

Rapid Communication**Knowledge of cycad aulacaspis scale (Hemiptera: Diaspididae) in Panama**

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Citation: Castillo-Gómez M, Chang-Pérez R, Jiménez-Puello J, Santos-Mugas A, Medianero E (2021) Knowledge of cycad aulacaspis scale (Hemiptera: Diaspididae) in Panama. *BioInvasions Records* 10(4): 1015–1021, <https://doi.org/10.3391/bir.2021.10.4.26>

Received: 17 March 2021

Accepted: 2 July 2021

Published: 20 September 2021

Handling editor: António Onofre Soares

Thematic editor: Angeliki Martinou

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Abstract

The genus *Cycas* forms one of the oldest plant groups. *Cycas* are utilized as ornamental plants in urban gardens, so they are found in different cities' landscapes. At present, *Cycas* are affected by serious infestations of *Aulacaspis yasumatsui* (cycad aulacaspis scale; CAS) that eventually lead to the plant's death. *Aulacaspis yasumatsui* is native to Thailand and has spread in all continents as an invasive species. To determine the distribution of *Aulacaspis yasumatsui* in Panama, we sampled 68 sites in 24 municipalities in nine of ten provinces of the Republic of Panama. Our results suggest that *Aulacaspis yasumatsui* is spread in the low territories of the country; however, we did not observe CAS-infested cycads in the highlands of Panama (> 700 m). Besides the economic loss caused by the death of plants whose price in Panama ranges from tens to hundreds of dollars, *Cycas* serve as a food supplier to birds and bats in the trophic food web.

Key words: *Aulacaspis yasumatsui*, *Cycas*, invasive species, ornamental plants, urban garden

Introduction

The genus *Cycas* (Cycadales: Cycadaceae), with approximately 98 known species, belongs to one of the oldest plant groups (Valverde 2015). They are slow-growing plants, and some species can reach 6 to 7 meters in height; however, this growth can take between 50 and 100 years (Stevenson 2001; Valverde 2015). Due to its structure, *Cycas* species are utilized as ornamental plants in urban gardens shaping the landscape of different cities. Commercialized cycads are sold at high prices and its commercialization brings about numerous challenges (Valverde 2015), which includes the

proliferation of pests, viruses such as CSNV (Cycad Necrotic Stunt Virus) (Han et al. 2002; Luo 2012), fungi [*Colletotrichum proteae* (Glomerellales: Glomerellaceae), *Fusarium* sp. (Hypocreales: Nectriaceae), *Nigrospora sphaerica* (Trichosphaeriales: Trichosphaeriaceae), *Pestalotiopsis foedans* (Amphisphaeriales: Pestalotiopsidaceae), and *Sclerotium* sp. (Erysiphales: Erysiphaceae) (Valverde 2015)], insects such as *Aulacoscelis melanocera* (Coleoptera: Orsodacnidae) (Sánchez-Soto 2020), and scale insects. Currently, the most serious threat to cycads is *Aulacaspis yasumatsui* Takagi (Hemiptera: Coccomorpha: Diaspididae) (cycad aulacaspis scale; CAS) (Giorgi and Vandenberg 2012; Wei et al. 2018). Out of more than 20 species of scale insects attacking cycads in Florida, the most damaging species is cycad aulacaspis scale (Hodges et al. 2003). Cycad aulacaspis scale have been found infesting 22 species of cycads in the Cutler Ridge area of Miami-Dade County, Florida, U.S.A. (Weissling et al. 2020). Severe infestations of CAS in cycad plants ultimately destroys the plant.

Aulacaspis yasumatsui is native to Thailand, where it is found on cycads and kept under control by natural predators and parasitoids (Weissling et al. 2020). The insect was originally described from specimens collected on a *Cycas* sp. in Bangkok, Thailand in 1972 (Takagi 1977). CAS is a member of the armored scale group, family Diaspididae; as adults, females produce a heavy coating that acts as a shield to protect her and her eggs (Weissling et al. 2020). This invasive insect species is now found in Asia (China, Hong Kong, Indonesia, Singapore, Taiwan, Thailand, and Vietnam), Oceania (Guam, New Zealand, Northern Mariana Islands, and Palau), Europe (Bulgaria, Croatia, France and United Kingdom), Africa (Ivory Coast and South Africa), the Americas (United States, Hawaii, Mexico and Costa Rica) and the Caribbean Islands (Barbados, Cayman Islands, Guadeloupe, Martinique, Puerto Rico and the Virgin Islands of the United States) (Normark et al. 2017; Sánchez-Soto and Chávez-García 2017; CABI 2021).

Due to its geographical position, the Republic of Panama has, in recent years, been experiencing damages to its economy due to the introduction of exotic insect species such is the case of *Hypothenemus hampei* Ferrari (Curculionidae), *Tuta absoluta* Meyrick (Gelechiidae), *Anastrepha grandis* Macquart (Tephritidae), *Brachyplatys subaeneus* (Westwood) (Plataspidae) (Aiello et al. 2015; Rédei 2016) and more recently, *Quadrastichus erythrinae* Kim (Eulophidae) (Barraza and Higuera 2019; Medianero and Zachrisson 2019). In November 2006, we collected specimens of a new scale insect in Ancon (Albrook) next to the Panama Canal and on Ricardo J. Alfaro Avenue. The specimens were identified as *Aulacaspis yasumatsui* Takagi. However, an official report has not been conducted on the distribution of CAS in Panama. The object of this paper is to report the presence and distribution of cycad aulacaspis scale since is yet unknown in Panama.

Materials and methods

Study Area

According to the Atlas Ambiental de la República de Panamá (Autoridad Nacional Del Ambiente 2010), the Republic of Panama is located in the Northern Hemisphere tropics near the equator, between 7°12'08" and 9°38'46"N and between 77°09'24" and 83°03'07"W. Panama is bounded by the Caribbean Sea to the north, the Pacific Ocean to the south, the Republic of Colombia to the east, and the Republic of Costa Rica to the west. The territory of Panama has an area of 75 845.072 km² and connects North America and South America; Panama has altitudes ranging from 0 to 3475 m a.s.l. Twenty-four vegetation types and twelve life zones have been identified in Panama according to UNESCO (Autoridad Nacional Del Ambiente 2010). The Republic of Panama experiences one rainy season annually from May to November and one dry season from December to April (Autoridad Nacional Del Ambiente 2010). The annual average precipitation varies from 1 200 to 7 000 mm, and the annual average temperature varies between 7.5 and 27 °C (Autoridad Nacional Del Ambiente 2010). The political division of the Republic of Panama comprises 10 provinces, 75 municipalities, and 3 indigenous comarcas at the provincial level (Autoridad Nacional Del Ambiente 2010).

The genus *Cycas* is not native to Panama, but *Cycas revoluta* L. and *Cycas circinalis* L. are imported as ornamental plants.

Field data were obtained by samplings conducted between October 2011 and January 2021. Different sites with diverse vegetation, life zones and altitudes were sampled. The samplings were carried out mainly in the dry season. We conducted intensive sampling in gardens within urban areas as well as in rural areas to find cycad plants. When a cycad plant was found, its foliage was studied for 10 to 20 minutes to determine the presence or absence of *Aulacaspis yasumatsui*.

At each site, the geographic information and date were recorded. The information was recorded in a Microsoft Excel sheet, and a distribution map was built with QGIS 3.14.

Specimens were slide-mounting according to the method described by Trencheva et al. (2010). The insects were identified using the original description of *Aulacaspis yasumatsui* Takagi (1977) and other characters included in Trencheva et al. (2010) and Weissling et al. (2020). Voucher specimens were deposited at the Museo de Invertebrados G.B. Fairchild (Laboratorio de Entomología Sistemática) of the Universidad de Panama.

Results and discussion

Material examined

25♀ and 10♂. PANAMÁ, Panamá, Panamá, Balboa, 8°57'20"N; 79°33'25"W, 4 m; on stems and leaf of *Cycas revoluta* L. November 2006. R. Chang leg.

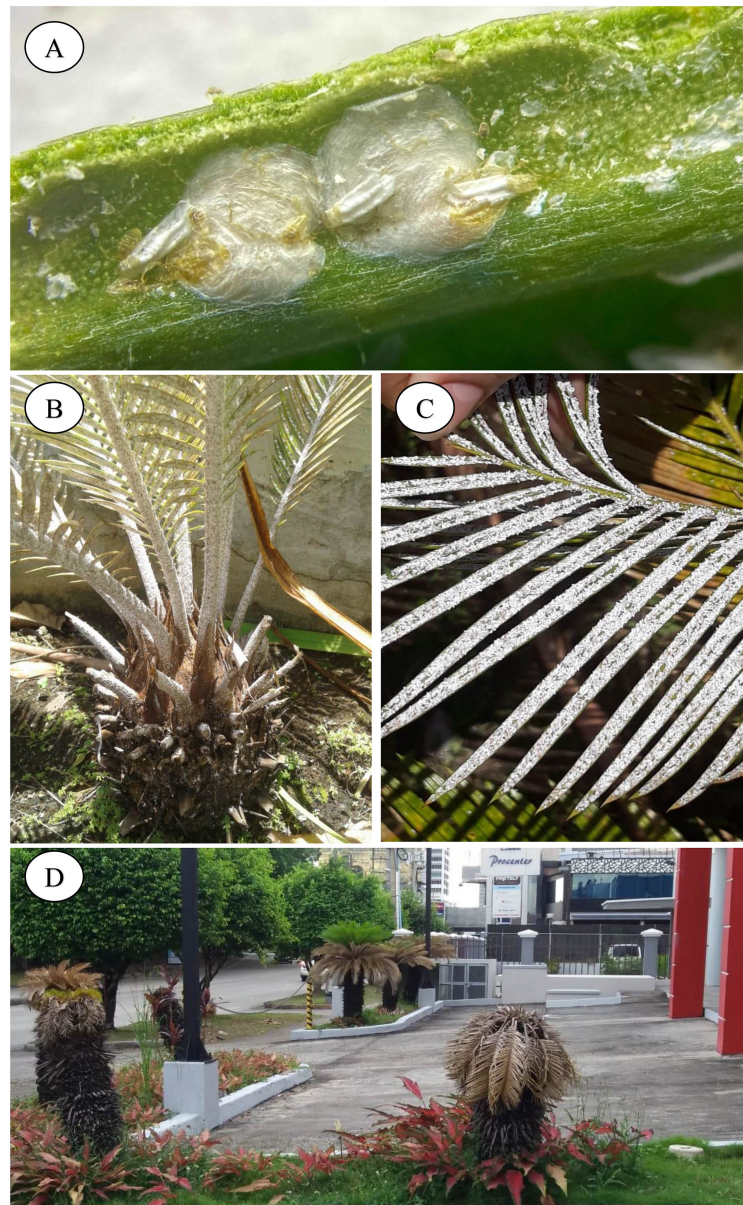


Figure 1. (A) Female and male of *Aulacaspis yasumatsui*. (B) Young *C. revoluta* plant infested with *A. yasumatsui*. (C) Infected *Cycas* leaves. (D) Landscape of an urban garden with cycad individuals killed due to infestations of *A. yasumatsui*. Photos by Alonso Santos-Murgas (A) and Magdalia Castillo (B–D).

15 ♀ and 5 ♂. PANAMÁ, Panamá, Panamá, Ave Ricardo J. Alfaro, 9°01'0,41"N; 79°32'04,56"W, 50 m; on stems and leaf of *Cycas revoluta* L. November 2006. M. Castillo and J. Jimenez legs. 50 ♀ and 15 ♂. PANAMÁ, Panamá, Panamá, Costa del Este, 9°00'48,16"N; 79°28'04,38"W, 3 m; on stems and leaf of *Cycas revoluta* L. March 3, 2021. M. Castillo, J. Jimenez, and A. Santos legs.

Diagnosis

According to Takagi (1977) and Trencheva et al. (2010), *A. yasumatsui* is characterized by both the female and male occur on the underside of the leaves (Figure 1A). The female armor is white, 1.2–1.6 mm in length. Adult

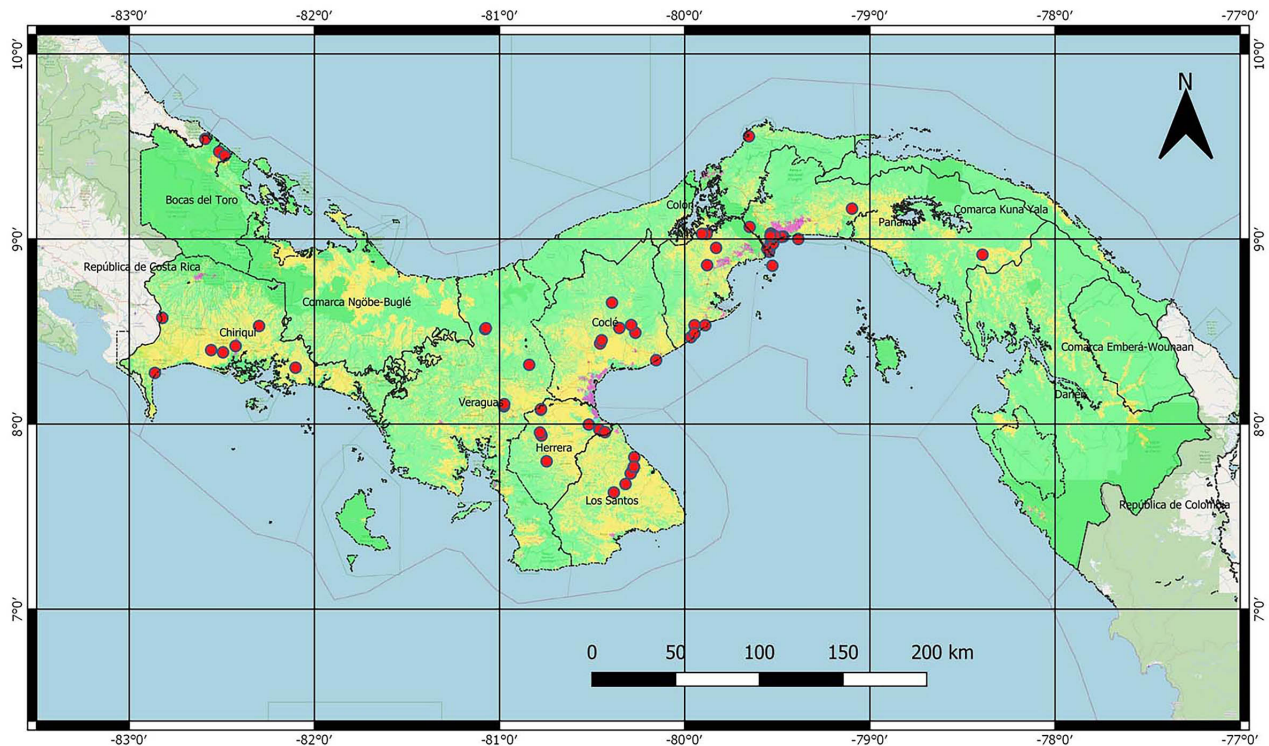


Figure 2. Map of the Republic of Panama indicating sites where cycads were found to be infested with *A. yasumatsui*.

females cover flat, circular to pear shaped, (or irregularly shaped occasionally). In the field, the scale of *A. yasumatsui* resembles that of the magnolia white scale, *Pseudaulacaspis cockerelli* Cooley, which is also common on cycads. However, a few characteristics distinguish the species: the color of the body of all stages and eggs of *A. yasumatsui* is orange, except in recently molted individuals, which are yellow, while the eggs and all stages of *P. cockerelli* are yellow.

Adult female body stout, prosoma rounded, at maturity broader than postsoma. Pygidium with 3 pairs of well developed lobes. Fourth and fifth lobes represented by sclerotized raised areas, fifth lobes sometimes absent. Paraphyses absent. Second lobes bilobed, noticeably smaller than median lobes. Third lobes bilobed, equal to or slightly larger than second lobes. Perivulvar pores in 5, rarely 4 groups, 37–57 pores on each side of the body. Perispiracular pores usually with 3 loculi, anterior spiracle with 10–29 pores, posterior spiracle with 6–30 pores. Eyes represented by circular or irregularly sclerotized area on body margin at level slightly posterior of anterior margin of clypeolabral shield. Antennae each with one seta. Body of characteristic shape, with head, prothorax, and mesothorax slightly swollen but with rounded margins, not rectangular. Pygidium with definite sclerotized areas (Trencheva et al. (2010).

Our results suggest that *A. yasumatsui* (Figure 1A) is distributed in all territories of the Republic of Panama (Figure 2). We sampled 68 sites in 24 municipalities in nine of the ten provinces of Panama (Supplementary material Table S1). We recorded 267 cycad individuals, mainly of the

species *C. revoluta*. We found 179 cycad individuals infested with *A. yasumatsui* (Figure 1B–D), which represented 67.04% of the total sampled plants. We did not find infested cycads in the highlands of Panama (> 700 m).

Fifteen years after its first identification at the urban gardens in Panama City, *A. yasumatsui* was already distributed throughout the country. Cycad species are not native in Panama (Taylor et al. 2012); hence, it is likely that *Aulacaspis yasumatsui* was introduced in imported infested plants that were sown in gardens. This mechanism of introduction surely continues to this day. However, our results indicate that this invasive species is naturally spreading in the country.

As in other countries (Howard et al. 1999; Segarra-Carmona and Perez-Dadilla 2008; González-Gómez et al. 2016), the impacts of the introduction of *A. yasumatsui* in urban landscapes have been devastating (Figure 1E). In addition to their use as ornamental plants, cycads are good CO₂ fixers, and their fruits are used as food by various animals. However, the death of these plants in Panama translates into economic losses ranging from tens to hundreds of dollars depending on the size of the plant (Sánchez-Soto and Chávez-García 2017).

Finally, the absence of infested plants in the high-altitude regions of Panama is consistent with the models proposed by Cave et al. (2009) and Wei et al. (2018), who established that temperature is the limiting factor for the distribution of this species. Panama is a tropical country, but in the highlands, it is estimated that the average temperature is 10 to 11 °C, and in the early mornings, the temperature can approach 0 °C (Autoridad Nacional Del Ambiente 2010).

Acknowledgements

To Universidad de Panama and Secretaria Nacional de Ciencia, Tecnología e Innovación (SENACYT) in Panama. To Alex Espinoza for assistance with field sampling. The authors thank to António Onofre Soares and the two anonymous referees who contributed to increasing the strength of this manuscript with their valuable suggestions.

Funding declaration

E. M. was funded by the Sistema Nacional de Investigación (SNI) of the National Secretariat of Science, Technology, and Innovation (SENACYT) in Panama, the University of Panama.

Authors' contribution

MC, JJ, EM planned and designed the research. MC, JJ, RC, AL, participated in the field survey, sorted and identified the material. EM wrote the manuscript. MC, JJ, RC, AL, revised the manuscript. All co-authors have read the submitted version of the manuscript and approved its submission. We confirm that all persons entitled to authorship have been included.

References

- Aiello A, Saltonstall K, Young V (2015) *Brachyplatys vahlii* (Fabricius, 1787), an introduced bug from Asia: first report in the Western Hemisphere (Hemiptera: Plataspidae: Brachyplatidinae). *BioInvasions Records* 5: 7–12, <https://doi.org/10.3391/bir.2016.5.1.02>
- Autoridad Nacional Del Ambiente (2010) Atlas Ambiental de la República de Panamá. Autoridad Nacional del Ambiente, Panamá, 187 pp
- Barraza E, Higuera M (2019) Erythrina Gall Wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae), reporte y distribución en Panamá. *Scientia* 29(1): 13–21

- CABI (2021) Invasive Species Compendium. www.cabi.org/isc (accessed 6 August 2021)
- Cave RD, Sciacchitano C, Diaz R (2009) Temperature-Dependent Development of the Cycad Aulacaspis Scale, *Aulacaspis yasumatsui* (Hemiptera: Diaspididae). *Florida Entomologist* 92: 578–581, <https://doi.org/10.1653/024.092.0407>
- Giorgi JA, Vandenberg NJ (2012) Review of the lady beetle genus *Phaenochilus* Weise (Coleoptera: Coccinellidae: Chilocorini) with description a new species from Thailand that preys on cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Hemiptera: Sternorrhyncha: Diaspididae). *Zootaxa* 3748: 239–255, <https://doi.org/10.11646/zootaxa.3478.1.24>
- González-Gómez R, Riverón-Giró FB, García-González A, Martínez-Rosas R, Solís-Montero L (2016) First report of *Aulacaspis yasumatsui* (Hemiptera: Diaspididae) in Mexico. *Florida Entomologist* 99: 583–584, <https://doi.org/10.1653/024.099.0346>
- Han SS, Karasev AV, Ieki H, Iwanami T (2002) Nucleotide sequence and taxonomy of Cycas necrotic stunt virus. *Archives of Virology* 147: 2207–2214, <https://doi.org/10.1007/s00705-002-0876-5>
- Hodges G, Howard FW, Buss EA (2003) Update On Management Methods for Cycad Aulacaspis Scale. Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL, 4 pp, <https://doi.org/10.32473/edis-in474-2003>
- Howard FW, Hamon A, McLaughlin M, Weissling T, Yang SL (1999) *Aulacaspis yasumatsui* (Hemiptera: Sternorrhyncha: Diaspididae), a scale insect pest of cycads recently introduced into Florida. *Florida Entomologist* 82: 14–27, <https://doi.org/10.2307/3495833>
- Luo H (2012) Using New Tools to Detect and Characterise Plant Viruses. Tesis Ph.D. Murdoch University, Australia
- Medianero E, Zachrisson B (2019) Erythrina gall wasp, *Quadrastichus erythrinae* Kim, 2004 (Hymenoptera: Eulophidae: Tetrastichinae): a new pest in Central America. *BioInvasions Records* 8: 452–456, <https://doi.org/10.3391/bir.2019.8.2.28>
- Normark BB, Normark RD, Vovides A, Solís-Montero L, González-Gómez R, Pulido-Silva MT, Escobar-Castellanos MA, Dominguez M, Perez-Farrera MA, Janda M, Cibrian-Jaramillo A (2017) Cycad aulacaspis scale (*Aulacaspis yasumatsui* Takagi, 1977) in Mexico and Guatemala: a threat to native cycads. *BioInvasions Records* 6: 187–193, <https://doi.org/10.3391/bir.2017.6.3.02>
- Rédei D (2016) The identity of the *Brachyplatys* species recently introduced to Panama, with a review of bionomics (Hemiptera: Heteroptera: Plataspidae). *Zootaxa* 4136: 141–154, <https://doi.org/10.11646/zootaxa.4136.1.6>
- Sánchez-Soto S (2020) Registro de daño de *Aulacoscelis melanocera* (Coleoptera: Orsodacnidae) sobre *Cycas revoluta* (Cycadaceae) en Campeche, México. *Revista Colombiana de Entomología* 46: e7111, <https://doi.org/10.25100/socolen.v46i2.7111>
- Sánchez-Soto S, Chávez-García E (2017) Presencia de la escama asiática de las cícadas, *Aulacaspis yasumatsui* (Hemiptera: Diaspididae), en el estado de Tabasco, México. *Revista Nicaragüense de Entomología* 127: 1–8
- Segarra-Carmona AE, Pérez-Padilla W (2008) The cycad scale, *Aulacaspis yasumatsui* Takagi (Homoptera: Diaspididae): A new invasive pest to Puerto Rico. *The Journal of Agriculture of the University of Puerto Rico* 92: 123–129, <https://doi.org/10.46429/jaupr.v92i1-2.2629>
- Stevenson D (2001) Cycadales. Flora de Colombia. Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, Colombia, 92 pp
- Takagi S (1977) A new species of *Aulacaspis* associated with a cycad in Thailand (Homoptera: Coccoidea). *Insecta Matsumurana New Series* 11: 63–72
- Taylor ASB, Haynes JL, Stevenson DW, Holzman G, Mendieta J (2012) Biogeographic insights in Central American cycad biology. In: Stevens L (ed), *Global Advances in Biogeography*. IntechOpen, Rijeka, Croatia, pp 73–98, <https://doi.org/10.5772/32253>
- Trencheva K, Trenchev G, Tomov R (2010) First Report of *Aulacaspis yasumatsui* Takagi, 1977 (Hemiptera: Diaspididae) in Bulgaria. *Plant Science* 47: 206–209
- Valverde MS (2015) Estudio de la etiología de la necrosis foliar (chasparría) en *Cycas revoluta* Thunb. y evaluación de estrategias para el manejo de la enfermedad. Thesis, Instituto Tecnológico de Costa Rica, Costa Rica, 175 pp
- Wei J, Zhao Q, Zhao W, Zhang H (2018) Predicting the potential distributions of the invasive cycad scale *Aulacaspis yasumatsui* (Hemiptera: Diaspididae) under different climate change scenarios and the implications for management. *PeerJ* 6: e4832, <https://doi.org/10.7717/peerj.4832>
- Weissling TJ, Howard FW, Hamon AB (2020) Cycad Aulacaspis Scale, *Aulacaspis yasumatsui* Takagi (Insecta: Homoptera: Sternorrhyncha: Diaspididae). Florida Coop. Ext. Service Publication document EENY096. University of Florida, Gainesville, FL, 4 pp

Supplementary material

The following supplementary material is available for this article:

Table S1. Sites in the Republic of Panama where *C. revoluta* were found to be infested with *A. yasumatsui*.

This material is available as part of online article from:

http://www.reabic.net/journals/bir/2021/Supplements/BIR_2021_Castillo-Gomez_et_al_SupplementaryMaterial.xlsx