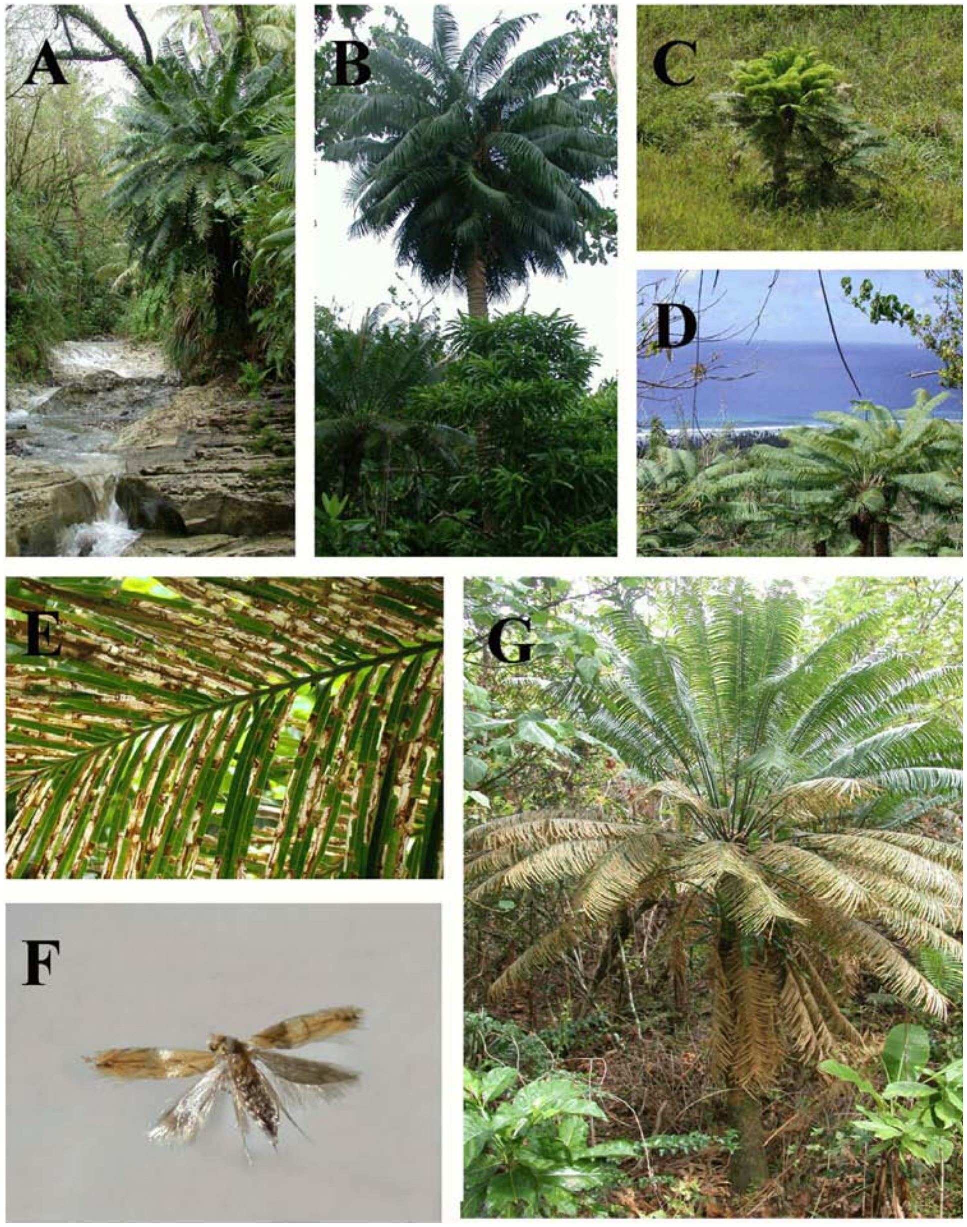

Figure 1. Guam's *Cycas micronesic*a can be found in interior habitats such as southern ravine forests (A), northern limestone forests (B), savanna (C), and throughout most coastal habitats (D). Cycad leafminer damage (E) includes larvae tunneling in leaflets, excavating large characteristic blotches. Leafminer adults (F) preferentially target older leaf cohorts (G), severely reducing lifespan.

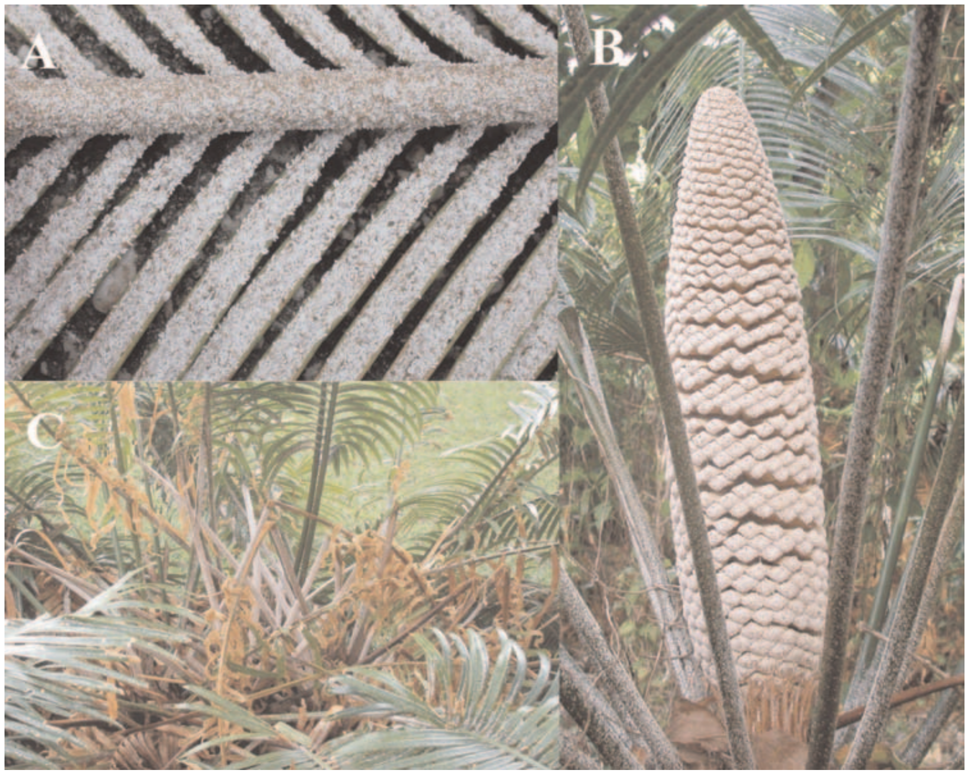

Figure 2. Phenotype of cycad aulacaspis scale infestation on *Cycas micronesica*. (A) Abaxial surface of heavily infested rachis and leaflets. (B) Petioles collapse following scale infestation. (C) Male cone and petiole infestation.

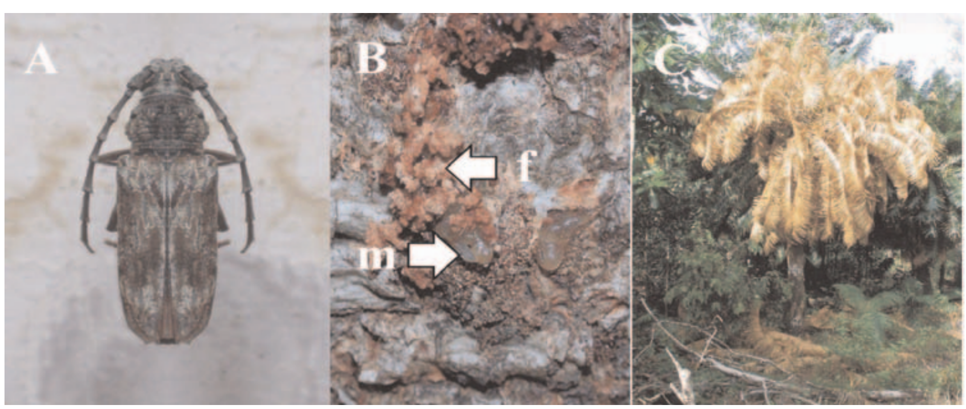

Figure 3. Stem borer damage to Cycas micronesica plants. (A) Adult *Dihammus marianarum*. (B) Stem surfaces may exhibit exudates of mucilage (m) and frass (f) in the area of infestation. (C) Common plant response to heavy infestation is complete death of upper stem and leaves, leaving live stem tissue below the zone of infestation.

Table 2. Summary of insects reported herein.

Common name	Scientific name	Order	Family	Damage to leaf	Damage to Stem	Damage to Cone
Cycad leaf miner	*Erechthias* sp. *	Lepidoptera	Tineidae	X		
Cycad aulacaspis scale	*Aulacaspis yasumatsui**	Hemiptera	Diaspididae	X	X	X
Armored scale	*Lepidosaphes* sp. near *rubrovittata*	Hemiptera	Diaspididae	X		
Indian wax scale	*Ceroplastes ceriferus*	Hemiptera	Coccidae	X		
Hemisperical scale	*Saissetia coffeae*	Hemiptera	Coccidae	X		
Stem borer	*Dihammus marianarum*	Coleoptera	Cerambycidae		X	X
Sap beetle	*Carpophilus mutilatus*	Coleoptera	Nitidulidae		X	X
Stem borer	*Dasyses rugosella**	Lepidoptera	Tieneidae		X	
Cycad male cone borer	*Anatrachyntis* sp.*	Lepidoptera	Cosmopterigidae			X
Oriental flower beetle	*Protaetia orientalis*	Coleoptera	Scarabaeidae			X

*New records for Guam

The damage to cycad leaflets by this moth was extensive in the southern ravine forests in early 2003 when we first identified the organism, yet minimal in the northern forests. Damage to cycads in northern Guam has steadily increased in the past two years since our initial observations. These changes in the spatial pattern of plant damage may indicate this pest was recently introduced to the island.

Cycad Aulacaspis Scale: *Aulacaspis yasumatsui* Takagi (Hemiptera: Sternorrhyncha: Diaspididae). Det. Gregory Evans, USDA, Beltsville, Maryland.

This scale was originally collected in Thailand in 1972 and described in 1977 (Takagi 1977). It is considered a minor pest of cycads in Thailand, where it is maintained at low densities by parasitoids (Tang et al. 1997). The accidental introduction of this scale to Florida in the 1990s (Howard et al. 1999) initiated the further spread of this pest throughout several states and territories.

The cycad aulacaspis scale was recently introduced to Guam, and currently is the greatest abiotic or biotic threat to *C. micronesica.* This introduction to Guam marks the first time this scale is a threat to any cycad species within endemic habitats. The scale was first observed in late 2003 on cultivated ornamental cycads in the urban landscape. Within one year it had become well-established throughout the urban landscape on *C. revoluta* and *C. micronesica,* and had escaped cultivation into *C. micronesica* habitats south of Tumon Bay. This scale is now found on *C. micronesica* in most habitats throughout the island.

The response of *C. micronesica* plants to this armored scale is particularly severe. Every part of the leaf is attacked, and shortly after infestation the entire petiole, rachis, and abaxial leaflet surfaces become entirely white. Unlike infested *C. revoluta* leaves that retain integrity as they senesce, infested leaves collapse because they cannot maintain integrity at high densities (Figure 2B). Without intervention infestation is lethal, with death of the entire plant occurring less than one year after initial infestation in some cases.

Armored Scale: *Lepidosaphes* sp. nr *rubrovittata* Cockerell (Hemiptera: Diaspididae). Det. Gillian Watson, Natural History Museum, London.

This scale has been reported on *Barringtonia, Inocarpus, Ficus, Araucaria* and *Eugenia* from the Philippines, New Guinea, Guam, Palau, Fiji, and Tonga (Williams & Watson 1988). Beardsley (1975) has reported it on cycad from Guam. We observed this scale feeding on petiole, rachis, and leaflet tissue. There is an unidentified hymenopteran parasitoid parasitizing this scale in Guam. Moreover, all of the scales we found were covered by fungal mycelium, possibly a *Basidium* species. This scale is a minor pest of Guam's cycad.

Indian wax scale: *Ceroplastes ceriferus* (Fabricius) (Hemiptera: Coccidae). Det. R. Muniappan.

The Indian wax scale is reported in Micronesia only from Guam and Palau (Schreiner 1991). Muniappan et al. (2002) reported it on several plants on Guam. This scale is rarely observed on *C. micronesica* on Guam, and occurs on the petiole or rachis.

Hemispherical scale: *Saissetia coffeae* (Walker) (Hemiptera: Coccidae). Det. Gillian Watson, Natural History Museum, London.

The Hemispherical scale is a polyphagous insect and is a pest of several vegetable and fruit crops. It has been reported on *C. circinalis* in Tonga and *Cycas* sp. in Western Samoa (Williams and Watson 1990). However, the Tonga report was undoubtedly *Cycas seemannii* A. Braun., and the Western Samoa report was also probably this species. This *Cycas* species has a natural range from Tonga to New Caledonia (Hill & Stevenson 2006). *Cycas circinalis* does not occur naturally on any of the South Pacific islands. As with the Indian wax scale, this insect is a minor pest of Guam's cycad population.

Stem Feeders

Stem borer: *Dihammus marianarum* (Aurivillius) (Coleoptera: Cerambycidae). Det. Steven W. Lingafelter, Smithsonian Institute, Washington, D.C.

This longhorn beetle (Figure 3A) is a major threat to Guam's cycad population. Gressitt (1956) originally reported the species as an endemic to the Mariana Islands, and provided a description of the adults. The beetles were collected primarily from dead branches of many species including *Artocarpus, Ficus, Pithecellobium, Hibiscus, Theobroma, Anacardium,* and *Barringtonia*. Adults have been collected during the day at numerous sites on Guam. In our surveys we found the grub of this beetle boring into the stem of live cycads and causing extensive plant damage.

This beetle lays single eggs in cavities gnawed in the surface of the stem. The grub tunnels into the stem tissue, plugging the tunnel with frass and fibrous chips. The larva is yellowish, cylindrical, soft bodied, apodus, with a black head. Longevity of the larval stage is not known for this species. However, its larval stage is likely to be many months since the life cycle of closely related species from temperate regions may last one or two years (Lingafelter & Hoebeke 2002). Pupation takes place in the tunnel in the stem.

Signs of larval feeding are seen on the cycad stem surface as frass and mucilage secretion (Figure 3B). These symptoms are not obligate components of infestation, as we have found infested plants devoid of any external symptoms. A hollow cavity at the primary site of tunneling becomes evident by applying pressure to the surface of an infested or previously infested stem. The primary tunneling site is largely confined to heights between 0.5 and 1.0 m regardless of total plant height.

Few observable symptoms are present in infested plants until the leaves of an infested plant rapidly become chlorotic in synchrony (Figure 3C). Close examination of these plants reveals that the entire stem above the major tunneling cavity becomes necrotic. However, the stem below the cavity remains healthy and these plants initiate new stem growth from this healthy tissue close to the stem base. Damage by this beetle does not kill plants, but does severely reduce an individual's competitive stature in the forest mosaic and the individual's ability to contribute to population recruitment. The longevity of longhorn beetle larval stage may explain its ability to damage stem tissue severely enough to elicit this extreme plant response.

Sap beetle: *Carpophilus mutilatus* Erichson (Coleoptera: Nitidulidae). Det. M. Barclay, Natural History Museum, London.

This sap beetle is common and widespread. It has been reported from Iraq, Philippines and Micronesia (Gillogly 1962), and is attracted to sweet and fermenting substances. Dybas (as reported by Gillogly 1962) collected this beetle in decaying *Pandanus* fruits and in "dead" stems and male cones of *Cycas* in Guam.

We collected adults and grubs on live cycad stems that were being used for vegetative propagation. Damage was so severe in the nursery environment that 100% of the stem sections died. Pupation occurred on the surface of the sand in the propagation bed, usually beneath the stem sections.

We do not know if this pest is a major consumer of damaged or toppled cycad stem sections in natural habitats. However, this is possible since Dybas collected it from what he thought were dead stems (Gillogly 1962). Toppled or damaged cycad stems do not necessarily die, but readily develop adventitious roots and buds (Norstog & Nicholls 1997). We believe Dybas collected from damaged cycad stems that contained living tissue. The tunneling we observed was restricted to live parenchyma tissue in the stem pith and cortex of cut stem sections.

Stem borer: *Dasyses rugosella* (Stainton) (Lepidoptera: Tineidae). Det. G.S. Robinson, Natural History Museum, London.

This species has been recorded from lowland areas of India, Sri Lanka, Thailand and Java. The larvae have been reared from what was reported as dead Cycas stems and from vegetable refuse including oil palm fruits (Robinson & Nielsen 1993). *D. rugosella* seems to be polyphagous as the caterpillars have been reported feeding on dead cycad stems, vegetable refuse, and stored yams in west Africa, and on oyster mushroom culture media in different countries (G.S. Robinson, personal communication). In Guam we found the larvae boring into wounded *C. micronesica* stems. This pest does not currently pose a threat to Guam's cycads.

Minor pests on stems:

The cycad aulacaspis scale also colonizes stem tissue. This pest is lethal to its host, primarily due to leaf mortality. The scale's ability to colonize other organs, such as stems, exacerbates the problem of detection and control. Scales on these plant parts are difficult to observe and to contact with pesticide sprays. This is especially true where overlapping cataphylls protect the stem tip and persistent leaf bases protect the stem surface. Leaves emerging after infestation are frequently distorted by direct feeding damage of the meristem prior to leaf emergence. Moreover, new leaf flushes are readily colonized by scales from the stems.

Male Cone Feeders

Cycad male cone borer: *Anatrachyntis* sp. (Lepidoptera: Cosmopterigidae). Det. Sergij Sinev, St. Petersburg.

The larvae of this moth tunnel into the male cones of *C. micronesica* and cause the cones to deteriorate rapidly. An abundance of larvae are found in every male cone following pollen shedding. Pupation takes place in a silken cocoon on the surface of the cone. We do not consider this insect as a pest. In contrast, this moth seems to aid in the rapid degradation of the massive and metabolically costly cone tissue once its function of supplying pollen has ceased.

Oriental flower beetle: *Protaetia orientalis* (Gory and Percheron), (Coleoptera: Scarabaeidae). Det. R. Muniappan.

This large beetle is a native of the region comprising China, Korea and Japan. It was introduced to Guam in the 1970s, and was recently introduced to Oahu in the Hawaiian Islands. It occurs within Micronesia only on Guam, and has been reported feeding on flowers of papaya, coconut, betel nut, mango and corn (Nafus 1997). Adults feed primarily on pollen but may also damage flower structures. They also feed on fermenting plant sap, rotting fruit, and wounds in trees. Eggs are laid in the soil, and grubs feed on decaying plant material. Pupation takes place within an earthen cocoon in the soil.

The adult beetle feeds on male *C. micronesica* cones. Foraging does not include microsporophyll tissue, but the adult beetle preferentially consumes pollen directly from microsporophyll surfaces. Oriental flower beetle ingestion of cycad pollen is common throughout all cycad habitats in Guam, but does not appear to be a serious threat to the species.

Minor pests on male cones:

The cycad aulacaspis scale also colonizes the surface of male cones extensively (Figure 2C). *Cycas micronesica* male cones grow in height at rates ca. 1 cm per day, and may have a midpoint circumference greater than 40 cm (T.E. Marler, unpublished data). The ability of a scale to so densely cover this rapidly expanding surface area is remarkable. We feel this to be a minor pest of male cones because cone herbivory does not pose a specific threat to Guam's cycad population. The tissues in this organ are naturally short-lived.

The sap beetle *Carpophilus mutilatus* was collected from male cones of *Cycas* in Guam (Gillogly, 1962). In our observations, grubs of this sap beetle were observed feeding on microsporophyll tissue, and adults were moving between microsporophylls. Cycads are known to be pollinated by various insects, primarily in the order Coleoptera (Norstog & Nicholls, 1997). Further observations are needed to determine if this sap beetle may play a role in cycad pollination. Pollination systems of *C. micronesica* remain entirely unknown to date.

We observed grubs of the stem borer *Dihammus marianarum* tunneling through the central axis of male cones. Male cones are ephemeral, and rarely maintain integrity 3 months beyond emergence (Marler, unpublished data). We therefore believe that these long-lived grubs that begin their life cycle in male cones rapidly tunnel into subtending stem tissue prior to cone maturity, but certainly prior to cone senescence.

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References

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

Beardsley, J.W. 1975. Homoptera: Coccoidea, Supplement, Insects of Micronesia, Bernice P. Bishop Museum 6: 657–662.
Beller, S. 1948. A summary of the insects and flora of Guam. Division of Foreign Plant Quarantines, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, USDA. 279pp.
Blair, K. G. 1942. Coleoptera Heteromera from Guam. Insects of Guam-I, Bernice P. Bishop Museum Bulletin 172: 56–60.
Chabot, B.F. & D.J. Hicks. 1982. The ecology of leaf life spans. Annual Review of Ecology and Systematics 13:229–259.
Gillogly, L.R. 1962. Coleoptera: Nitidulidae. Insects of Micronesia, Bernice P. Bishop Museum 16: 133–188.
Gressitt, J.L. 1954. Introduction. Insects of Micronesia, Bernice P. Bishop Museum 1: 1–257.
Gressitt, J.L. 1956. Coleoptera: Cerambycidae. Insects of Micronesia. Bernice P. Bishop Museum 17: 61–183.
Hikosaka, K. 2005. Leaf canopy as a dynamic system: ecophysiology and optimality in leaf turnover. Annals of Botany 95: 521–533.
Hill, K.D. & D.W. Stevenson. 2006. World list of cycads. http://plantnet.rbgsyd.gov.au/PlantNet/cycad/wlist.html. Royal Botanic Gardens, Sydney, Australia. 13 May 2006.
Howard, F.W., A. Hamon, M. McLaughlin, T. Weissling, & S.-L. Yang. 1999. *Aucalaspis yasumaatsui* (Hemiptera: Sternorrhyncha: Diaspididae), a scale insect pest of cycads recently introduced into Florida. Florida Entomologist 82: 14–27.
Kitajima, E., S.S. Mulkey, M. Samaniego, & S.J. Wright. 2002. Decline of photosynthetic capacity with leaf age and position in two tropical pioneer tree species. American Journal of Botany 89: 1925–1932.
Lallemand, V. 1942. Homoptera: Cercopidae on Guam. Insects of Guam-I, Bernice P. Bishop Museum Bulletin 172: 17–18.
Lingafelter, S.W. & E.R. Hoebeke. 2002. Revision of *Anaplophora* (Coleoptera: Cerambicidae). Entomological Society of Washington, Washington, D.C., U.S.A.
Marler, T.E. 1999. Photosynthetic characteristics of two *Cycas micronesica* leaf cohorts. (Abstract) HortScience 34: 497.
Marler, T.E. 2004. Leaf physiology of shade-grown *Cycas micronesica* leaves following removal of shade. The Botanical Review 70: 63–71.
Muniappan, R., T. Marler & J.H. Lawrence. 2002. Pests of *Eleaeocarpus joga* in Guam. Micronesica 34: 109–111.
Nafus, D.M. 1997. An insect survey of the Federated States of Micronesia and Palau. South Pacific Commission Technical Paper 210.
Norstog, K.J. & T.J. Nicholls. 1997. The Biology of the Cycads. Cornell University Press. Ithaca, New York.
Robinson,G.S. & E.S. Nielsen. 1993. Tineid Genera of Australia (Lepidoptera). Monographs on Australian Lepidoptera 2. CSIRO. Melbourne.

Schreiner, I.H. 1991. Sources of new insects established on Guam in the post World War II period. Micronesica Supplement 3: 5–13.

Takagi, S. 1977. A new species of *Aulacaspis* associated with a cycad in Thailand (Homoptera: Cocoidea). Insecta Matsumurana New Series 11: 63–72.

Tang, W., S.-L. Yang & P. Vatcharakorn. 1997. Cycads of Thailand. Nong Nooch Tropical Garden and the Cycad Conservation Company. Bangkok, Thailand.

Townes, H. 1946. Results of an entomological tour of Micronesia. US Commercial Company Economic Survey, Honolulu.

Usinger, R.L. 1946. Hemiptera: Heteroptera of Guam. Insects of Micronesia - II, Bernice P. Bishop Museum Bulletin, 189: 11–103.

Williams, D.J. & G.W. Watson. 1988. The Scale Insects of the Tropical South Pacific Region, Part 1. The Armoured Scales (Diaspididae), C.A.B. International Institute of Entomology, Wallingford, Oxon, UK.

Williams, D. J. & G.W. Watson. 1990. The Scale Insects of the Tropical South Pacific Region, Part 3. The Soft Scales (Coccidae) and Other Families. C.A.B. International Institute of Entomology, Wallingford, Oxon, UK.

Zimmerman, E.C. 1942. Curculionidae of Guam. Insects of Guam - I. Bernice P. Bishop Museum Bulletin 172: 73–146.

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