Cycad Aulacaspis Scale: A Global Perspective

Jody Haynes*

Introduction

Cycad aulacaspis scale (CAS), *Aulacaspis yasumatsui* Takagi (Hemiptera: Diaspididae), is a tiny, white, armored scale insect that normally feeds on cycads in the genus *Cycas*. It is native to areas with wild *Cycas* populations, from the Andaman Islands across to Vietnam, Thailand, and most likely Cambodia, Laos, peninsular Malaysia, Myanmar, and southernmost China (Howard *et al.*, 1999; IUCN, 2005; Muniappan, 2005). In areas that lack native predators and parasitoids to keep it in check, it is an extremely aggressive pest on cycads. It recent years, it has spread through human activity and commerce to the point where two species of cycads face imminent extinction in the wild.

CAS has reportedly been introduced into numerous states in the U.S. (Alabama, Florida, California, Georgia, Hawaii, Louisiana, South Carolina, Texas), throughout the Caribbean basin (Cayman Islands, Puerto Rico, St. Kitts, U.S. Virgin Islands, and Vieques), as well as Guam, Hong Kong, Singapore, and Taiwan (Ben-Dov *et al.*, 2005; Broome, 2000; J. Haynes, pers. obs.; Hodges *et al.*, 2004; Marler, 2004a,b; W. Tang, pers. obs.).

The objective of this article is to provide an overview of CAS, its global spread and establishment, and current research and control efforts being conducted worldwide. Much of the information provided herein was extracted from an unpublished report produced by the IUCN/SSC Cycad Specialist Group – Subgroup on Invasive Pests, co-written and edited by William Tang and the current author (IUCN, 2005).

Summary of CAS Outbreaks

Into Areas without Native Cycads

The first known outbreak of CAS outside its natural range occurred at the Bogor Botanic Garden in Java in the late 1980's, where it wiped out that garden's *Cycas* collection (A. Lindstrom, pers. comm.). It is unknown whether CAS persists on other cultivated or wild plants in Java. Unfortunately, this outbreak was not publicized, so no warning was given to avoid future outbreaks (IUCN, 2005).

The second known outbreak occurred in south Florida in 1995 (Howard *et al.*, 1999). Although the exact origin of this outbreak remains unknown, it may have originated from plants collected in either China or Vietnam by two botanical gardens in Miami. Another possibility is that it came in via the little-known illegal importation of *Cycas* plants from that region to Miami, which was going on about the same time. If the former is the case, then CAS came in undetected by USDA inspectors—which is not too surprising, given this insect's propensity to hide under old leaf bases on the trunk and in the root system. If it was the latter, then USDA inspections, which are the last line of defense against such invasions, were bypassed completely. Either way, pest alerts and trade restrictions were unfortunately too slow to prevent its spread. In south Florida, CAS virtually wiped out the thriving nursery trade in king sagos (*Cycas revoluta*) within a few years, causing millions of dollars in damage. Ten years later, South Florida remains a major center of the commercial plant industry in the U.S., and, surprisingly, *C. revoluta* and other cycads are still being imported and grown in wholesale quantities for national and international distribution (IUCN, 2005). As a result, CAS has now been transported on living plants to other parts of the U.S., especially through chain stores supplied by south Florida nurseries. Movement of infected *C. revoluta* plants also resulted in the transport of CAS to Guam, even though officials there were repeatedly warned of the danger of importing sagos from Florida (see below).

A third outbreak occurred in China in the mid 1990's via wholesale trade of wild-collected *Cycas inermis* from southern Vietnam into two botanical gardens in southern China. Due to this trade, CAS has become widespread in botanical gardens and nurseries throughout southern China. South China is also a center for a nursery industry that grows and exports *C. revoluta*. The increasing affluence in China in the 1990's led to enormous demands for *C. revoluta* as an ornamental. When domestic markets became saturated in the early 2000's, Chinese cycad nurseries received their government's permission to export. This may have led to the introduction of CAS to Taiwan, another center of *C. revoluta* production and export. Today, China and Taiwan are still among the world's largest exporters of *C. revoluta* and, with it, presumably CAS. Every month, 20- and 40-foot containers packed with thousands of *C. revoluta* arrive in Miami from these countries (W. Tang, pers. obs.), destined for re-establishment and ultimately retail distribution. Undoubtedly, similar shipments are being sent to other equally or more vulnerable parts of the world (IUCN, 2005).

These three outbreaks illustrate the three primary pathways for the spread of CAS: botanical gardens seeking to expand their living collections, the commercial nursery industry, and private collectors trading plants among themselves. Although the volume of plant movement in the "collector pathway" is much smaller than that of botanical gardens and the nursery industry, the risk of spreading CAS may be just as high, depending on where plants are sent from and to and whether or not there are safeguards in place at the origination to detect the pests and at the destination to prevent establishment. Collectors often circumvent plant quarantine inspections (*i.e.*, smuggle) to avoid CITES requirements. In this sense, CITES regulations ironically increase the risk of spread of CAS (IUCN, 2005).

Into Native Cycad Habitats

Although officials in Guam were repeatedly warned against importing king sagos from Florida due to the possibility of them harboring this invasive pest (Marler, 2000), the warnings went unheeded and CAS arrived in Guam (from Florida – on infected *Cycas revoluta* plants!) in October 2003 (see the Guam invasion timeline in Table 1 of Moore *et al*. on pg. 8). At that time, the pest was confined to landscape plants in urban areas, but last year it escaped into wild populations of the native *Cycas micronesica* (Haynes & Marler, 2005; Marler 2004a, 2004b, 2005), where it is spreading rapidly, wreaking havoc and killing large numbers of plants as it goes (see the photos in the Terry & Marler article in the full-color issue).

CAS made it to Taiwan (by unknown means) in 2000, where it promptly killed more than 100,000 cycads in the nursery trade in Taoyuan County alone that year (J.-T. Chao, pers. comm.). Last year, it began invading populations of the endemic cycad, *Cycas taitungensis*, including plants growing in the well-known Taitung Cycad Nature Reserve (J.-T. Chao, pers. comm.). Table 1 illustrates the invasion timeline of CAS in Taiwan.

Areas & Species at Risk

This scale is probably the worst plague attacking cycads since the ad-

**Montgomery Botanical Center, 11901 Old Cutler Rd., Miami, FL 33156*

vent of modern cultivation (T. Broome, pers. comm.). **Wild populations of *Cycas micronesica* on Guam and *C. taitungensis* on Taiwan are currently facing the possibility of extinction as a result of CAS infestations.** Virtually all other *Cycas* outside the natural range of CAS are also at risk of being infested and extirpated. *Cycas revoluta* is highly vulnerable to attack in cultivation, and wild populations in Japan must be considered vulnerable. All Australian *Cycas* that have been tested in cultivation have proven themselves highly vulnerable to attack (there are 27 species in Australia). *Cycas* plants in northern and northeastern Australia number in the millions, sometimes forming dense, continuous stands for tens of miles and comprising significant components of the native flora. An outbreak of CAS there may lead to a cycad holocaust that would far exceed any damage done by habitat destruction and commercial collecting combined. Many species of the *C. rumphii* complex—which ranges from New Caledonia and Micronesia across to the Philippines, Celebes, Indonesia, and Madagascar—are also vulnerable. The movement of infected plants—either through commercial or scientific shipments or through mail or baggage of collectors—to any of these regions could result in the catastrophic demise of wild *Cycas* populations or even entire species (IUCN, 2005).

In cultivation, with heavily infested *Cycas* plants in proximity, various species of *Bowenia*, *Ceratozamia*, *Dioon*, *Encephalartos*, *Microcycas*, *Macrozamia*, and *Stangeria* have been observed to be infected by CAS on leaves or cones (J. Haynes, pers. obs.; Howard *et al.*, 1999; W. Tang, pers. obs.). Of the other genera, several taxa are at particular risk. The monotypic *Stangeria eriopus* seems particularly susceptible, as does *Macrozamia lucida*. The cones of *Encephalartos manikensis* and its allies, as well as *Ceratozamia robusta* (Belize), become covered with CAS to the point where seed production is aborted. In the event that CAS is introduced to wild populations of these species, reproduction would likely fail, possibly leading to their eventual extinction (IUCN, 2005).

Summary of Research & Control Efforts

The University of Florida's Institute of Food & Agricultural Sciences, the Florida Department of Plant Industry, and Montgomery Botanical Center have led research efforts on chemical and biological control of this pest in landscape situations (*e.g.*, Caldwell, 2005; Cave, 2005; Cave & Duetting, 2004; Emshousen & Mannion, 2004; Hodges *et al.*, 2003; Mannion, 2003; Weissling *et al.*, 1999; Wiese *et al.*, *in press*; Wiese & Mannion, *in press*). Of particular interest were the efforts of Dr. Richard Baranowski (UF-IFAS Tropical Research & Education Center, Homestead, FL), who, in collaboration with Banpot Napompeth, director of the Natural Biological Control Research Center at Kawetsart University in Bangkok, Thailand, identified two potential biocontrol organisms—the parasitoid wasp, *Coccobius fulvus* (Compere & Annecke) (Hymenoptera: Aphelinidae), and the predatory beetle, *Cybocephalus nipponicus* (Endrody-Younga) (Coleoptera: Nitidulidae). The quarantine and efficacy research was conducted, in part, on the grounds of Nong Nooch Tropical Garden in Pataya, Thailand, and both insects have been tested and widely released in Florida as biocontrol agents of CAS. Knowing that most people will not have access to the biocontrol organisms, Greg Holzman has developed an effective method of controlling CAS in landscape situations and private cycad collections (see his article on pg. 10).

Not surprisingly, very little work has been done on controlling CAS in natural cycad habitats. Below is a list of researchers currently working on this problem, the types of research they are conducting, and their future funding and research needs (when known).

Dr. Thomas Marler (University of Guam)

- Demographic studies on populations of *Cycas micronesica* before and after infestation
- Efficacy testing of chemical controls on CAS in landscape situations on Guam
- Tracking the spread of CAS and the introduced predatory lady beetle, *Rhyzobius lophanthae*, in wild populations of *C. micronesica* using GIS
- Working with the U.S. Navy to establish a population-based *ex-situ* collection of *C. micronesica* on the island of Tinian
- Submitted proposal to USDA for a study that will define molecular markers for populations of *C. micronesica* on Guam, Rota, Yap, Palau, and the Philippines
- *Immediate research needs*:
  - Formulating an immediate salvage plan for affected populations and a long-term conservation plan for the species on Guam
  - Alerting residents via print and other media of the importance of controlling this invasive insect pest on Guam and keeping it from spreading to nearby islands
  - Upgrading the conservation status of *Cycas micronesica* via the U.S. Fish & Wildlife Service and IUCN Red List
  - Sending an expert biocontrol entomologist to Asia to collect additional predatory insect species that may be useful in continuing biocontrol efforts; this will be followed by experiments aimed at determining the effectiveness of control and prey specificity of each new potential predator
  - Testing growth regulators sprayed on or injected into cycads for effectiveness of suppression of the CAS in urban environments and the urban-wildland interface
  - Continuing GIS mapping of CAS and predatory beetle populations on Guam
  - Surveying additional islands for CAS—including Tinian, Yap, and Palau—and increasing the frequency of surveys on Rota, which carries the highest risk of secondary invasion by CAS because (1) it is the closest island to Guam and the many daily flights are just a few minutes in duration, and (2) it has the second largest population of *Cycas micronesica*
- *Long-term research*:
  - Studies on the interactions of various wildlife species associated with cycads
  - Molecular studies of mycorrhizal fungi and cyanobacteria symbionts associated with cycads, both within and among cycad habitats on Guam
- *Funding needs*:
  - If there is any hope of controlling this pest on Guam, a **minimum** of $250,000 will be required to conduct the necessary research and implement appropriate control measures.

Dr. R. Muniappan (U of Guam)

- Recently released a new ecotype of *Coccobius fulvus* into natural populations of *Cycas micronesica*
- Testing efficacy of this wasp in natural populations on Guam
- *Funding needs*:
  - Foreign exploration for natural enemies of CAS: $30,000
  - Conservation of endemic cycads in India (workshop & CAS survey of native populations): $22,450

Dr. Aubrey Moore & Dr. Ross Miller (U of Guam)

- Collaborating with Drs. Marler and Muniappan on various CAS biocontrol

efforts in Guam

Ms. Anne Brooks (Guam National Wildlife Refuge)

- Developing emergency and long-term plans for control of CAS in natural populations of *Cycas micronesica* on Guam, as follows:
  - *Emergency plans*: Introduction of scale predators; chemical treatment trials; dispersing introduced biocontrol beetle around the island
  - *Long-term plans*: Detailed studies of treated plots; moving seed to Tinian where there is no scale

Dr. Ronald Cave (UF – Indian River Research & Education Center)

- Population dynamics of CAS and parasitism by *Coccobius fulvus*
- Taxonomy, biology, and pesticide susceptibility of *Cybocephalus nipponicus*
- Exploration and screening of additional exotic parasitoids
- Study of entomopathogenic nematodes for control of CAS
- *Immediate funding needs*:
  - Nematode control: $15,000 for 2 years
  - Studies on *Rhyzobius lophanthae* behavior and feeding: $50,000 for 2.5 years, including M.Sc. student stipend
  - Exploration to other areas of Asia to find all possible biological control agents: $180,000 for 5 years, including Ph.D. student stipend

Dr. Po-Yung Lai (National Pingtung University of Science and Technology, Taiwan)

- Imported *Cybocephalus nipponicus* from Thailand to a quarantine facility in Taiwan
- Field released *C. nipponicus* in Taitung Cycad Nature Reserve (Oct. 2005) and at Pingtung and Taichung (Nov. 2005)
- Overseeing M.Sc. student conducting research on efficacy of *C. nipponicus* in controlling CAS (see below)

Mr. Rafique Bailey (National Pingtung University)

- M.Sc. student in the Department of Entomology
- Conducting thesis research on biocontrol of CAS by *Cybocephalus nipponicus*

Dr. Jung-Tai Chao (Taiwan Forestry Research Institute, Taiwan)

- Surveying natural populations of *Cycas taitungensis* and tracking spread of CAS in Taiwan
- Testing of chemical control measures on CAS in Taiwan
- Releasing, tracking, and efficacy testing of *Cybocephalus nipponicus* and *Coccobius fulvus* in wild populations of *C. taitungensis*, including within the Taitung Cycad Nature Reserve

International Logistical Support

CAS has been given top priority status by the IUCN/SSC Cycad Specialist Group (CSG) (see letter from CSG Chair J. Donaldson on pg. 11). The CSG Subgroup on Invasive Pests has taken on the following responsibilities:

1. Compiling information and writing a report to the Cycad Specialist Group on the status of CAS in cycad habitats and collections of conservation importance worldwide (this report is completed and is available from the CAS Information Page [Haynes, 2005]);
2. Providing updated CAS-related information on a centralized "clearinghouse" web page (Haynes, 2005); and
3. Organizing a global media campaign to alert governments and NGO's in countries with native *Cycas* populations—including additional islands in the Pacific, as well as India, SE Asia, and Australia—of the seriousness of this pest.

At the prompting of the CSG Subgroup on Invasive Pests, the IUCN/SSC Invasive Species Specialist Group recently added *Aulacaspis yasumatsui* to its Global Invasive Species Database (ISSG, 2005). Also, the Pacific Programme of the Cooperative Islands Initiative has assumed the responsibility of alerting its member island nations of the seriousness of CAS.

Financial Support

As mentioned above, an enormous amount of funding is going to be required to bring this pest under control within the wild cycad populations that it has already infested. Unfortunately, this problem has not yet been recognized by any of the world's foremost conservation funding agencies. The USDA has provided some funding for R. Cave to go to Vietnam in search of new biocontrol organisms, and J. Haynes and T. Marler have received a grant from the Association of Zoological Horticulture to begin establishing a population-based *ex-situ* collection of *Cycas micronesica* from Guam at Montgomery Botanical Center in Miami, FL.

This past September the Cycad Society board of directors met and is now proud to announce that $2,500 has been donated toward CAS biocontrol research (see Moore *et al*. pg.6 for a description of how TCS funds will be used.) TCS is also developing a new CAS Fund and is now soliciting private donations to be applied toward CAS research (see the *"President's Message"* on pg. 2).

References

Ben-Dov, Y., D.R. Miller & G.A.P. Gibson. 2005. Scalenet. Website: http://www.sel.barc.usda.gov/catalogs/diaspidi/Aulacaspisyasumatsui.htm

Broome, T. 2000. The Asian cycad scale. *Cycad Newsletter* 24(4):6-7.

Caldwell, D. 2005. Some beneficial insects and a fungus that attacks the cycad aulacaspis scale. Website: http://collier.ifas.ufl.edu/Horticulture/CAS_index.htm

Cave, R. 2005. Biological control of *Aulacaspis yasumatsui*, a serious pest of cycads in Florida, Hawaii and Gaum: exploration for and screening of natural enemies. Unpublished grant proposal.

Cave, R. & P. Duetting. 2004. Predatory Coleoptera on king sago (Cycadaceae) in south Florida. Paper presentation at Entomological Society of America meetings, 17 November 2004, Salt Lake City, UT. Website: http://esa.confex.com/esa/2004/techprogram/paper_15445.htm

Emshousen, C. & C. Mannion. 2004. Taming Asian cycad scale (*Aulacaspis yasumatsui*). *Cycad Newsletter* 21(1):8-10.

Haynes, J. 2005. CAS Information Page: http://www.montgomerybotanical.org/Pages/CASlinks.htm

Howard, F.W., A. Hamon, M. MacLaughlin, T. Weissling & S.-L. Yang. 1999. *Aulacaspis yasumatsui* (Hemiptera: Sternorrhyncha: Diaspididae): A scale insect pest of cycads recently introduced into Florida. *Florida Entomologist* 82(1):14-27.

Hodges, G., F. Howard & E. Buss. 2003. Update on management methods for cycad aulacaspis scale. University of Florida Extension publication #ENY-680. Website: http://edis.ifas.ufl.edu/IN474

ISSG. 2005. IUCN/SSC Invasive Species Specialist Group's Global Invasive Species Database. Website: http://www.issg.org/database/species/ecology.asp?si=814&fr=1&sts=sss

IUCN. 2005. Report and recommendations on cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Hemiptera: Diaspididae). IUCN/SSC Cycad Specialist Group – Subgroup on Invasive Pests. Unpublished.

Mannion, C. 2003. Management of cycad aulacaspis scale (*Aulacaspis yasumatsui*). Unpublished. Website: http://ipm.ifas.ufl.edu/community/landscape/commercial/cycad_aulacaspis_scale_management.htm

Marler, T. 2000. Looking out for scale insects. "Gardening" section, *Pacific Daily News*, Feb. 13, 2000.
Marler, T. 2004a. Alien insect attacking Guam's native flora. "Lifestyle" section, p. 20, *Pacific Daily News*, Mar. 13, 2004.
Marler, T. 2004b. Cycad scale attacking Guam plants. "Lifestyle" section, pp. 23-24, *Pacific Daily News*, Sep. 25, 2004.
Marler, T. 2005. A landscape in danger: Experts advise fighting back to combat Asian Cycad Scale. "Lifestyle" section, *Pacific Daily News*, Jun. 5, 2005.
Muniappan, R. 2005. Foreign exploration for natural enemies of the cycad scale, *Aulacaspis yasumatsui* (Homoptera: Diaspididae). University of Guam.
Weissling, T.J., F.W. Howard & A.B. Hamon. 1999. Cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Insecta: Homoptera: Sternorrhyncha: Diaspididae). University of Florida Extension publication #EENY-096. Website: http://edis.ifas.ufl.edu/IN253
Wiese, C., D. Amalin, R. Coe & C. Mannion. In press. Effects of the parasitic wasp, *Coccobius fulvus*, on cycad aulacaspis scale, *Aulacaspis yasumatsui*, at Montgomery Botanical Center, Miami, Florida. *Proceedings of the Florida State Horticultural Society*.
Wiese, C. & C. Mannion. In press. Managing cycad aulacaspis scale (*Aulacaspis yasumatsui* Takagi) at Montgomery Botanical Center, USA. *Proceedings of the 7th International Conference on Cycad Biology, Xalapa, Mexico*.

Table 1. Taiwan CAS invasion timeline.

Date	Event/Location
2000	CAS introduced into northern Taiwan through an unknown channel, killing 110,000 nursery cycads (seedlings and adults of various ages) in Taoyuan County—a northern county south of the capital of Taipei—in its first year.
9/2003	The predatory beetle, *Cybocephalus nipponicus*, imported from Thailand to the quarantine facility at National Pingtung University, Neipu, Pingtung, Taiwan.
2004	CAS invaded the Taitung Cycad Nature Reserve—home of one of the largest populations of the endemic *Cycas taitungensis*—in southeastern Taiwan.
10/2005	*Cybocephalus nipponicus* field released in Taitung Cycad Nature Reserve.
11/2005	*C. nipponicus* released at Pingtung and Taichung.