19 Recent Adventive Scale Insects (Hemiptera: Coccoidea) and Whiteflies (Hemiptera: Aleyrodidae) in Florida and the Caribbean Region

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19.1 Introduction

The flora and fauna of Florida and the Caribbean region are in continual flux. Underlying this flux is the dynamic and complex international trade of plant material involving the USA, the countries of the Caribbean region, South America, Europe and Asia. Vast quantities of fruits and vegetables, and propagative and non-propagative plants, are distributed through ports in the Caribbean region and Florida, and inspection of this material results in a constant struggle against the threat of adventive species. Among the most prominent of potentially and actually adventive animal species are hemipterous insects in the family Aleyrodidae (the whiteflies) and numerous families in the superfamily Coccoidea, such as Diaspididae (armored scales), Pseudococcidae (mealybugs) and soft scales (Coccidae). Several factors conspire to make insects in these groups some of the most noxious of plant pests. First, they are typically quite small, and are therefore more likely to pass unnoticed through inspection sites. Second, many species are parthenogenic. Therefore, it is possible that a new infestation could be started from the introduction on plant material of a single juvenile female, or even a single egg mass. Third, all of these insects are plant parasites, and are therefore almost always in close association with their host plant; thus, they are likely to be introduced already attached to a suitable host. The ecological and economic impact of adventive scales and whiteflies is enhanced primarily by the fact that the natural complement of predators and parasitoids is often absent in the new environment, but also by the fact that, given an expanded diversity of novel potential host plant species, the insects become far more polyphagous than they are in their native environment.

Complicating still further attempts to control the flow of adventive scales and whiteflies is the fact that, in many cases, we have very little information about the species beyond the name, known host(s) and collection locale (which may or not be the original provenance). Also, it is not uncommon that undescribed species are discovered because they are adventive and have become, at least initially, prominent members of the plant–pest insect community.

This chapter will focus on recent invasions of scales and whiteflies as a result of international trade among Florida and the countries and territories that comprise the Caribbean region. The data presented in table format are derived primarily from the extensive database maintained by the Florida Department of Agriculture, Division of Plant Industry (FDACS-DPI), and ScaleNet, an

  Potential Invasive Pests of Agricultural Crops (ed. J. Peña)

online database that endeavours to maintain an exhaustive compendium of literature pertaining to scale insects.[1] ScaleNet offers numerous database search options that enable the user to 'data-mine' under various parameters, such as distribution, host and literature citation information. Other information presented is derived from the primary literature, especially Miller *et al.* (2005), which is an excellent synopsis of the adventive Coccoidea fauna of the USA.

The length of time under consideration, and therefore the list of relevant taxa, is somewhat arbitrary, since the number of adventive taxa in Florida and the Caribbean region has been growing inexorably since record-keeping began. Also, the list is biased toward a description of those taxa introduced into Florida. This is primarily due to the fact that FDACS-DPI has a long history of detailed record-keeping, but also to the intensive sampling and surveying that takes place within Florida. Thus, Florida overall has a better-known fauna than the islands in the Caribbean region. The taxa considered in this review are presented in Table 19.1.

To place these recent developments in perspective, of ~7400 described species of Coccoidea (Miller *et al.*, 2005), there are c. 1300 species of Coccoidea in the Neotropical (NT) region, and c. 320 species of this total are recorded from at least one territory in the Caribbean region (75 species of Pseudococcidae; 132 species of Diaspididae; 55 species of Coccidae; 54 species in assorted families). By comparison, ScaleNet retrieves ~1020 species of Coccoidea in the continental USA, of which ~340 species are recorded from Florida (67 species of Pseudococcidae; 165 species of Diaspididae, 45 species of Coccidae, 61 species in assorted families). A comparison of the respective lists of species indicates that while

Table 19.1. Taxa discussed in this chapter. The year of first report in Florida is given, and the known ranges as reported by ScaleNet and Evans (2008).

Family	Scientific Name	First Recorded in Florida	Range
Pseudococcidae	*Nipaecoccus viridis* (Newstead)		
	Pseudococcus dendrobiorum Williams	2009	AF, AU, OR, PA
	Palmicultor lumpurensis (Takahashi)	2009	AU, OR, PA
	Palmicultor palmarum (Ehrhorn)	2003	AU, NE, OR, PA
	Chaetococcus bambusae (Maskell)	1999	AU, NE, NT, OR, PA
	Paracoccus marginatus Williams	1998	AF, AU, NA, NT, OR, PA
	and Granara de Willink	1998	AU, AF, NE, NT
	Maconellicoccus hirsutus (Green)		
	Planococcus minor (Maskell)	2002	AF, AU, OR, PA, NT, NA
		2010	AF, AU, OR, NA, NT
Kerriidae	*Paratachardina pseudolobata* Kondo and Gullan	1999	NA
	Tarchardiella mexicana (Comstock)	1985	NA
Coccidae	*Pulvinaria psidii* Maskell	1985	AU, AF, NA, NT, OR, PA
	Protopulvinaria longivalvata Green	NR, intercepted	AF, AU, NT, OR
	Phalacrococcus howertoni Hodges		
	& Hodgson	2008	NA, NT
Diaspididae	*Poliaspis cycadis* Comstock	2007	NA, OR, PA
	Unachionaspis tenuis (Maskell)	2007	OR, PA
	Aulacaspis yasumatsui Takagi	1996	AU, NA, NT, OR, PA
	Aulacaspis tubercularis Newstead	2002	AF, AU, OR, PA, NT, NA
	Duplachionaspis divergens (Green)	2000	AU, OR, PA, NA, NT
Monophlebidae	*Crypticerya genistae* (Hempel)	2006	NT, NA
Aleyrodidae:			
Aleurodicinae	*Aleurodicus dugesii* Cockerell	1996	NT, AU, OR
	Aleurodicus rugioperculatus Martin	2009	NT, NA
Aleyrodidae:			
Aleyrodinae	*Siphoninus phillyreae* (Haliday)	2010	NA, NT, AU, AF
	Dialeurodes schefflerae Hodges and Dooley	1986	NA, NT, AU, OR

OR, Oriental; PA, Palearctic; AU, Australasian; NT, Neotropical; AF, Afrotropical; NR, not recorded in Florida.

there is substantial similarity, there are nonetheless significant differences. It is these differences that are of concern, because they are the primary source of species that are available for transport between Florida and the Caribbean region. Given the diversity in numerous characteristics of the territories and countries that comprise the countries and territories in the Caribbean region, it is not surprising that species distribution across the Caribbean region is uneven; some countries are relatively well sampled and support a large number of species, while others, for various reasons, are less well sampled or support a lower diversity. Even many common and polyphagous species are unrecorded from many Caribbean region countries. For instance, the seriously pestiferous mealybug *Maconellicoccus hirsutus* (Green) (Pink hibiscus mealybug), is officially recorded from only ten of the 27 territories in the Caribbean region; *Coccus viridis* (Green) (green scale) from 11 territories; *Ceroplastes floridensis* Comstock (Florida wax scale) from 13 territories; *Coccus hesperidum* L. (brown soft scale) from 12 territories; *Pinnaspis strachani* (Cooley) (lesser snow scale) from 15 territories.

Compilation of detailed distribution and species-richness data for Aleyrodidae is complicated by the lack of a whitefly database similar to ScaleNet; however, Evans (2008) enumerated species richness for the biogeographic regions of the world, so rough numbers are available. The distributional and host data given for the species discussed in this review are derived from that source.

Worldwide, there are 1560 species of whitefly in 161 genera (Martin and Mound, 2007). In the NT region, there are 15 genera with c. 120 species in the subfamily Aleurodicinae, and 42 genera with c. 210 species in the subfamily Aleyrodinae. The FDACS-DPI database contains 72 species recorded from Florida, but, as with the scales, this number increases almost yearly. No data are readily available for the number of whitefly species in the Caribbean region, but as the number of monographic systematic works increases, and our knowledge of the distribution of species improves (Martin, 2008), compiling those data will become easier. For instance, Martin (2008) lists 14 species from the Caribbean region in the mainly NT genus *Aleurodicus* (Aleurodicinae), and there are three from Florida, including *A. dispersus* Russell and the recently introduced and established species *A. dugesii* and *A. rugioperculatus*; however, although many of the Caribbean records pertain to Trinidad, whose fauna has a distinctly South American character (Peck *et al.*, 2002), there are almost certainly more species of *Aleurodicus* more widely distributed in the Caribbean region, but that are as yet officially unrecorded.

Several species will be excluded from consideration in this chapter because they will be discussed elsewhere in this book: *Planococcus minor* (Maskell) (Pseudococcidae), *Praelongorthezia praelonga* (Douglas) (Ortheziidae) and *Singhiella simplex* (Singh) (Aleyrodidae).

19.2 Mealybugs: Pseudococcidae

Some of the most seriously noxious Coccoidea are mealybugs, attacking not just plants grown and sold for decoration and aesthetic purposes, but numerous fruit and vegetable crops. In Florida, a large proportion of the known species are adventive. Two particularly pestiferous species have been introduced in recent years, the papaya mealybug (*Paracoccus marginatus*) and the pink hibiscus mealybug (*Maconellicoccus hirsutus*), but each appears to be under significant natural control by parasitoid wasps and predatory lady beetles. Given the very recent arrival in Florida of two additional species of mealybugs, the lebbeck mealybug (*Nipaecoccus viridis*) and the passionvine mealybug (*Planococcus minor*), it is too early to know what effect these two well-known pest species will have on Florida agriculture and horticulture.

19.2.1 *Nipaecoccus viridis* (Newstead)

Common names: lebbeck mealybug, spherical mealybug, karoo thorn mealybug. Distribution: Australasian (AU), Afrotropical (AF), Oriental (OR), Palearctic (PA), Nearctic (NE) (USA: Florida). ScaleNet reports that it is present in Mexico and the Bahamas, but these records are apparently based on misidentifications (Meyerdirk *et al.*, 1988; Dr G. Evans and Dr D. Miller, pers. comm.).

Five other species of *Nipaecoccus* occur throughout the Caribbean region: *N. annonae*

Willams and Granara de Willink (Guadeloupe and Martinique), *N. filamentosus* (Cockerell) (Turks and Caicos, Puerto Rico, Haiti), *N. neogaeus* Willams and Granara de Willink (Trinidad) and *N. pitkini* Willams and Granara de Willink (Trinidad and Tobago). *Nipaecoccus floridensis* Beardsley, which is possibly native to Florida, appears to be restricted to Florida. Only the potentially pestiferous species *N. nipae* (Maskell) is widespread in the Caribbean region, occurring on 17 islands. In general, specimens of *Nipaecoccus* require slide mounting for positive identification, but there are some recognizable differences between species in the colour and shape of the wax produced.

Lebbeck mealybug was first recorded in Florida in late 2009 from Palm Beach County attacking dodder (*Cuscuta exaltata* Engelm; Cuscutaceae) growing in a natural area, and its discovery prompted the release of a pest alert (Stocks and Hodges, 2010). A ground survey to determine the extent of the infestation was initiated, which revealed that it had become widespread in the natural area, feeding on a variety of host plants, and was possibly responsible for the demise of the dodder (K. Griffiths and A. Derksen, pers. comm.); however, it was of only limited distribution in the surrounding suburban areas, where it was found to be feeding most frequently on *Citrus* sp. and *Gardenia jasminoides* Ellis (Rubiaceae). As of February 2011, the host list had grown to 14 plant species, with *Citrus* spp., *G. jasminoides* and dodder seeming to be preferred hosts (FDACS-DPI database). In citrus-growing areas of Jordan, where lebbeck mealybug had been a pest prior to the introduction of biological controls, it caused such extensive damage that orchards were burned in an effort to eradicate it. Through their feeding, developing fruits are aborted and drop prematurely, and toxins in the saliva kill the terminal branch tip near feeding sites, causing die-back (Meyerdirk *et al.*, 1988).

Almost contemporaneous with the discovery of the mealybug in Florida was the discovery of predators and parasitoids associated with *N. viridis* populations. Adult flies reared from masses of mealybug ovisacs were identified as *Leucopis* sp. (Chamaemyiidae), known predators of mealybugs. Also reared from sequestered infested plant material was the parasitoid wasp *Pachyneuron eros* Girault (Pteromalidae). Curiously, it is not clear whether these wasps are parasitoids of the mealybugs, the predatory flies or perhaps both, as both mealybugs and flies are listed as known hosts of *Pachyneuron* wasps. If they are parasitoids of the mealybugs, they would join the other wasp fauna that might exert some measure of biological control, such as *Anagyrus kamali* Moursi (Encyrtidae). After it was reared and released for the control of pink hibiscus mealybug (PHM), *A. kamali* can now be found in both Florida and the Caribbean region (Hoy *et al.*, 2006; Division of Plant Industry, 2004). Overall, some 65 species of Hymenoptera primary parasitoids have been recorded from *N. viridis* (Noyes, 2003), with *A. indicus* (Subba Rao) having an exceptional record of control in Guam and Jordan (Meyerdirk *et al.*, 1988).

19.2.2 *Pseudococcus dendrobiorum* Williams

Common name: dendrobium mealybug. Distribution: AU, OR, PA, NE (USA: Florida, Hawai'i).

This species was reported from Florida in 2009 from a population of *Phalaenopsis* orchids maintained in a greenhouse on the University of Florida campus. Although it prompted the publication of a pest alert (Hodges and Buss, 2009), it has not been collected since, and the population may have been eradicated. Other than distribution information and host data, nothing has been published on the biology, ecology or economic impact of this species. Hosts are exclusively Orchidaceae, including the genera *Ascoglossum, Cymbidium, Dendrobium, Phalaenopsis, Pholidota* and *Promatocalpum*. Records from USDA-ARS report 16 interceptions in the past 25 years, all but one from orchid shipments, and all originating from Asia (15 interceptions) and Australia (one interception).

19.2.3 *Palmicultor browni* (Williams)

No common name. Distribution: AU, NE (USA: Florida)

Nothing was known about the biology or ecology of this host prior to its discovery in Florida in 2002, and very little has been learned since. In the literature, it is recorded from coconut, oil palm (*Elaeis guineensis* Jacq.), *Howea forsteriana*

(F. Muell. ex H. Wendl.) Becc. and *Veitchia* spp. In Florida, it has a broad palm-host range, with coconut (*Cocos nucifera* L.), *Phoenix roebelenii* O'Brien and *Adonidia merrillii* (Becc.) Becc. (Arecaceae) accounting for 60% of records. The majority of records (58%) are from Miami-Dade County, but it is also recorded from Broward, Collier, Monroe and Orange counties. Heavy infestations of this species may cause dieback (Dr G. Hodges, pers. comm.)

19.2.4 *Palmicultor palmarum* (Ehrhorn)

Common name: Ehrhorn's palm mealybug. Distribution: AU, PA, OR, NT (Bahamas, Bermuda, Guadeloupe, Jamaica, St Barthélémy, St Martin, St Croix), NE (Mexico, USA: Florida).

This pest was described from Hawai'i from specimens feeding on palms. Ali (1987), citing Beardsley (1966), speculated that it may be indigenous to the Pacific region, and Williams and Martin (2003) speculated that the natural hosts are Arecaceae and possibly Pandanaceae (*Freycinetia* sp.). ScaleNet also records Fabaceae (*Kentia* sp.) and Poaceae (*Phyllostachys* sp.) as additional hosts, but these are such aberrant records that they could be erroneous. Very little is known about the biology or ecology of this species, but it does not seem to be a large threat to palms in general. It was first recorded in the New World in Nassau, Bahamas, in 1980 (Williams, 1981), and has been recorded from Florida 26 times since its first collection in 1999. In Florida, it has been recorded from the following counties: Broward, Flagler, Miami-Dade, Monroe, Palm Beach, Polk and Sarasota, although most frequently from Miami-Dade. Collection records indicate that numerous species of palms are suitable hosts, but *Phoenix roebelenii* O'Brien and coconut are preferred.

19.2.5 *Palmicultor lumpurensis* (Takahashi) (=*Trionymus lumpurensis*)

No common name. Distribution: AU, OR, PA, NE (USA: Florida).

This mealybug is presumably endemic to the Old World, possibly China or Malaysia. Hosts are exclusively Poaceae, especially *Bambusa* spp. Very little has been published about this species, so presumably it is not of economic concern in its native range, nor are there reports of its status in Australia, where it has also been recorded. In Florida, it has been collected 65 times, primarily from *Bambusa* spp., but also *Arundinaria* sp., *Dendrocalamus hamiltonii* Nees and Arn. ex Munro, *Gigantochloa atroviolacea* Widjaja, *Guadua angustifolia* Kunth and *Phyllostachys nigra* (Lodd. ex Lindl.) Munro. It appears to have been introduced into Florida via the international trade in exotic bamboo, in particular into the landscaping of an amusement park (Hodges, 2004a; Hodges and Hodges, 2004). It is now widely distributed across Florida, but does not appear to be having a large negative impact.

19.2.6 *Chaetococcus bambusae* (Maskell)

Common name: giant bamboo scale. Distribution: AF, AU, OR, PA, NE (USA: Florida), NT (Bermuda, Guadeloupe, Jamaica, Puerto Rico, Trinidad, US Virgin Islands).

Giant bamboo mealybug was first introduced into Florida in 1956, but was thought to have been eradicated (Hodges and Hodges, 2004). It was subsequently re-collected in Miami-Dade County 1998, and has been infrequently and sporadically collected around the state. Hosts are exclusively species of grasses, primarily bamboo, including *Bambusa* spp., *Phyllostachys* sp., *Dendrocalamus latiflorus* Munro and *D. asper* Backer ex K. Heyne (FDACS-DPI database), and *Gigantochloa* spp., *Lingnania chungii* (McClure) McClure, *Miscanthus* sp. and *Schizostachyum* sp. (ScaleNet). Hodges and Hodges (2004) reported that since the species was not causing economic damage, the initial infestation in 1998 was not discovered until older leaf sheaths were peeled back from the bamboo for cosmetic reasons.

19.2.7 *Paracoccus marginatus* Williams and Granara de Willink

Common name: papaya mealybug, la cochenille du papayer. Distribution: AU, AF; NE (Mexico, Florida); NT (Antigua, Cuba, Dominican Republic, Guadeloupe, Haiti, St Kitts, Martinique, Puerto Rico, St Martin and St Barthélémy, British Virgin Islands, US Virgin Islands).

Papaya mealybug is an excellent example of an insect species moving from the relative obscurity of the newly described, to an increasingly wide distribution as a pest species as it moves globally through international trade, and back to a status as pest of negligible importance. As such, it is a testament to the power of classical biological control. Papaya mealybug is thought to be a native of Mexico or Central America (Walker *et al.*, 2006), and was described relatively recently (Williams and Granara de Willink, 1992; Miller *et al.*, 1999; Miller and Miller, 2002); however, it moved rapidly through the Caribbean region, and by 2006 was present in at least 12 Caribbean islands. It was first recorded in Florida in 1998 and spread rapidly throughout the state. ScaleNet records papaya mealybug from 45 species in 20 families, but in Florida, hibiscus accounts for 67% of host records, with *Jatropha integerrima* Jacq. and *Acalypha wilkesiana* Muell. Arg. (Euphorbiaceae), and *Carica papaya* L. (Caricaceae) also common hosts. Twenty-five percent of records are from Mimi-Dade County.

The wide host range, attraction to certain hosts (such as hibiscus and papaya) and rapid worldwide spread made papaya mealybug an ideal candidate for classical biological control. Thus, parasitoids collected from mealybug populations in Mexico were artificially reared as part of various USDA programs (Meyerdirk *et al.*, 2004; Muniappan *et al.*, 2006; Amarasekare *et al.*, 2009). The parasitoids *Acerophagus papayae* Noyes and Schauff, *Anagyrus loecki* Moyes and *Pseudoleptomastix mexicana* Noyes and Schauff (Encyrtidae) were released almost contemporaneously in Florida (2003), Guam (2002) and Palau (2003–2004) from cultures maintained in Puerto Rico. Amarasekare *et al.* (2009) reported that, of the three parasitoid species reared and released in Florida, only *A. papayae* and *A. loecki* were recovered from experimental plots, with *A. papayae* accounting for the highest mealybug mortality. Papaya mealybug population reduction in Florida, as measured by the number of samples submitted to FDACS-DPI, has been dramatic, with a decline from a peak in 2004 of 230 samples, to 28 samples in 2010. In quantitative studies of field effectiveness of parasitoid controls, a reduction in mealybugs of as much as 97% has been observed (cited in Meyerdirk *et al.*, 2004).

19.2.8 *Maconellicoccus hirsutus* (Green)

Common names: pink hibiscus mealybug, grape mealybug, La cochenille de l'Hibiscus, la cochinilla rosada del hibisco. Distribution: AU, AF, OR, PA, NE (USA: California, Florida, Louisiana, Texas), NT (Cuba, Guadeloupe, Grenada, Haiti, St Kitts and Nevis, Martinique, Puerto Rico, St Barthélémy and St Martin, Trinidad and Tobago).

Pink hibiscus mealybug (PHM) is one of the most recognizable names in the pantheon of pest insect species, familiar throughout much of the tropical to sub-tropical world to agricultural workers and the ornamental growing public alike. This pest of worldwide distribution was first recorded from Florida in 2002 (Hodges, 2002), and its invasion into Florida from the Caribbean region, where it had been moving from island to island since the mid-1990s, proved to be inevitable despite robust quarantine measures. PHM is one of the most polyphagous species of all known Coccoidea, having been recorded from over 340 plant species in 75 families, with Euphorbiaceae, Fagaceae and Malvaceae appearing to be the most preferred of host families (ScaleNet). In Florida, it has been recorded from 175 host species, but by far the majority of records (90%) are from *Hibiscus rosa-sinensis*. Other common hosts are *Viburnum odoratissimum* Ker-Gawl (Caprifoliaceae), *Trema micrantha* (L.) Blume (Ulmaceae), *Talipariti tiliaceum* (L.) Fryxell (Malvaceae), *Senna polyphylla* (Jacq.) Irwin and Barneby (Fabaceae) and *Calophyllum* spp. (Clusiaceae). Of c. 3600 Florida records since 2002, 25% are from Miami-Dade County and 15% from Broward County.

In Florida, although PHM is particularly destructive to hibiscus, various cultivars differ in their degree of susceptibility and degree of damage incurred through feeding (Vitullo *et al.*, 2009). With hibiscus, PHM feeding typically induces abnormalities in the length of the internode, resulting in a gall-like condition known as 'bunchy-top' or 'rosetting', which negatively affects the aesthetic value of the plant (Meyerdirk *et al.*, 2001). Prolonged feeding results in defoliation and eventually death of the plant.

In anticipation of its eventual arrival into the NT region, the USDA, in conjunction with state and university cooperators, and the agricultural agencies of several countries in the Caribbean

region, initiated biocontrol programs to help reduce the economic impact of PHM on horticulture and agriculture in the Caribbean region and Florida. Economic losses in the Caribbean region following introduction were significant, with Grenada reporting losses of US$3.5–10 million over the 1996–1997 season, and Trinidad and Tobago anticipated losses in excess of US$100 million per annum (Meyerdirk *et al*., 2001). PHM was found in Louisiana in 2006 (Hodges *et al*., 2007), Texas in 2007 (Anonymous, 2011a) and Georgia in 2008 (Anonymous, 2011b), each infestation presumably the result of shipments of infested nursery stock from Florida, even though FDACS-DPI quarantines shipments of stock positive for PHM.

Of the 30 species of parasitoid wasps listed by the Universal Chalcidoid Database as documented primary host for PHM, the two encyrtid species *Anagyrus kamali* Moursi and *Gyranusoidea indica* Shafee, Alam and Agarwal were deemed most suitable for importation, rearing and release. Each parasitoid has a preferred host stage for the deposition of the egg and development of the larva, with *Anagyrus kamali* females preferring 3rd-instar PHM larvae, and *G. indica* females preferring late 2nd-instar larvae (Sagarra and Vincent, 1999; Ahmed *et al*., 2007; Roltsch, 2007). Additionally, two coccinellid predators (*Cryptolaemus montrouzieri* Mulsant and *Scymnus coccivora* Ayyar) were released, but only *C. montrouzieri*, the mealybug destroyer, appears to be effective in Florida. Through these biocontrol efforts, the reduction in PHM pest load has been dramatic, with countries in the Caribbean region experiencing persistent reductions of 90–95% (Osborne *et al*., 2011). In Florida, PHM is a quarantinable pest, which helps reduce the overall pest load in the environment. However, it remains a common landscaping pest.

19.2.9 *Planococcus lilacicus* (Cockerell)

Common names: coffee mealybug, oriental cacao mealybug. Distribution: AF, AU, OR, PA, NT (Dominican Republic, Haiti).

ScaleNet lists 89 recorded host plants in 36 families, but this mealybug is most widely known in the NT region as a pest of coffee (*Coffea arabica* L.; Rubiaceae) and cacao (*Theobroma cacao* L.; Sterculiaceae). However, Fernando and Kanagaratnam (1987) reported that in Sri Lanka, *P. lilacinus* was found feeding on the peduncle and stalk of the inflorescence of coconut, causing it to dry up, and Waite and Martinez Barrera (2002) reported that it was a minor pest of avocado (*Persea americana* Mill; Lauraceae) in the Philippines, where it occasionally caused early fruit drop. In a study to determine which biocontrol agents would be most suitable for control of *P. lilacinus* in various crop systems in India, Mani (1995) found that several predators and parasitoids from Java and the Philippines were associated with the mealybug, and were possibly suitable for release in India. The species *Tetracnemoidea indica* Ayyar and *Leptomastix dactylopii* Howard (Encyrtidae) and *Aprostocetus purpureus* Cameron (Eulophidae), and the predators *Spalgis epius* (Westwood) (Lycaenidae), *Brumus* sp., *S. coccivora* and *Cryptolaemus montrouzieri* Mulsant (Coccinellidae), *Triommata coccidivora* (Felt) (Cecidomyiidae), and *Cacoxenus perspicax* (Knab.) (Drosophilidae) were recovered from infested crops, but *T. indica, A. purpureus* and *S. epius* appeared to be the most efficient at reducing mealybug populations, with *L. dactylopii* having little effect. In a separate study, Mani and Krishnamoorthy (1990a) found that *C. montrouzieri* eliminated *P. lilacinus* populations on pomegranate (*Punica granatum* L.; Lythraceae) fruits in India. In the laboratory, Mani and Krishnamoorthy (1990b) found that the predatory larvae of the lacewing *Mallada desjardinsi* (Navás) (=*Malladaboninensis* (Okamato)) (Chrysopidae) was also effective against passionvine mealybugs.

19.3 Soft Scales: Coccidae

Numerous pestiferous soft-scale species are found in Florida and the Caribbean region, including the recently described croton scale, *Phalacrococcus howertoni* Hodges and Hodgson, and there are fears that several other pest species could be introduced. The soft wax scale, *Ceroplastes destructor* Newstead, is a major pest of *Citrus* in parts of its introduced range, but thus far is not known from the New World. *Vinsonia stellifera* (Westwood) (=*Ceroplastes stellifera*), believed in 1954 to have been eradicated from

Florida (Hodges, 2004b), is being collected more frequently, predominantly in Miami-Dade County, and occurring most commonly on *Schefflera* spp. and *Ixora* sp. Also, in 2007, it was newly reported from New Providence, Bahamas, on *Melaleuca quinquenervia* (Cav.) S.F. Blake (Myrtaceae), a previously unreported host (Blackwood and Pratt, 2007).

19.3.1 *Protopulvinaria longivalvata* Green

No common name. Distribution: AF, AU, OR, NT (South America, Guadeloupe, Haiti, Martinique, Puerto Rico, US Virgin Islands), NE (USA: Florida, interceptions only).

This presumably Old World species began appearing in the Caribbean region in the 1950s (Guadeloupe). It is frequently intercepted by the United States Department of Agriculture, with 200 quarantine interceptions from 1985 to 2010 from shipments or passengers originating in South and Central America and the Caribbean region, including Antigua and Barbuda, Dominica, Jamaica, St Vincent and the Grenadines, and Trinidad and Tobago. The most frequent interceptions are from the Dominican Republic (23%), Puerto Rico (18%) and Jamaica (12%) (USDA-ARS database). This scale has been intercepted in quarantine in Florida by FDACS-DPI inspectors seven times in the past 2 years, all from *Schefflera arboricola* (Hayata) Merr. (Araliaceae) plants originating in Costa Rica. ScaleNet lists 21 host plant species in 12 families, including *Mangifera indica* L. (Anacardiaceae), *Psidium guajava* L. (Myrtaceae), *Gardenia* spp. and *Citrus* spp. The most frequent host interceptions by the USDA were on *Citrus* spp. (29%), *Schefflera* sp. (15%) and *M. indica* (12%). *Protopulvinaria longivalvata* is very similar to *P. pyriformis* Cockerell (pyriform scale), and needs to be slide mounted for accurate identification. There is relatively little information on *P. longivalvata*, but thus far it does not appear to be as pestiferous as pyriform scale, which has a host list of 68 species in 34 families (but does not include *S. arboricola* as a known host). No data are available regarding natural enemies, but observations on submitted samples with parasitoid emergence holes indicate that there may be at least one species of parasitoid wasp attacking it (Anonymous, 2009).

19.3.2 *Pulvinaria psidii* Maskell (=*Chloropulvinaria psidii* Borchsenius)

Common names: green shield scale, guava mealy scale, guava scale. Distribution: AF, AU, NE (USA: Alabama, DC, Florida, Georgia, Missouri, Mississippi, New York, Pennsylvania); NT (South America, Central America, Antigua, Bahamas, Bermuda, Cuba, Dominican Republic, Guadeloupe, Haiti, Jamaica, St Kitts, Montserrat, Martinique, Puerto Rico, Trinidad and Tobago, St Vincent and the Grenadines, US Virgin Islands).

Green shield scale was first recorded in Florida in 1985 (FDACS-DPI database), but it has been moving slowly through the Caribbean islands since the late 1890s (Jamaica 1895, Cuba 1926, Guadeloupe 1957), being present in 17 Caribbean countries by 1993 (ScaleNet, 2011). ScaleNet lists 207 host species in 62 families, with Moraceae, Myrtaceae, Rubiaceae and Rutaceae the most commonly reported families. The FDACS-DPI database lists 118 host species, with a distinct preference for *Schinus terebinthifolius* Raddi (Anacardiaceae), *Ficus* spp. (Moraceae), *Ixora* sp. and *Gardenia* spp. (Rubiaceae), and agreeing in general with that reported by ScaleNet. Nada *et al.* (1990) reported that *P. psidii* (as *Cribropulvinaria psidii*) was one of the three most important pests of mango in Egypt. El-Minshawy and Moursi (1976) reported that *P. psidii* was also a serious pest of guava in Egypt, but was also found throughout the year attacking *S. terebinthifolius, Meyerta sinclairii* Seem. (Araliaceae) and *Jasminum humile* L. (Oleaceae). In Bangalore, India, Puttarudriah and ChannaBasavanna (1957) reported that *P. psidii* was attacked by *Cryptolaemus montrouzieri*, Mulsant (Coleoptera: Coccinellidae) (mealybug destroyer). In Bermuda, *Microterys kotinskyi* (Fullaway) and *Coccophagus* (=*Aniseristus*) *ceroplastae* (Howard) were released as biocontrol agents, but *M. kotinskyi* was primarily responsible for control (Bennett *et al.*, 1976). The predators *C. montrouzieri* and *Azya luteipes* (Mulsant) (Coccinellidae) were also released and became established. In combination with the parasitoid wasps, green shield scale was reduced to noneconomic levels in Bermuda. Similarly, in South Africa, Annecke and Moran (1982) found that coccinellid predators were common and that populations of green shield scale were parasitized so heavily that the scale is no longer of economic importance (cited in de Villiers, 2001).

19.3.3 *Phalacrococcus howertoni* Hodges and Hodgson

Common name: croton scale. Distribution: NE (USA: Florida); US Virgin Islands (St Thomas, St Croix; FDACS-DPI database); Figs 19.1 and 19.2.

Croton scale was first detected in Florida in 2008 and soon thereafter was determined to be an undescribed species (Hodges, 2008). The description followed in 2010, by which time croton scale was recorded from 72 host plant species in 34 families. As of February 2011, the host list had grown to 90 species in 36 families, with 60% of the host records from *Codiaeum variegatum* (L.) A. Juss. (Euphorbiaceae; croton).

Fig. 19.1 Croton scale *Phalacrococcus howertoni* Hodges and Hodgson (Coccidae) adult female on croton (*Codiaeum variegatum*). Photograph, Ian Stocks.

Fig. 19.2 Croton scale immature male puparia (left), adult male under puparium (center), immature female (right). Photograph, Ian Stocks.

Bursera simaruba L. (Burseraceae; gumbo-limbo) is the next most common host, with 7% of records, but *Ficus* spp. (Moraceae) and *P. guajava* L. are also common hosts. Thus far, naturally occurring infestations are limited to the southern-most regions of Florida, with 56% and 10% of records from Miami-Dade County and Broward County, respectively; however, due to the transport of infested nursery stock, FDACS-DPI has records of croton scale from 27 counties.

At this time, relatively little is known regarding the biology of this pest species, but some life history details have been discovered (Hodges and Hodgson, 2010; C. Mannion and S. Brown, unpublished data). In primary areas of infestation in south Florida, year-round warm weather allows for overlapping generations throughout the year, with females taking roughly 30 days to complete development. Female fecundity is high, with egg production of up to 400 eggs per female. Natural predators have been associated with croton scale infestations, including *C. montrouzieri* Mulsant, *Azya orbigera* Mulsant (Coccinellidae) (H. Liere, pers. comm.) and *Laetilia coccidivora* Comstock (as *Laelilla* in Hodges and Hodgson, 2010). The commercially available parasitoid wasp *Metaphycus flavus* (Howard) (Hymenoptera: Encyrtidae) has also been collected in the field, but is apparently at such low levels that it has little effect on population size.

Infestations can build rapidly and can cover almost all above-ground parts of the plant (especially croton). Females prefer the stems and petioles, while males prefer the adaxial leaf surface (personal observation). A heavily infested croton becomes highly stressed through loss of nutrients and the production of honeydew, and can eventually succumb. At Sanibel Island (Lee County, Florida), conservation staff have observed this scale on both native and non-native plants in a wildlife refuge. They report that gumbo limbo and strangler fig (*Ficus aurea* Nutt.) are showing signs of stress, with branch and twig die-back attributed to heavy scale infestations (J. Evans and S. Brown, pers. comm.). They report that, in addition to gumbo-limbo and strangler fig, firebush (*Hamelia patens* Jacq.), wild coffee (*Psychotria nervosa* Sw.), and Bahama wild coffee (*P. ligustrifolia* (Northrop) Millsp.) (Rubiaceae), paradisetree (*Simarouba glauca* DC; Simaroubiaceae), and marlberry (*Ardisia escallonoides* Schiede and Deppe ex Schltdl. and Cham.)

and myrsine (*Myrsine cubana* DC) (Myrsinaceae) are also heavily affected. However, horticultural experience with this scale is still so limited that it is too early to tell what effect it will have on the natural landscape in the long term.

19.4 Lac Scales: Kerriidae

Two lac scales are known from Florida, both of which are adventive, and either or both of which could easily become established widely in the Caribbean region. *Paratachardina pseudolobata* Kondo and Gullan is seriously pestiferous, whereas the pest status of *Tachardiella mexicana* (Comstock) is still under investigation. Although an additional 17 species of Kerriidae are found in the NT region, only *Austrotachardiella gemmifera* (Cockerell) (=*Tachardia gemmifera*), which is endemic to Jamaica on *Chrysobalanus* spp. (Chrysobalanaceae), and *P. pseudolobata*, which is adventive, are currently found in the Caribbean region (ScaleNet, 2011). Other than the report by Cockerell (cited in ScaleNet, 2011) that *A. gemmifera* was destroying *Chrysobalanus* spp. trees in Kingston, no life-history data are published for this species.

19.4.1 *Paratachardina pseudolobata* Kondo and Gullan

Common name: lobate lac scale, escama lobada de laca. Distribution: AU, NE (USA: Florida), NT (Bahamas: Andros, Grand Bahamas, New Providence).

Confusion as to the identity of this scale was finally clarified by Kondo and Gullan (2007) in their revision of the genus *Paratachardina*. The lac insect christened lobate lac scale was originally identified as *P. l. lobata* (Chamberlin), but was found by Kondo and Gullan (2007) upon a more detailed analysis to be a distinct and undescribed species. Thus, the literature on the lobate lac scale is confused, with some publications referring to what is actually *P. l. lobata*, and others referring to the new species *P. pseudolobata*; this should be borne in mind when consulting the literature. For instance, it was originally claimed that the lobate lac scale (as *P. l. lobata*) was native to India and Sri Lanka (Howard and Pemberton, 2003). In fact, lobate lac scale (as *P. pseudolobata*) has an unknown provenance, which hinders the task of finding parasitoids for biocontrol considerably.

Lobate lac scale was first discovered in Florida in 1999, but subsequent examination of slides in the Florida State Collection of Arthropods (FSCA) revealed that the scale has been in several Bahamian islands since at least 1992. In Florida, by 2004 the scale had spread to six counties and was by that time considered to be a serious pest (Anonymous, 2004; Mannion *et al.*, 2005), prompting the publication of several factsheets (Hamon and Hodges, 2004; Mannion *et al.*, 2005; Howard *et al.*, 2009). The host list for this species is extensive, with up to 307 plant species enumerated in a report by Howard *et al.* (2006). While many plants from the list of known host plants are variable in their suitability as hosts or susceptibility once infested, there are a number of species that are clearly preferred hosts. Howard and Pemberton (2003) list wax myrtle (*Morella cerifera* (L.) Small = *Myrica cerifera*; Myricaceae), *Chrysobalanus icaco* L. (Chrysobalanaceae), *Conocarpus erectus* L. (Combretaceae), *Myrsine guianensis* (Aublet) Kuntze, *Psychotria* spp., *Annona* spp. (Annonaceae), *Averrhoa carambola* L. (Oxalidaceae), *Litchi chinensis* Sonn. (Sapindaceae), *Ficus* spp., *H. rosa-sinensis* and *M. indica* as preferred hosts. Wax myrtle is so susceptible that several plants in one survey plot in south Florida died within 1 year after becoming heavily infested (Howard *et al.*, 2006), and another experimental host had to be found because the wax myrtles died soon after experimental infestation.

Controlling this pest scale has proved challenging. The hard resinous test is extremely effective at preventing topically applied insecticides from reaching the scale. Soil drenches of imidacloprid were effective at suppressing scale populations (Howard and Pemberton, 2003), but long-term suppression will require finding, rearing and releasing parasitoid biocontrol agents. Initial reports of effective biocontrol agents are now known to refer to *P. lobata lobata*, and are therefore unsuitable candidates; however, field populations of lobate lac scale monitored in south Florida yielded *Metaphycus* sp. and *Ammonoencyrtus* sp. (Encyrtidae), but the numbers of these parasitoids relative to the number of potential hosts was very low (Howard and Pemberton, 2003).

19.4.2 *Tachardiella mexicana* (Comstock) (also including *T. texana* as a junior synonym)

No common name. Distribution: NE (Mexico, USA: Texas, Florida).

Native to the south-west of the USA and to Mexico, this lac scale was first discovered in Florida in 1985 infesting *Acacia* sp. at an amusement park in Orange County, and a second disjunct population was discovered at a nursery in Seminole County in 1987 infesting Texas ebony (*Ebenopsis ebano* (Berl.) Barneby and Grimes = *Pithecellobium flexicaule*). Since then, this scale has been found in other locations and on other hosts, including *Lysiloma latisiliquum* L. (Benth.), *L. sabicu* Benth., *Acacia pinetorum* F.J. Herm. and *A. cornigera* (L.) Willd. Overall, this lac scale shows a marked preference for Fabaceae, including *Mimosa* sp. in its native range. Thus, it is disconcerting that another population of this scale was discovered in 2010 infesting wax myrtle at the same amusement park.

Nothing is known about the biology of this scale in its native environment. In Florida, it can have profound consequences for the tree or shrub, leading to defoliation and death of the plant (S. Brown, unpublished data). In Lee County, massive populations killed several wild tamarind (*L. latisiliquum*) trees, and numerous small wax myrtleshrubs were dead or dying in Orange County (pers. obs.). Massive quantities of honeydew are secreted, leading to a proliferation of sooty mold on the plant, surrounding plants and ground. Although initially each scale starts growth in isolation, in heavy infestations larger females will coalesce into a hard resinous mass that completely envelops the branch. Thus far, no parasitoids are known, and control efforts using horticultural oils are only minimally effective, even at low infestation levels.

19.5 Armored Scales: Diaspididae

Armored scales are notorious tramp species, primarily due to their small size and the attendant difficulty in finding them during inspections. Also, because of the protective cover that they manufacture (which substantially protects them from topical insecticides), and the fact that they feed directly from plant cells as opposed to xylem or phloem (which reduces their exposure to systemic insecticides), they are notoriously hard to control once established. Five adventive species have recently been detected in Florida: *Unachionaspis tenuis* (Maskell), *Aulacaspis yasumatsui* Takagi, *Poliaspis cycadis* (Comstock), *Aulacaspis tubercularis* Newstead and *Duplachionaspis divergens* (Green). Unfortunately, other than host and distribution information, no information is available about the biology of either *P. cycadis* or *U. tenuis*.

19.5.1 *Unachionaspis tenuis* (Maskell)

No common name. Distribution: PA, OR, NE (USA: Florida, South Carolina).

Hosts are grasses (Poaceae), including: *Bambusa* sp., *Phyllostachys* spp., *Pleioblastus* spp., *Sasa* sp. and *Shibataea kumasaca* (Zoll. ex Steud.) Makino. In Nassau County, Florida, it has been taken exclusively from *Bambusa* sp. There is one additional unpublished record of this species from one collection in South Carolina in a botanical garden, also on *Bambusa* sp.

19.5.2 *Aulacaspis yasumatsui* Takagi

Common names: cycad aulacaspis scale, cycad scale, sago palm scale. Distribution: AU, OR, PA, NE (USA: Florida, Texas, Louisiana), NT (Cayman Islands, Puerto Rico, US Virgin Islands: St John, Barbados); Figs 19.3–19.4.

Thought to be native to Thailand, cycad scale has spread widely across the globe and

Fig. 19.3 Cycad scale, *Aulacaspis yasumatsui* Takagi (Diaspididae) adult female scale covers on adaxial leaflet surface. Photograph, Ian Stocks.

Fig. 19.4 Cycad scale, primarily male puparia on adaxial leaflet surface. Photograph, Ian Stocks.

can now be found wherever *Cycas* spp. (Cycadales: Cycadaceae) and *Zamia* spp. (Cycadales: Zamiaceae) grow naturally or are cultivated (Hodgson and Martin, 2001; Germain and Hodges, 2007). Cycad scale was first collected in Florida in 1996, presumably having been introduced via the international trade in ornamental cycads (Weissling and Howard, 1999). Other regions of the southern US that are suitable for the outdoor cultivation of cycads (Louisiana and Texas) also have the scale (Germain and Hodges, 2007), but thus far in California it remains unrecorded outside of nursery settings (G. Watson, pers. comm.). ScaleNet reports that the Caribbean region distribution includes Cayman Islands, Puerto Rico and the US Virgin Islands (St John). The Puerto Rico records are derived from the FDACS-DPI sample submission database, but the Cayman Islands and US Virgin Islands reports were unverified at the time of their publication (Howard and Weissling, 1999). As reported by the Barbados Ministry of Agriculture and Rural Development website, it has been present there since 2003 (Lavine, 2010). Reports of the scale's presence in Martinique since 2005 were cited by Germain and Hodges (2007), and it is now considered established; however, given the rapidity of the worldwide spread of this pest, and the size of the populations that can build up, it is very unlikely that the Caribbean region in general will escape the establishment of this scale. For a general discussion of the biology of cycad scale, the reader is referred to Howard *et al.* (1999), and the synopsis available at Ben-Dov *et al.* (2011).

While the commercially popular *Cycas revoluta* is by far the most common host in Florida, and may in fact be the primary native host for *A. yasumatsui*, it has also been collected from six other commercially available species, *Microcycas calocoma* (Miq.) DC (native to Cuba and endangered; Vovides *et al.*, 1997), the Zamiaceae hosts *Dioon* spp., *Encephalartos* spp. and *Macrozamia moorei* F.J. Muell. and *Stangeria eriopus* (Kunze) (Stangeriaceae). A heavily infested plant will have scales on all parts of the plant, including the roots (Howard *et al.*, 1999).

In its native range, naturally occurring parasitoids and predators help maintain populations below levels that cause significant damage to the plants (Hodgson and Martin, 2001). However, outside its native range, pest load can cause from 70% to 100% mortality of infested *C. revoluta* (Hodgson and Martin, 2001). Howard *et al.* (1999) reported that leaves of recently infested experimental *C. revoluta* plants were necrotic within 112 days of exposure, with the death of the plant occurring in 1 year post exposure. In control experiments, levels of pesticide application (imidacloprid) exceeding that practicable by home gardeners were only marginally successful, perhaps because the plants were rapidly reinfested from the root populations untouched by the pesticide application (Howard *et al.*, 1999). To date, the only pesticide products with known efficacy are certain formulations of horticultural oils, the primary benefit being a reduction in the crawler stage (Howard and Weissling, 1999).

Natural enemies, which often provide the best and most efficient long-term control, have been discovered and have provided partial control. In Florida, the scale predator *Cybocepahlus nipponicus* Endroudy-Younga (Nitidulidae, originally identified as *C. binotatus*) and parasitoid *Coccobius fulvus* (Compere and Annecke) (Encyrtidae) were bred for a release program. These are now established throughout the cycad scale infestation range, and can eliminate a scale population (Howard and Weissling, 1999). Recently, other predators and parasitoids have been recovered from cycad scale-infested areas. In south Texas, where ornamental cycads are grown commercially, the predator *Rhizobius lophanthae* Blaisdell (Coccinellidae) and *Aphytis* sp. *lingnanensis* group (Aphelinidae) appear to be keeping the cycad scale at relatively low levels (Flores and Carlson, 2009).

Field recognition of this species is relatively straightforward, although slide-mounting adult female specimens is necessary for positive

identification. The adult female scale is white to off-white, tear-drop to roughly circular in outline and 1–2 mm along the longest axis (Plate 2). Beneath the scale cover, the insect is orange in colour. Females preferentially colonize the adaxial surface of the leaflet, with relatively lower density on the rachis and abaxial surface; however, the male scale covers, which are <1 mm long and parallel sided, preferentially colonize the abaxial leaflet surface and both sides of the rachis. In heavily infested plants, almost the entire surface of the leaf will be covered. Care should be taken in identifying cycad scale in the field, because the white magnolia scale (= false oleander scale), *Pseudaulacaspis cockerelli* (Cooley) has a similar scale cover with a similarly shaped body; however, white magnolia scale adult females and their eggs are yellow, and they typically do not build up large populations on the leaflets.

19.5.3 *Poliaspis cycadis* Comstock

No common name. Distribution: OR, PA, NE (USA: California, Florida, DC).

Hosts include *Cycas* spp. (Cycadaceae), *Dioon edule* (Zamiaceae), *Gaultheria* spp. (Ericaceae) and *Microsemia* sp. (Brassicaceae). UK and Scottish records are presumably from hothouse plants, and in fact the type series is from Washington DC on *Cycas revoluta* Thunb., *Dioon edule* Lindl. and *Microsemia* sp. plants grown in a conservatory. In Florida, it has been collected in Miami-Dade County from *Dioon* sp., but appears to be either not established or at very low levels in the environment (FDACS-DPI database; Hodges and Dixon, 2007).

19.5.4 *Aulacaspis tubercularis* Newstead

Common names. cinnamon scale, mango scale, white mango scale, escama del mango, escama blanca del mango. Distribution: PA, OR, AF, AU, NE (USA: Florida), NT (Antigua, Aruba, Barbados, Bermuda, British Virgin Islands, Dominican Republic, Grenada, Guadeloupe, Jamaica, Martinique, Puerto Rico, Saint Croix, St Lucia, Trinidad and Tobago, US Virgin Islands).

This scale was first observed in Florida in 2002, and has since become a common, though not very significant, pest of mango (FDACS-DPI database). ScaleNet lists 44 host species records in 17 families, with a heavy bias to members of the Lauraceae; however, thus far, Lauraceae of Florida appear to have not become common host plants, with one record each from *Cinnamomum zeylanicum* Garcin ex Blume and *Persea palustris* (Raf.) Sarg. Seventy-five percent of records are from Miami-Dade County, but we have records from five other primarily southern Florida counties.

19.5.5 *Duplachionaspis divergens* (Green)

No common name. Distribution: AU, OR, PA, NT, NE (USA: Florida, intercepted from Alabama and Texas, possibly established in Texas).

This species was first discovered in 2002 on *Miscanthus* sp., but an examination of slides of unidentified scales from *Miscanthus* revealed that it has been in Florida since at least 2000 (Hodges, 2004c). Evans and Hodges (2007) published a brief article on this species in which they provide a synopsis of the known ecology, economic impact and biological control issues. This species is now widely distributed around Florida, known from 35 counties. In 2010, FDACS-DPI received a sample from St Croix, US Virgin Islands, on *Bothriochloa pertusa* (L.) A. Camus. It has been collected exclusively from Poaceae, including *Andropogon* spp., *Cimbopogon citratus* (DC ex Nees) Stapf, *Eustachys* sp., *Miscanthus sinensis* Andersson, *Pennisetum* sp., *Saccharum* spp., *Stenotaphrum secundatum* (Walt.) O. Kuntze, *Tripsacum dactyloides* (L.) L. and *T. floridanum* Porter ex Vasey. In regions where sugarcane is grown, it has caused minor economic impact, but parasitoids appear to suppress the scale to below economic levels. In Florida, *Aphytis* sp. *lingnanensis* group and *Encarsia citrine* (Craw) (Aphelinidae) have been reared from populations of *D. divergens*.

19.6 Cushiony Scales: Monophlebidae

Nine species of monophlebid scales are known from the Caribbean. Perhaps the most seriously

pestiferous is *Icerya p. purchasi* Maskell (citrus fluted scale, cottony cushion scale), which is present on 14 Caribbean islands, but *Crypticerya genistae* (Hempel), known from Guadeloupe, also causes economic injury. *Icerya s. seychellarum* (Westwood) has recently been recorded from Guadeloupe on *M. indica* and *Citrus* sp., and from Martinique on *P. guajava* (Matile-Ferrero and Étienne, 2006), but nothing is known yet of its biology on these islands. Williams and Butcher (1987) reported that this species is capable of killing *Citrus* trees, and Beardsley (1966) reported that it was a severe pest of breadfruit (*Artocarpus altilis* (Parkinson) Fosberg).

19.6.1 *Crypticerya genistae* (Hempel) (=*Icerya genistae*)

Distribution: NT (Barbados, Guadeloupe), NE (USA: Florida).

There is no accepted common name for this species, but images of it are returned after an internet search using the name 'white partridge pea bug'. Little has changed regarding our knowledge of this species since a Pest Alert was created in 2006 (Hodges, 2006) and short technical note written in 2008 (Hodges *et al.*, 2008). This species was first collected in Florida in Broward County in 2006, and has since spread throughout Broward County and into Miami-Dade and Palm Beach Counties. The host list, which is quite broad at over 50 species, continues to grow. There is little evidence of host preference pattern other than a slight bias to Asteraceae, Fabaceae and Euphorbiaceae (especially *Chamaesyce* spp.), an observation in Florida that was also made for this species in Guadeloupe (Étienne and Matile-Ferrero, 2008). Hodges *et al.* (2008) reported that it is a pest of several vegetable crops in Barbados, where the Ministry of Agriculture is currently surveying for this pest and searching for biocontrol agents. Étienne and Matile-Ferrero (2008) also reported that the coccinellid beetle *Rodolia cardinalis* (Mulsant), the vedalia beetle, was found associated with the mealybugs. In Guadeloupe, Gagné and Étienne (2009) found the presumably predatory midge *Pectinodiplosis erratica* (Felt) (Cecidomyiidae) along with remains of *C. genistae* feeding on *Mimosa* sp. (Fabaceae).

19.7 Whiteflies: Aleyrodidae

This family contains many well-travelled species, several of which have had profound and long-lasting impacts on agriculture, namely *Dialeurodes citri* (Ashmead) (citrus whitefly), *Aleurocanthus woglumi* Ashby (citrus blackfly) and *Aleurodicus dispersus* Russell (spiraling whitefly). In recent years, several species of whiteflies have become established either in Florida, the Caribbean region or both. Four species are of interest for this review, at least three of which either could be, or are currently, found in the Caribbean region.

19.7.1 *Dialeurodes schefflerae* Hodges and Dooley (Aleyrodinae)

Common name: schefflera whitefly. Distribution: Indonesia, USA (Florida, Hawai'i); NT (Puerto Rico).

Dialeurodes schefflerae was described in 2007, but a systematic review of unidentified slide specimens collected from *Schefflera* species in preparation for the published description indicated that it has been in Hawai'i since c. 1960, California since 1988–1990 and Florida since 1986 (Hodges and Dooley, 2007). Various lines of evidence, such as host-plant affiliation and affinity with other *Dialeurodes* species, suggest that it is native to Asia. Collection data indicate that it is polyphagous within the genus *Schefflera*, but has a marked preference for the popular landscape and potted-plant species *S. arboricola* (Hayata) Merr. Hodges and Dooley (2007) noted that no serious damage occurs to the plant, even though the whiteflies can reach quite high densities on the leaf (pers. obs.). The current distribution in Florida includes 16 counties, with greatest abundance in two of the southernmost counties, Broward and Miami-Dade. The records for San Juan, Puerto Rico are based on pre-departure quarantine interceptions of infested propagative *Schefflera* sp. plants (Hodges and Dooley, 2007).

19.7.2 *Siphoninus phillyreae* (Haliday) (Aleyrodinae)

Common names: ash whitefly, pomegranate whitefly, la mosca blanca del Fresno, mosca blanca del granado. Distribution: Western PA; AU; NT

(Mexico, Central America, USA: California, Florida, Georgia, Hawai'i, North Carolina, Virginia; also reported from Arizona, New Mexico and Nevada).

Throughout much of its range, ash whitefly has historically been a severe pest on a wide variety of commercial and non-commercial plant species, especially pomegranate and *Citrus* spp. (Abd-Rabou, 2006). Ash whitefly was discovered in California in 1988, where it quickly became a severe pest that resulted in millions of dollars of economic loss. A similar situation ensued when ash whitefly appeared on ornamental pear trees (*Pyrus calleryana* Decne. 'Bradford'; Rosaceae) in North Carolina in 1993. Taking advantage of the results of biological control programs developed in the Middle East, whitefly parasitoid *E. inaron* Walker (=*E. partenopea* Masi) (Aphelinidae) was imported into California and reared for eventual release (Pickett *et al.*, 1996). Two years after release, the parasitoid had effected a nearly complete suppression of ash whitefly on both major hosts, ash (*Fraxinus* sp.) and pomegranate. Additionally, several other parasitoids and the beetle predator *Clitostethus arcuatus* (Risso) (Coccinellidae) have been used in biological control programs in other parts of the ash whitefly's range. In Mexico, Myartseva (2006) discovered *Eretmocerus* sp. (Aphelinidae) and the hyperparasite *Signiphora aleyrodis* Ashmead (Signiphoridae) attacking ash whitefly, and she concluded that the parasitoids had been introduced along with the whitefly. Overall, 23 Hymenoptera parasitoids or associates of ash whitefly are reported in the Universal Chalcidoid Database.

In Florida in 2010, a small population of ash whitefly was discovered on containerized pomegranate trees in the nursery grounds of an amusement park in Orange County, the discovery of which prompted the release of a FDACS-DPI Pest Alert (Stocks and Hodges, 2010b). Later in 2010, a second population was discovered on *Citrus* trees on private property in Bay County, and is presumed to be the result of a separate introduction. The parasitoid *E. inaron* was reared from the whiteflies from Orange County and an unidentified parasitoid was reared from the whiteflies in Bay County.

19.7.3 *Aleurodicus dugesii* Cockerell (Aleurodicinae)

Common name: giant whitefly. Distribution: NE (USA: Arizona, California, Florida, Hawai'i, Louisiana, Texas; Mexico) NT; Pakistan; Java.

Giant whitefly was first discovered in the USA in Texas in 1991, and by 1996 was established in California, Louisiana and Florida. This whitefly is a highly polyphagous species that can build to severe infestation levels, producing such large quantities of long stringy wax that the plant itself becomes obscured (Hodges, 2004d; Smith and Fox, 2004; Martin, 2008). The FDACS-DPI database lists 51 host plant species, but 66% of the samples received were from *H. rosa-sinensis*; however, there appears in recent years to be a substantial decrease in the populations, reflected in a decrease in samples submitted to FDACS-DPI. The reasons for this are not entirely clear, but the decrease may be due to suppression by parasitoids. Shortly after the giant whitefly's discovery in Texas, *Entedononecremnus krauteri* Zolnerowich and Rose (Eulophidae) was collected from puparia, and subsequently reared and released in California. The other parasitoids associated with giant whitefly are: *Encarsia guadeloupe* Viggiani, *E. brasiliensis* Hempel, *E. meritoria* Gahan, *E. noyesi* Hayat (=*Encarsiella noyesi*) (Eulophidae) and *Idioporus affinis* LaSalle and Polaszek (Pteromalidae) (Noyes, 2003). The beetle *Delphastus catalinae* Horn (Coccinellidae), a generalist whitefly predator, has also been recovered from giant whitefly infestations (Evans, 2008). This beetle is present in Florida (FSCA museum records), but several related *Delphastus* species are found throughout the Caribbean region, including *D. chapini* Gordon (Trinidad), *D. guiniculus* Gordon (Dominican Republic), *D. nebulosus* Chapin (Puerto Rico), *D. pallidus* (LeConte) (Bahamas, Cuba, Dominican Republic, Virgin Islands), *D. pusillus* (LeConte) (Cuba, Jamaica) (Gordon, 1970; FSCA museum data).

In Florida, release of *E. krauteri* was initiated in 1997 in Seminole, Indian River, St Lucie and Volusia Counties. In 1998, *E. noyesi* and *Encarsia* sp. were added to the biocontrol program. Survey data from 2001 found that *E. krauteri* and *E. noyesi* had become established and appeared to be having a significant effect on giant whitefly populations.

19.7.4 *Aleurodicus rugioperculatus* Martin

Proposed common name: rugose spiraling whitefly. Distribution: USA (Florida); Belize, Guatemala, Mexico (Martin, 2008) (Figs 19.5–19.6).

Fig. 19.5 Puparia of rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin. Photograph, Lyle Buss.

Fig. 19.6 Rugose spiraling whitefly, adult female. Photograph, Lyle Buss.

Rugose spiraling whitefly was described from Belize in 2004 from *Cocos nucifera* L. (Martin, 2004), with subsequent records from Mexico and Guatemala on *Caryocar amygdaliferum* Mutis (Caryocaraceae), *P. guajava, P. americana* Mill., *Musa* sp. (Musaceae) and *Melia* sp. (Meliaceae). No additional information about the biology or ecology of this whitefly was published, so all that is currently known about rugose spiraling whitefly is derived from limited experience with it in Florida. The first specimens received by FDACS-DPI were collected in March 2009, from Miami-Dade County, and by December 2010, FDACS-DPI had accumulated 87 records. In response, two factsheets were released to inform homeowners, landscapers and plant regulatory officials (Mannion, 2010; Stocks and Hodges, 2010c).

The majority of records are from Miami-Dade County, but through the spread of infested nursery stock, it is now recorded from two additional counties. In Miami-Dade County, rugose spiraling whitefly has spread rapidly through the environment on its own to infest an ever-increasing area. Furthermore, the host list, which is currently at 37 species, keeps expanding as more collections are made. *Bursera simaruba* (L.) Sarg. (Burseraceae) is the most common, with 23% of the host records, followed by coconut with 10%, *Bucida buceras* L. (Combretaceae) with 9% and *P. americana* with 7% of records. While coconut is a preferred palm host, at least five other palm species are suitable hosts.

Rugose spiraling whitefly is, at present, considered to be seriously pestiferous, causing extensive aesthetic damage to the host plants and physical damage by the production of prodigious quantities of honeydew. The time since infestations were noted has been too brief to determine if it causes significant health problems to the tree, but it seems likely that it will have severe negative consequences. In many cases, the leaves of *Bursera simaruba* and palms have been entirely covered with puparia and the sticky flocculent wax they produce. The honeydew promotes the growth of sooty mold, further compromising the aesthetic quality of the tree and hindering normal tree physiology. Whether rugose spiraling whitefly continues to increase its range and effect in the landscape will almost certainly depend on the role of parasitoids and predators. Martin (pers. comm.) noted parasitoid emergence holes in puparia from Belize, and at least one species of parasitoid wasp (*Aleuroctonus vittatus* Dozier; Eulophidae) has been associated with infestations in Florida, often at high levels, and samples received by FDACS-DPI frequently show signs of parasitism (I. Stocks, pers. obs.).

Acknowledgements

The author would like to thank several people for their assistance during the preparation of this chapter. Beverly Pope (FDACS-DPI) helped to

locate several obscure articles; Dr Greg Evans (USDA-APHIS) extracted interception data from USDA databases; Dr Catharine Mannion (UF-IFAS), Dr Greg Hodges (FDACS-DPI), Jenny Evans (Sanibel-Captiva Conservation Foundation) and Stephen Brown (UF-IFAS); Gillian Watson (CDFA) provided unpublished information on several species of scales and whiteflies discussed in this article. Lyle Buss, UF, kindly allowed reproduction of photographs.

Note

[i] www.sel.barc.usda.gov/ScaleNet/ScaleNet.htm, accessed 8 August 2010.

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