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**Biological Control of the Cycad Aulacaspis Scale, *Aulacaspis yasumatsui***

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**NON-TECHNICAL SUMMARY**

The cycad aulacaspis scale, *Aulacaspis yasumatsui*, is a worldwide pest of cycads. In Florida, Hawaiʻi, and elsewhere, cycads are planted as urban landscape plants and exported for sale as potted plants. The scale has decimated the cycad production industry and reduced the use of the king sago, *Cycas revoluta*, and other cycads as ornamental plants. On western Pacific islands, the scale is destroying populations of native *Cycas micronesica*. The invasion of Guam by the cycad aulacaspis scale has led to the death of at least 90% of the island’s *C. micronesica* trees. The parasitic wasp *Coccobius fulvus* and the predatory beetle *Cybocephalus nipponicus* were released in Florida and became established, but do not provide satisfactory control of the pest. The predatory lady beetle *Rhyzobius lophanthae* was established on Guam but does not protect young plants. Foreign exploration in Asia discovered the lady beetle *Phaenochilus kashaya*, which may be an effective biological control. A species of *Aphytis* in Hawaiʻi may also offer hope to save native forests of *C. micronesica*. RON EXPAND

**HISTORY OF INVASION AND NATURE OF PROBLEM**

**The Species Invasion**

The cycad aulacaspis scale, *Aulacaspis yasumatsui* (Hemiptera: Diaspididae), was discovered infesting cycads in 1994 in the Montgomery Botanical Center in southern Florida after unknowingly being brought to the Center on cryptically infested plants imported from Southeast Asia (Tang et al., 2006), where it is native (Takagi, 1977). Infestations of the scale were particularly severe on *Cycas* spp. and *Stangeria eriopus* (a South African cycad in a monotypic genus)*.* From this single infestation point, the scale spread throughout Florida and into other southeastern U.S. states and Texas. Hawaiʻi became infested with the cycad aulacaspis scale by 1998, when the pest was detected on Oahu, and the scale has subsequently been found on the islands of Hawaiʻi and Kaua’i (Heu et al., 2003). The scale was found in Guam in 2003 on ornamental king sagos (*Cycas revoluta*) (Terry and Marler, 2005). Within two years, the scale spread throughout most of Guam and invaded the native forests of *Cycas micronesica*, an indigenous tree unique to Micronesia (Moore et al., 2005a). The pest was discovered on Rota in 2007 (Calonje, 2008) and Palau in 2008 (Orapa and Cave, 2010). The cycad aulacaspis scale is now established in many tropical and subtropical regions and countries, including the West Indies, Mesoamerica, New Zealand, Indonesia, Singapore, Philippines, China, Vietnam, Micronesia, West and South Africa, and southern Europe (Howard et al., 1999; Weissling et al., 1999; Hodgson and Martin, 2001; Moore et al., 2005 (there is no 2005b); Bográn et al., 2006; Germain and Hodges, 2007; Segarra-Carmona and Pérez-Padilla, 2007; Marler, 2012; Muniappan et al., 2012; Normark et al., 2017; Dimkpa et al., 2021; Marler et al., 2021). The dispersal factor responsible for this broad distribution is the intracontinental commercial movement of cycads, but private collectors may in part be another pathway for spread. The presence of cycad aulacaspis scales on the leaves is easily visible, but the insect can cryptically occupy coralloid roots (Fig. 1A), excised leaf bases on trunks, and cataphylls covered by tomentum (Fig. 1B), where it is difficult to be seen by phytosanitary inspectors (Marler and Moore, 2010).

**Nature of the Problem**

The sessile adult female scale creates a round, white armor under which it feeds by using piercing-sucking mouthparts and produces eggs. From the eggs emerge tiny nymphs, called crawlers, that have functional legs but do not feed. The crawlers walk to other plant parts or adjacent host plants, or they can be dispersed to other host plants by wind. When the crawler finds a suitable site on the plant, it settles and molts to the next stadium that has no legs but does have functional piercing-sucking mouthparts. While it feeds, the sessile scale secretes a substance that forms the armor covering the insect. Male scales produce a white, three-ridged covering under which the male molts and eventually emerges as the tiny adult male with one pair of wings but no functional mouthparts. Females secrete additional covering material, mate with mobile males, and then produce eggs to repeat the life cycle.

All plants in the family Cycadaceae and several species of Zamiaceae are hosts of the cycad aulacaspis scale (Marler et al., 2021). Uncontrolled, the scale forms dense populations on the trunk, roots, seeds (Fig. 1C), and leaves (Fig. 1D). Feeding by dense scale populations deprives the host plant of nutrients, weakening the plant, which may die of plant pathogens that healthy plants could tolerate or resist.

Based on an island-wide census of Guam’s trees by the US Forest Service in 2002, the year before the arrival of the cycad aulacaspis scale, the tree cycad *C. micronesica* was identified as the most abundant tree in Guam’s forests (Donnegan et al., 2004). Within 12 years of the scale’s invasion, *C. micronesica* was listed as endangered under the U.S. Endangered Species Act. Rapid decline of the *C. micronesica* population on Guam was documented by Marler and Krishnapillai (2020) (Fig. 2). Cycad stem count declined to only 12.5% of the original count within the first three years of survey work (2005–2008), and this decline continued as it reached just 4% of the original count in succeeding years (2009–2020). In addition to high plant mortality, surviving cycads stopped reproducing in the research plots on Guam. The last seedling (0–10 cm tall) was seen in 2006, and the last juvenile (10–100 cm tall) was seen in 2014. In some areas of Guam, the mortality rate of 100-year-old *C. micronesica* trees has reached 100%.

Secondary effects of cycad aulacaspis scale on the health of *C. micronesica* are not obvious. Perhaps the most important secondary impact is much lower reproductive capability in plants recovering from scale infestation. Seeds from scale-infested plants are deficient in nonstructural carbohydrates, and germination rates are much lower, i.e., 43% of seeds from healthy plants germinate versus 7% of seeds from infested plants (Marler and Cruz, 2019). In addition, Marler and Terry (2021) reported that mature male plants that survive the initial scale infestation have significantly smaller cones than healthy plants.

Marler (2013) reported on results of nondestructive stem-winching stress tests performed on *C. micronesica* trees to simulate the effects of typhoon strength winds. Stems of plants that had not been infested by cycad aulacaspis scale were significantly stiffer than those that had been infested by the scale for either two or five years. Marler hypothesized that scale-infested plants would be more susceptible to stem failure during typhoons. Evidence supporting this hypothesis came two years later when Typhoon Dolphin passed over Guam on May 15, 2015. Marler et al. (2016) compared the level of damage from Typhoon Dolphin with that of a previous cyclone, Supertyphoon Paka, that damaged Guam’s forests in 1997 when the *C. micronesica* population was healthy. Less than 2% of the healthy *C. micronesica* population exhibited windsnap damage during Supertyphoon Paka’s peak winds of 298 km/h. In contrast, Typhoon Dolphin’s peak winds of only 170 km/h caused windsnap of 6% of Guam’s unhealthy *C. micronesica* population after only 10 years of infestations by the cycad aulacaspis scale.

Cycads are highly desired by landscapers and homeowners as ornamental plants because they are long-lived, require low maintenance, and are resistant to most pests. Cycad aulacaspis scale infestations on ornamental cycads are unsightly (Fig. 3). *Cycas revoluta* (the king sago), the most popular ornamental cycad, is particularly susceptible to the scale. Many ornamental king sagos throughout the world have died due to the cycad aulacaspis scale.

**WHY CONTROL THIS INVASIVE SPECIES?**

Populations of *C. micronesica* on several island groups (Guam, the Northern Mariana Islands, and other western Pacific islands) are now threatened by the cycad aulacaspis scale (Fig. 4). Currently, unhealthy mature *C. micronesica* plants in Guam’s forests are not producing seeds nor being replaced by juvenile plants. Without control of the invasive scale, this endemic plant, the most abundant tree in Guam’s forests only two decades ago, is headed towards local extinction. Marler and Lawrence (2012) predicted the extinction of *C. micronesica* from western Guam by 2019, but small pockets of large trees still struggle to survive. There is an urgent need to control cycad aulacaspis scale so that some recovery can take place, without further loss of biodiversity.

The disappearance of *C. micronesica* from Guam is likely to threaten the survival of other endangered organisms. The Mariana fruit bat, *Pteropus mariannus*, eats the fleshy, aromatic covering of *C. micronesica* seeds, which may be the bat’s sole food source after a passing cyclone’s destroys temporarily other food sources (is that what you meant here?) (Haynes and Marler, 2005). In 2020, the US Fish and Wildlife Service estimated that only 45 Mariana fruit bats remain on Guam in a single roost site on Andersen Air Force Base.

A moth, *Anatrachyntis* sp. (Lepidoptera: Cosmopterigidae), is a probable pollinator of *C. micronesica* and possibly an obligate symbiont, i.e., it cannot survive without the cycad. Larvae are numerous in male cones following pollen shedding, and they pupate in silken cocoons on the surfaces of cones (Marler and Muniappan, 2006). These authors hypothesized that the moth contributes to rapid degradation of the large and metabolically costly cone tissue after pollen dispersal. Terry et al. (2009) used sticky traps to sample insects and pollen in the vicinity of female *C. micronesica* cones. They observed that 30% of the pollen grains were associated with *Anatrachyntis* moths or moth scales and <5% with other insects; over 60% of the pollen was not associated with any insect, suggesting most pollen is wind-dispersed. Based on these observations, the authors hypothesized that *Anatrachyntis* sp. is an important pollinator of the tree.

Cycads are also economically valuable. The king sago is the most preferred ornamental cycad species in the international horticulture industry; nearly 110,000 plants were exported in 1993 (Whitelock, 2002). According to a report of the Convention on International Trade in Endangered Species, 99% of the 30 million cycads traded internationally from 1977 to 2001 originated from propagation nurseries (Anon., 2003a). Before 2003, 17 countries were involved in the international cycad trade (Anon., 2003b). Soon after the arrival of the cycad aulacaspis scale in Florida, exports of cycads from the state likely spread the scale internationally (Marler et al., 2021). All former cycad propagation nurseries in Florida have ceased production and export of the plants.

**THE ECOLOGY OF THE PROBLEM**

The cycad aulacaspis scale is a member of the armored scale family Diaspididae. Only two other species of *Aulacaspis* occur in North America, and both are considered agricultural pests. *Aulacaspis rosae* is a pest of roses, and *Aulacaspis tubercularis* is a pest of mangoes. Both species are adventive in North America and have a circumtropical distribution. There are no native species of *Aulacaspis* or other armored scales in either Hawaiʻi or Guam. Because the cycad aulacaspis scale is a non-native insect outside of Thailand, it is not a keystone species or a unique prey or host for any native predator or parasitoid.

Ecological harm by the cycad aulacaspis scale on Guam, Rota, Palau, and other islands in the western Pacific is threatening with destruction the ancient, once-extensive native forests of *C. micronesica.* The armored scale weakens cycad trees and reduces their resistance to tropical cyclone winds and delays recovery after a storm (Marler and Lawrence, 2013). Dead trees are not being replaced because the scale kills seeds and seedlings (Marler and Cruz, 2019). Native animals that depend on *C. micronesica* as food are adversely affected by the loss of plants (Haynes and Marler, 2005).

Chemical pest management of the cycad aulacaspis scale is expensive because applications of horticultural oils and synthetic pesticides must be frequent and regularly scheduled (Howard et al. 1999; Emshousen et al. 2004; Hara et al. 2005; Bográn et al. 2006). Pesticide treatments are not always effective owing to physical refuges on the plant where scales remain unreached by treatments. Moreover, broad-spectrum pesticides are highly toxic to the parasitoids and predators of the cycad aulacaspis scale (Smith and Cave 2006a). Pesticide applications to the cycad forests of Guam and other western Pacific islands would be economically unfeasible and ecologically adverse to native wildlife.

**PROJECT HISTORY THROUGH AGENT ESTABLISHMENT**

**Biological Control Efforts in Florida**

Classical biological control of the cycad aulacaspis scale in Florida began in 1998 when the parasitic wasp *Coccobius fulvus* (Hymenoptera: Aphelinidae) and the predatory beetle *Cybocephalus nipponicus* (Coleoptera: Cybocephalidae) (erroneously identified as *Cybocephalus binotatus* [Smith and Cave, 2006b]), both from Thailand, were imported and released in Florida (Howard et al., 1999). Approximately 15,000 individuals of *C. fulvus* were released during February-April 2002 in 14 Florida counties (Hodges et al., 2003). *Coccobius fulvus* collected from northern Vietnam was released in Gainesville, Florida in 2007, and this cold-hardy race became established (R. Nguyen, pers. comm.). The wasp is now widespread throughout Florida, but its northern range is apparently defined by its intolerance to cold temperatures during the winter months. Rates of parasitism may reach close to 100% on individual leaflets, but overall parasitism by *C. fulvus* on a plant is usually between 10 and 40%, with greater parasitism occurring on leaves with high scale densities (Fig. 5). At extremely high densities, parasitism rates decrease because the scale population on a leaf is layered, and the bottom scales covered by the top scales are not accessible to female *C. fulvus*.

Larvae and adults of *C. nipponicus* are frequently observed in abundance on king sagos infested with the cycad aulacaspis scale throughout Florida. The life history of the beetle was studied by Smith and Cave (2006b). Adult females live 89-110 days. Adult *C. nipponicus* eat about four scales per day, which means they can consume 356-444 scales during their adult life. The predator is widely distributed in Southeast Asia, where it occurs in very large numbers on scale-infested cycads in southern China and Vietnam (R. D. Cave, pers. obser.). *Cybocephalus nipponicus* was released in the northeastern USA to control euonymous scale (*Unaspis euonymi*), where it became established (Drea and Carlson, 1988; Alvarez and Van Driesche, 1998). According to label data on specimens in the FSCA, *C. nipponicus* has been in Florida since at least 1990 (Smith and Cave 2006c). The species also occurs in Texas and Hawaiʻi. The wasp *Aphanogmus albicoxalis* Hymenoptera: Ceraphronidae) parasitizes the prepupae and pupae of *C. nipponicus* (Evans et al., 2005). This parasitoid is native to Florida and may lessen the biological control capability of *C. nipponicus* there.

During exploration in Asia to find new natural enemies of the cycad aulacaspis scale, the lady beetle *Phaenochilus kashaya* (Coleoptera: Coccinellidae) (Fig. 6)was discovered in Thailand in 2007 (Cave et al., 2009a) and again in 2009. The beetle is not known to occur elsewhere (Giorgi and Vandenberg 2012). Adults, larvae, and pupae were observed on *Cycas siamensis* in a forest near the Sakaerat Environmental Research Station in eastern Thailand. The cycads in the area had either very sparse infestations of the cycad aulacaspis scale or no scales at all (R. D. Cave, personal observation). The biology of this predator was studied in a quarantine facility by Manrique et al. (2012). Early instars of *P. kashaya* consume on average 4–8 scales/day, whereas fourth instars eat about 21 scales/day at 25° C. The daily consumption rates of *P. kashaya* larvae are quite high compared to those of larvae of the predatory lady beetle *Rhyzobius lophanthae,* whoseolder instars consume on average 5 scales/day at 24° C (Thorson, 2009). The mean total number of scales consumed by the larval stage of *R. lophanthae* is 420 at 20° C, 380 at 25° C, and 145 at 30° C. For comparison, *R. lophanthae* larvae consume on average 58 cycad aulacaspis scale females at 24° C (Thorson, 2009). Adult *P. kashaya* consume on average 26-32 scales/day at 25° C. For comparison, *R. lophanthae* adults consume on average 2-3 cycad aulacaspis scales per day at 24° C (Thorson, 2009). Adult females at 25° C live up to six months and lay eggs until shortly before death, whereas at 20° C they live up to seven months. Females at 20° C produce about 339 eggs during their adult life, while *R. lophanthae* feeding on cycad aulacapis scales lay about 50 eggs (Thorson, 2009). A petition to release *P. kashaya* from quarantine in Florida was not approved, but the petition review panel did recommend that it be approved for release in Guam and Rota. The natural enemy has not been released for biological control of the cycad aulacaspis scale anywhere.

The parasitoid *Arrhenophagus chionaspidis* (Hymenoptera: Encyrtidae) attacks male scales at rates ranging from 18 to 83% in China and Vietnam (R. D. Cave, unpublished data in report to APHIS PPQ). Material collected in Asia in 2007 was brought to quarantine in Florida for study and mass rearing. The parasitoid is very difficult to rear, and colonies of it could not be maintained. *Arrhenophagus* *chionaspidis* was discovered attacking cycad aulacaspis scale in Florida in 2012 (E. Rohrig, pers. comm.; R. D. Cave, pers. obser.). Ball and Stange (1979) reported the species in Florida on white peach scale (*Pseudaulacaspis pentagona*). However, Bennett and Noyes (1989) subsequently stated that the *Arrhenophagus* species reported by Ball and Stange (1979) is *Arrhenophagus albitibiae*, a species described from Japan and known from Hong Kong and Sri Lanka. Therefore, it is uncertain if the *Arrhenophagus* species attacking cycad aulacaspis scale in Asia and Florida is *A. chionaspidis*, *A. albitibiae*, or an undescribed species. *Arrhenophagus* species attack male scales, thus offering no control of the female scales. In Asia, it was collected from plants with very heavy infestations of male cycad aulacaspis scale. For these reasons, *A. chionaspidis* does not appear to have potential as a biological control agent of cycad aulacaspis scale.

*Aprostocetus purpureus* (Hymenoptera: Eulophidae) was collected from female cycad aulacaspis scales in China and Vietnam in 2006 and brought to quarantine in Florida for study and mass rearing. The parasitoid was very difficult to rear, and colonies of it could not be maintained. This species has a wide distribution throughout India and Southeast Asia (Noyes 2019). In Asia, it was collected from plants with very heavy infestations of cycad aulacaspis scale (R. D. Cave, personal observation). For these reasons, *A. purpureus* does not appear to have potential as a biological control agent of cycad aulacaspis scale.

**Biological Control Efforts in Hawaiʻi**

No program for classical biological control of cycad aulacaspis scale has been implemented in Hawaiʻi. Some natural enemies previously introduced to Hawaiʻi have expanded their prey or host ranges to attack the scale. *Rhyzobius lophanthae*, introduced into Hawaiʻi in 1894 for the control of scale insects (Funasaki et al., 1988), readily began preying upon cycad aulacaspis scale in Hawaiʻi when the pest first arrived. It is considered the most promising agent for scale management (Hara et al., 2005), and it can be effective under a range of conditions from dry to mesic habitats (M. G. Wright, pers. obs.).

The parasitoid *Aphytis lingnanensis* (Hymenoptera: Aphelinidae) was introduced into Hawaiʻi in 1964 as a biological control agent for Florida red scale (Davis and Krauss, 1964). It appears to have a significant effect on cycad aulacaspis scale populations in Hawaiʻi. Plants with quite severe infestations seem to survive the impacts of the scale insect when the parasitoid is present and causes high levels of scale mortality (M. G. Wright, pers. obs.). Little is known of the effect of different environments and cycad species on the effectiveness of this parasitoid as a biological control agent of cycad aulacaspis scale.

**Biological Control Efforts in Guam**

In November 2004, about 100 adults of *R. lophanthae* were field collected on Maui in Hawaiʻi and imported to Guam. The beetles were reared on scale-infested leaves cut from *C. micronesica*. Reared adults were collected and released in the field starting in February 2005 at the Guam National Wildlife Refuge at Ritidian Point. The beetles established readily. By July 2005, high densities of adults were observed on cycads within a 1 km radius of the release point. Establishment and dispersion of *R. lophanthae* were monitored by using yellow sticky traps from July 2005 to May 2006 (Fig. 7). Following establishment of *R. lophanthae* at Ritidian Point, laboratory-reared and field-collected beetles were released at about 30 other sites throughout Guam.

By 2010, *R. lophanthae* larvae or adults could be found on almost every infested cycad plant on Guam, and their predation on scales allowed mature cycads to survive. Unfortunately, the *C. micronesica* population is not recovering because almost all seeds and seedlings are being killed by the cycad aulacaspis scale and other causes (Marler and Terry, 2011). Marler et al. (2013) showed that predation by *R. lophanthae* is significantly lower close to the ground and suggested that this may partially account for failure of the beetle to protect seedling plants. Although the causes of reduced scale predation near the ground are unknown, the authors suggested a parasitoid biological control agent may not exhibit the same limitations because a parasitoid much smaller than *R*. *lophanthae* would likely be better able to access scale infestations within cracks and crevices on *C. micronesica* and *C. revoluta*. Unfortunately, a parasitoid would not be able to reach the scales settled on the coralloid roots in the soil.

According to G. V. Reddy’s Hatch project report (Reddy, 2007-2008), *C. fulvus* (China strain) was imported from Florida and released at three sites in Guam (by Muni in 2005?). Adults of field-collected *C. fulvus* from Florida were imported on at least two occasions; lab-rearing failed, but several individuals were directly released in the field at Ritidian Point (will check hardcopy records). The establishment of populations has not been detected. In 2013, *Arrhenophagus* sp. was discovered attacking CAS on Guam (A. Moore, personal observations), and it has since become very common. It is assumed that this was an accidental or fortuitous introduction. However, Reddy’s 2007 Hatch report indicates the importation of *A. chionaspidis* from Florida to Guam was carried out (right?), but it is uncertain where in Florida the material was collected since *A. chionaspidis* was not observed parasitizing cycad aulacaspis scale in the state until 2012. Checking to see if any of these were released on Guam.

**HOW WELL DID BIOLOGICAL CONTROL WORK?**

Despite releases of *C. fulvus* and *C. nipponicus* when the cycad aulacaspis scale was restricted to southeastern Florida, the scale quickly spread due to the movement of infested plants or natural dispersal by wind. Although the natural enemies also dispersed throughout Florida, they do not provide adequate control (Wiese et al., 2005; Cave, 2006). Rates of parasitism by *C. fulvus* do not exceed 50% on leaves (Fig. 5), and thus are inadequate for effective control of a scale that develops quickly and is very fecund (Cave et al., 2009b; Ravuiwasa et al., 2012). Although adult *C. nipponicus* consume about four scales per day (Smith and Cave, 2006b) and larvae are also predaceous, plants on which the predator occurs are still heavily infested in Florida and Asia. No data have been collected to quantify the effect of *A. chionaspis* on the scale populations in Florida, but the effect is not likely significant since the parasitic wasps only attacks males.

Because biological control of the cycad aulacaspis scale has been ineffective in Florida, nurseries in the state no longer grow king sagos for retail businesses or export to out-of-state markets. Also, very few ornamental king sagos remain in Florida’s urban landscape. Those plants that remain are infested by the cycad aulacaspis scale, but they survive due to chemical applications by landscape managers and homeowners.

What happened on Guam

**BENEFITS OF BIOLOGICAL CONTROL OF CYCAD AULACASPIS SCALE**

There likely is no hope to rebuild the cycad production nurseries in Florida. No natural enemy of the cycad aulacaspis scale has shown an ability to reduce scale populations to levels that can be practically and economically managed with chemical control. No biological control agents adequately suppress the pest.

Successful biological control of the cycad aulacaspis scale in the urban landscape, be it in Florida, Texas, Hawaiʻi, or elsewhere, would benefit the environment where ornamental cycads have survived. Broad-spectrum pesticides applied as a soil drench and as foliar sprays and horticultural oils applied to the leaves are the primary control methods used by the landscape care industry and homeowners. Unfortunately, chemical control can be expensive. For example, dinotefuran is a systemic pesticide that is water soluble that can be applied either as a drench or applied twice a year to foliage for temporary control (Caldwell, 2005). A 3-lb container of Safari 20SG Systemic Insecticide with Dinotefuran costs about $422–$468 (www.amazon.com; www.domyownpestcontrol.com;). Therefore, it is not economical for homeowners to treat 1-2 plants. Applications of horticultural oils must be frequent and regularly applied (Howard et al., 1999; Emshousen et al., 2004; Hara et al., 2005; Bográn et al., 2006), and therefore their use is also costly. Some homeowners have applied pesticides not registered for use on cycads, such as flea and tick sprays (R. D. Cave, pers. obs.). If biological control agents cannot effectively control the cycad aulacaspis scale, then, landscapers, homeowners, and botanical garden managers will continue to use costly pesticides that interfere with the resident natural enemies and contaminate soil and water.

Mature *C. micronesica* trees in Guam’s forests are dying, and these plants are not being replaced by seeds or juvenile plants. It is obvious that without a change, this endemic plant, the most abundant tree in Guam’s forests only two decades ago, is headed towards local extinction. Restoration of Guam’s forests to their pristine state is no longer possible. However, there is an urgent need to control cycad aulacaspis scale so that some recovery can take place, without further loss of biodiversity.

Field release of the lady beetle *P. kashaya*, a voracious, oligophagous predator of armored scales, may contribute significantly to the biological control of the cycad aulacaspis scale in Guam. Both the larval and adult stages consume the cycad aulacaspis scale, and the insect is easily reared in the laboratory. There is evidence in its homeland (Thailand) that it can suppress cycad aulacaspis scale populations to very low levels. If released in Guam, Rota, Tinian, and Palau, this beetle would likely reduce the abundance of cycad aulacaspis scale to levels that no longer threaten the survival of native *C. micronesica* forests on those islands. The actions of other natural enemies, such as *R. lophanthae* and *A. chionaspidis*, might also be enhanced. Here, you should mention that APHIS has approved release of *P. kashaya* in Guam and indicate what plans are underway to make the release.

New attempts to establish *C. fulvus* on Guam may also lead to increased biological control of the cycad aulacaspis scale. But studies are needed to investigate its searching behavior and ecology in the environment. Species of *Aphytis* that have been reared from cycad aulacaspis scales collected in China, Texas, and Hawaiʻi need to be carefully examined taxonomically and biologically to determine their potential as biological control agents in Florida and Guam.

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**Fig. 1.** Cycad aulacaspis scale, *Aulacaspis yasumatsui*, on the coralloid roots (A), cataphyll (B), leaves (C), and seeds (D) of *Cycas revoluta*. Photos by R.D. Cave.

**Fig. 2.** Number of *Cycas micronesica* stems per ha (all size categories) in 12 Guam habitats from 2005 to 2020. The inset shows results from 2008 to 2020 with smaller vertical axis range. Ordinates of markers with the same letter are not significantly different. Taken from Marler and Krishnapillai (2020).

**Fig. 3.** *Cycas revoluta* with an intense infestation of the cycad aulacaspis scale, *Aulacaspis yasumatsui*. Photo by R.D. Cave.



**Fig. 4.** Dead and dying *Cycas micronesica* at Tarague, Guam. Photo by ?????

**Fig. 5.** Rate of parasitism of cycad aulacaspis scale, *Aulacaspis yasumatsui*, by *Coccobius fulvus* in relation to female scale density on *Cycas revoluta* in Florida.

**Fig. 6.** *Phaenochilus kashaya* larva, pupa, and adult. Photos by R. D. Cave.

**Fig. 7.** Insects trapped on yellow sticky cards at Ritidian Point, Guam following field release of *Rhyzobius lophanthae* in February 2005. X axis runs from July 2005 through May 2006; Y-axis, in log scale, is number of insects trapped per square meter per day.