Insects associated with the soursop (*Annona muricata* L.) crop in Nayarit, Mexico

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Abstract

The objective of the study was to identify the entomofauna associated with soursop cultivated commercially in the municipalities of Compostela and San Blas in the state of Nayarit, Mexico. The entomofauna obtained from samples taken from Nov 2016 to Dec 2017 were morphologically identified using taxonomic keys. A total of 3,674 insects were collected, with 20 species being phytophagous, including the pink hibiscus mealybug *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) and an armored scale *Pinnaspis* sp. (Hemiptera: Diaspididae). There were 12 species of predators in the families Coccinellidae (*Azya orbigera* [Mulsant], *Chilocorus* sp., *Cryptolaemus montrouzieri* [Mulsant], *Cycloneda sanguinea* L., *Cycloneda* sp., *Hippodamia convergens* Guérin-Méneville, *Olla v-nigrum* [Mulsant], *Paraneda pallidula guticollis* [Mulsant], and *Stethorus pinachi* [Gordon & Chapin]), and Chrysopidae (*Ceraeochrysa valida* [Banks], *Ceraeochrysa* sp., and *Chrysoperla externa* [Hagen]), and 5 species of parasitoids of the genera *Aphytis*, *Coccophagus*, *Encarsia* (all Hymenoptera: Aphelinidae), *Anagyrus*, and *Gyranusoidea* (both Hymenoptera: Encyrtidae). The ladybird beetle *P. pallidula guticollis* was recorded for the first time in the state of Nayarit. Also, 9 phytophagous species are new records for soursop in Mexico.

Key Words: Entomofauna; phytophagous; parasitoids; predators

Resumen

El objetivo del estudio fue identificar a la entomofauna asociada al cultivo de guanábana producida comercialmente en los municipios de Compostela y San Blas del estado de Nayarit, México. La entomofauna obtenida de los muestreos realizados de noviembre de 2016 a diciembre de 2017 se identificó morfológicamente mediante el uso de claves taxonómicas. Se recolectaron un total de 3,674 insectos, de los cuales, 20 son fitófagos, donde se incluye la cochinilla rosada del hibisco *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) y la escama, *Pinnaspi*s sp. (Hemiptera: Diaspididae). Se registraron 12 especies de depredadores de las familias Coccinellidae (*Azya orbigera* [Mulsant], *Chilocorus* sp., *Cryptolaemus montrouzieri* Mulsant, *Cycloneda sanguinea* L., *Cycloneda* sp., *Chilocorus* sp., *Hippodamia convergens* Guérin-Méneville, *Olla v-nigrum* [Mulsant], *Paraneda pallidula guticollis* [Mulsant], y *Stethorus pinachi* [Gordon y Chapin], y Chrysopidae: (*Ceraeochrysa valida* [Banks], *Ceraeochrysa* sp., y *Chrysoperla externa* [Hagen]), y 5 especies de parasitoides de los géneros *Aphytis*, *Coccophagus*, *Encarsia* (todos Hymenoptera: Aphelinidae), *Anagyrus*, y *Gyranusoidea* (ambos Hymenoptera: Encyrtidae). Se registra por primera vez al coccinélido *P. pallidula guticollis* en el estado de Nayarit. Además, 9 especies fitófagas son nuevos registros para guanábana en México.

Palabras Clave: Entomofauna; fitófagos; parasitoides; depredadores

Soursop, *Annona muricata* L. (Annonaceae), is native to the tropical regions of the Americas and the Caribbean, and is considered the most important species of the family. The principal use of this fruit is fresh consumption; however, it has a variety of medicinal and industrial uses (Coto & Saunders 2001; Jiménez et al. 2017). According to Hernández et al. (2013), Mexico is the principal producer of soursop in the world. Production currently is about 23,715 metric tons per yr, with a commercial value of around 159,856 million pesos (US $8,295,632). Most of the production is concentrated in the state of Nayarit, with a planted area of 1,990 ha, distributed in the municipalities of Compostela (1,912 ha), San Blas (52.4 ha), Bahía de Banderas (12 ha), Tepic (7.16 ha), and Xalisco (6.54 ha) (SIAP 2016).

The crop has several phytosanitary problems that considerably affect the production of fruit. At least 296 species of arthropods associated with the genus *Annona* are known from tropical countries; insects in the families Coccidae (Hemiptera), Noctuidae (Lepidoptera), Oecophoridae (Lepidoptera), and Eurytomidae (Hymenoptera) are most common (Vidal et al. 2014). In Costa Rica, Coto and Saunders (2001) recorded 10 species of insects that affect soursop cultivation and cause decreases in the yield and quality of the fruit.

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In Mexico, several species of insect pests have been associated with *A. muricata*, including *Optatus palmaris* Pascoe (Coleoptera: Curculionidae), *Euphoria sepulcralis* (Fabricius) (= *E. leucographa* [Gory & Percheron]) (Coleoptera: Melolonthidae), *Anastrepha ludens* (Loew) (Diptera: Tephritidae), *Saissetia nigra* (Nietner) (Hemiptera: Coccidae), *Acanthocephala femorata* F. (Hemiptera: Coreidae), *Membracis mexicana* Guérin-Méneville (Hemiptera: Membracidae), *Vanduzea segmentata* (Fowler) (Hemiptera: Membracidae), *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae), *Ferrisia virgata* (Cockerell) (Hemiptera: Pseudococcidae), *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae), *Planococcus citri* Risso (Hemiptera: Pseudococcidae), *Corythucha gossypii* F. (Hemiptera: Tingidae), *Bephratelloides cubensis* Ashmead (Hymenoptera: Eurytomidae), *Oenomaus ortygnus* Cramer (Lepidoptera: Lycaenidae), *Gonodonta pyrgo* Cramer (Lepidoptera: Noctuidae), *Cerconota anonella* Sepp (Lepidoptera: Oecophoridae), and unspecified specimens of Lonchaeidae (Diptera) and Pyralidae (Lepidoptera) (MacGregor & Gutiérrez 1983; Sánchez & Franco 2001; Ruiz et al. 2014; Vidal et al. 2014; Hernández et al. 2013, 2015; Cambero et al. 2017).

Chemical control is the method most used by producers for the management of these pests, although in Mexico there are no pesticides authorized for use in soursop by the Federal Commission for Protection against Health Risks (COFEPRIS 2018). Hernández et al. (2008) evaluated the insecticides dimethoate, malathion, chlorpyrifos-ethyl, cypermethrin, endosulfan, and azadirachtin for control of the seed borer *B. cubensis* in soursop, and reported that dimethoate was the most effective. A promising, sustainable, and ecological alternative for this problem is the use of beneficial organisms such as predators and parasitoids. Beneficial insects have the potential to regulate pest populations due to the dense-dependent relationship they establish, and they generally are considered to be harmless to humans and safe for the environment (Gutiérrez et al. 2013). Identification of the pest and beneficial insects associated with soursop cultivation in the state of Nayarit is of great importance, because this information will be important in identifying future actions for phytosanitary management of this crop. However, we undertook a survey of the insects associated with soursop cultivation in the principal producing municipalities of the state of Nayarit, Mexico.

Materials and Methods

The biological material (insect pests, parasitoids, predators, and insects associated with the crop) was obtained through biweekly sampling from Nov 2016 to Dec 2017 in 13 commercial soursop orchards, 7 located in the municipality of Compostela, and 6 in the municipality of San Blas, Nayarit, Mexico (Table 1).

Insect pest collections were carried out on 10 soursop trees selected randomly in each of the orchards, where 4 cardinal points of each tree were visually inspected for insects or their indicators (damage). Biological materials collected (insects, leaves, fruits, and seeds), were taken to the Laboratory of Agricultural Parasitology of the Multidisciplinary Center of Scientific Research 03 of the Autonomous University of Nayarit, where the insect specimens were separated and deposited in 50 mL clear plastic bottles with 70% ethyl alcohol for preservation prior to identification.

Fruits, seeds, and leaves with the presence of insects or signs of damage were placed in 1.8 L black plastic containers with a perforation in the middle, where a 50 mL clear plastic bottle was attached in order to use attraction to light as a means to obtain adult parasitoids associated with the principal soursop insect pests. These containers were maintained at a temperature of 25 ± 2 °C, and the material was systematically examined every 24 h.

Table 1. Orchards studied to obtain the insects associated with soursop cultivation in Nayarit, México.

Municipality	Orchard	Location	Altitude (masl)
Compostela	Altavista 1	21.045556°N, 105.185278°W	437
	Altavista 2	21.067778°N, 105.213889°W	74
	Altavista 3	21.102222°N, 105.229167°W	156
	Chacala 1	21.156111°N, 105.225°W	90
	Chacala 2	21.174167°N, 105.183056°W	39
	Chacala 3	21.164444°N, 105.201944°W	96
	Divisadero	21.135°N, 105.193889°W	198
San Blas	Tecuitata 1	21.4575°N, 105.143889°W	317
	Tecuitata 2	21.446944°N, 105.165278°W	381
	Tecuitata 3	21.460278°N, 105.155278°W	382
	El Llano	21.511111°N, 105.190278°W	350
	Palmas 1	21.530556°N, 105.168611°W	183
	Palmas 2	21.534444°N, 105.175556°W	242

The predators detected in action on insect pests of interest were collected directly from the leaves, branches, flowers, and fruits. When no predatory action was recorded directly in the field, putative predators and different stages of insect pests were collected with the help of an entomological aspirator and were taken to the laboratory, where they were placed with potential prey in 90 mm diam Petri dishes to observe their acceptance or rejection.

Representative insect pests, parasitoids, and predators were preserved in 70% alcohol for identification using Motic® SMZ 168 stereoscopic (Motic Inc., LTD, Hong Kong, China) and LEICA™ DME compound microscopes (Leica Microsystems, Wetzlar, Germany), both purchased in Mexico, and the use of taxonomic keys of Slater and Baranowski (1978), Gordon (1985), Williams and Watson (1988, 1990), Williams and Granara de Willink (1992), Gibson et al. (1997), Blackman and Eastop (2000), Strange (2000), Godoy et al. (2006), and Valencia et al. (2006) for insect pests, parasitoids, and predators, as well as those of Blake (1933), Blackwelder (1944), Curran (1965), and Lasoń and Przewoźny (2009) for other insects associated with the crop. Confirmation of the species was made by specialists of the Entomology and Acarology Laboratory of the National Phytosanitary Reference Center. The identified specimens were deposited in the Insect Collection of the Agricultural Parasitology Laboratory, Autonomous University of Nayarit.

Results

In this study, 3,674 insect specimens were collected, of which 3,103 were phytophagous, 353 were parasitoids, 92 were predators, and 126 were insects with different eating habits (Table 2).

In our study of the phytophagous species, 2,809 specimens were in the order Hemiptera, 165 in Hymenoptera, 84 in Coleoptera, and 45 in Lepidoptera; *M. hirsutus* was the most abundant species with 356 specimens, even though it was found in only 8 of the 13 orchards. Second in abundance was *Aphis spiraecola* Patch (Hemiptera: Aphididae) with 338 specimens from 5 orchards, but with a collection of 202 specimens in the "Altavista 2" orchard, the largest number of phytophagous insects collected by orchard. *Bephratelloides cubensis* is the only species that appeared in all orchards. "Chacala 1," "Chacala 3," and "El Llano" are the orchards from which we collected the lowest number of species (3). "Altavista 1" recorded the highest number of species (19), although with fewer specimens (523) than "Palmas 1," where there were (18) species and 613 specimens. When comparing soursop pests recorded in Mexico by different authors (MacGregor & Gutiérrez 1983;

Table 2. Number of specimens collected of phytophagous insect species associated with soursop cultivation in orchards of the municipalities of Compostela (39–437 masl) and San Blas (183–382 masl), Nayarit, Mexico.

Order Family Genus / species	Compostela								San Blas							
	Altavista 1	Altavista 2	Altavista 3	Chacala 1	Chacala 2	Chacala 3	Divisadero	Subtotal	Tecuitata 1	Tecuitata 2	Tecuitata 3	El Llano	Palmas 1	Palmas 2	Subtotal	Total
Coleoptera								28							56	
Curculionidae																
Optatus palmaris Pascoe	4	2	—	—	1	—	—	7	—	—	—	—	11	2	13	20
Melolonthidae																
Euphoria leucographa (Gory & Percheron)	11	2	5	—	—	—	3	21	2	—	7	—	23	11	43	64
Hemiptera								1587							1222	
Aphididae																
Aphis spiraecola (Patch)*	44	202	—	—	—	—	—	246	9	—	—	—	72	11	92	338
Toxoptera aurantii (Boyer de Fonscolombe)*	30	60	—	—	—	—	—	90	7	—	—	—	68	13	88	178
Coccidae																
Saissetia hemisphaerica (Targioni-Tozzetti)*	14	9	10	—	—	—	—	33	3	—	—	—	37	1	41	74
Saissetia nigra (Nietner)	11	23	3	—	—	—	—	37	5	—	—	—	31	6	42	79
Diaspididae																
Aulacaspis sp.*	20	10	40	29	20	39	—	158	50	10	10	6	26	27	129	287
Pinnaspis sp.*	39	46	67	41	29	50	—	272	91	46	33	18	51	70	309	581
Membracidae																
Guayaquila sp.*	11	7	2	—	—	—	12	32	—	—	—	—	21	23	44	76
Leioscyta spiralis (Haviland)*	9	3	8	—	—	—	6	26	—	—	—	—	18	27	45	71
Membracis dorsata (Fabricius)*	17	5	11	—	—	—	7	40	—	—	—	—	42	32	74	114
Membracis mexicana (Guérin-Méneville)	23	9	6	—	—	—	11	49	—	—	—	—	60	37	97	146
Pseudococcidae																
Dysmicoccus brevipes (Cockerell)	67	11	13	—	9	—	23	123	7	11	—	—	19	9	46	169
Ferrisia terani (Williams & Granara de Willink)*	18	—	2	—	7	—	21	48	18	—	2	—	17	4	41	89
Maconellicoccus hirsutus (Green)	104	—	21	—	49	—	106	280	14	6	7	—	49	—	76	356
Planococcus citri (Risso)	51	—	15	—	11	—	31	108	51	—	15	—	32	—	98	206
Planococcus sp.	—	20	—	—	—	—	—	20	—	—	—	—	—	—	—	20
Tingidae																
Corythucha sp.	20	5	—	—	—	—	—	25	—	—	—	—	—	—	—	25
Hymenoptera								82							83	
Eurytomidae																
Bephratelloides cubensis (Ashmead)	17	11	13	12	10	14	5	82	11	10	8	11	29	14	83	165
Noctuidae								30							15	
Gonodonta pyrgo (Cramer)	13	5	1	—	—	—	11	30	5	—	—	—	7	3	15	45
Altitudes (masl)	437	74	156	90	39	96	198		317	381	382	350	183	242		
Species	19	17	15	03	08	03	11	20	13	05	07	03	18	16	18	20
Total of specimens	523	430	217	82	136	103	236	1727	273	83	82	35	613	290	1376	3103

*New record of soursop pests in Mexico.

Sánchez & Franco 2001; Ruiz et al. 2014; Vidal et al. 2014; Hernández et al. 2013, 2015; Cambero et al. 2017), in this study we recorded an additional 9 species as new records of phytophagous pests. Orchard altitude did not seem to affect the number of pests or the number of specimens captured.

In the municipality of Compostela, 1,727 specimens from 20 species of phytophagous insects, and 10 families of 4 orders were observed. The order with greatest abundance and diversity was Hemiptera, with 1,587 specimens of 16 species, followed by Hymenoptera with 82 specimens of 1 species, Lepidoptera with 30 specimens of 1 species, and Coleoptera with 28 specimens of 2 species. The most abundant species was *M. hirsutus* with 280 individuals, followed by *Pinnaspis* sp. (272) and *A. spiraecola* (246). The orchard with the highest number of insects collected was "Altavista 1" (523), whereas the orchard with the lowest number was "Chacala 1" (82).

In the municipality of San Blas, 1,376 specimens from 18 species of phytophagous insects, and 9 families of 4 orders were observed. The order with the greatest abundance and diversity was Hemiptera, with 1,222 specimens of 14 species, followed by Hymenoptera with 83 specimens of 1 species, Coleoptera with 56 specimens of 2 species, and Lepidoptera with 15 specimens of 1 species. The most abundant species was *Pinnaspis* sp. with 309 individuals, followed by *Aulacaspis* sp. (129), *P. citri* (98), and *M. mexicana* (97). "Palmas 1" was the orchard with the highest incidence of pests (613) and "El Llano" was the lowest (35).

Relative to parasitoids and predators (Table 3), more parasitoid specimens (353) than predators were collected (92). Five species of parasitoids were collected; the most abundant species was *Anagyrus kamali* Moursi (Hymenoptera: Encyrtidae) with 93 specimens, followed by *Aphytis* sp. (75) and *Gyranusoidea indica* Shafee, Alam & Agarwal (Hymenoptera: Encyrtidae) (74). Parasitoids were collected from all the orchards of the 2 municipalities, although different species. In Compostela, a greater number was collected (242) than in San Blas (111); "Altavista 1" is the orchard where the largest number of parasitoids was collected (79), and "El Llano" was the least (5). "Altavista 1," "Tecuitata 1," and "Palmas 1" were the orchards with the greatest diversity (5 species), whereas in "Chacala 1," "Chacala 3," "Divisadero," and "El Llano," only 2 species were collected. Regarding the predators, 12 species were collected; the most abundant species was *C. sanguinea* with 36 specimens, followed by *S. pinachi* (14) and *H. convergens* (11). All the predators were collected from 6 orchards. In Compostela, a greater number of specimens was collected (47) than in San Blas (45), although in San Blas a greater number of predatory species was collected (8) than in Compostela (6). "Palmas 1" was the orchard where the largest number of specimens (31) and 7 species were collected, followed by "Altavista 1" with 28 specimens from 5 species; in the remaining orchards, 4 to 14 specimens and 1 to 4 species were collected per orchard. *Stethorus pinachi* was the most-collected species in a single orchard (11 specimens in "Altavista 1").

In the municipality of Compostela, *Aphytis* sp., *Coccophagus* sp., *Encarsia* sp., *A. kamali*, and *G. indica* were detected parasitizing *Pinnaspis* sp., *Saissetia nigra*, *Aulacaspis* sp., and *G. indica*. The most-represented species was *G. indica* with 64 individuals, followed by *A. kamali* (58) and *Aphytis* sp. (53). As for the predators, of the ladybird beetles *A. orbigera*, *C. sanguinea*, *S. pinachi*, and the lacewings *C. valida*, *Ceraeochrysa* sp., and *C. externa* were detected. The ladybird beetle *C. sanguinea* was the most abundant with 22 specimens, followed by *S. pinachi* (12) and *Ceraeochrysa* sp. (5); the lacewings were collected only in the orchard "Altavista 1." On the other hand, in the municipality of San Blas, the parasitoids *Aphytis* sp., *Coccophagus* sp., *Encarsia* sp., *A. kamali*, and *G. indica* were detected parasitizing *Pinnaspis* sp., *S. nigra*, *Aulacaspis* sp., and *M. hirsutus*. The parasitoid *A. kamali* was best represented with 35 individuals, followed by *Coccophagus* sp. (24) and *Aphytis* sp. (22). The species of predators recorded were *Chilocorus* sp., *C. sanguinea*, *Cycloneda* sp., *H. convergens*, *O. v-nigrum*, *P. pallidula guticollis*, and *S. pinachi* preying on aphids, and *C. montrouzieri* preying on *M. hirsutus. Cycloneda sanguinea* was the most abundant species with 14 specimens followed by *H. convergens* (11), and *C. montrouzieri* and *Cycloneda* sp. (6 each). Predators were collected in only 2 of the orchards (Palmas 1 and 2) and lacewings were not collected in this municipality.

In addition to the pests and natural enemies (parasitoids and predators), 126 specimens of insects with 'other' eating habits (e.g., fungi, honeydew, etc.) were detected: *Disonycha glabrata* F. (Coleoptera: Chrysomelidae), *Chalcolepidius silbermanni* Chevrolat (Coleoptera: Elateridae), *Rhodobaenus 13-punctatus* (Gyllenhal) (Coleoptera: Curculionidae), *Lobiopa insularis* Castelnau (Coleoptera: Nitidulidae), *Agathon* sp. (Diptera: Blephariceridae), *Drosophila icteroscuta* Wheeler (Diptera: Drosophilidae), *Nephrocerus scutellatus* (Macquart) (Diptera: Pipunculidae), *Anasa armigera* (Say) (Hemiptera: Coreidae), *Ochrimnus lineoloides* Slater (Hemiptera: Lygaeidae), and *Kallitaxila granulata* (Stål) (Hemiptera: Tropiduchidae), which were collected either directly from the soursop trees, or emerged from the decaying fruits (Table 4).

Discussion

The diversity of species with phytophagous habits recorded in this study surpass those found by Hernández et al. (2013), who reported 9 species associated with the cultivation of soursop, among which *B. cubensis*, *C. anonella*, and *O. ortygnus* are considered pests of economic importance in Mexico. Ruíz et al. (2014) reported that the species *Neosilba* spp. (Diptera: Lonchaeidae), *B. cubensis*, and *C. anonella* were the most abundant phytophagous species in the state of Veracruz, whereas Sánchez and Franco (2001) and Hernández et al. (2006) recorded *B. cubensis* in soursop plantations in the states of Tabasco and Nayarit, respectively. It should be mentioned that the species with the greatest abundance in this study were *Pinnaspis* sp., *M. hirsutus*, *Aulacaspis* sp., *A. spiraecola*, and *B. cubensis*, and their presence in the production zones in the state broadens the range of organisms that could be considered part of the important soursop pest complex.

Among the secondary species (those of lesser abundance), *E. leucographa*, *O. palmaris*, and *G. pyrgo* were observed. Ruiz et al. (2014) and Cambero et al. (2017) also reported *E. leucographa* feeding on the soursop fruit, without mentioning the level of damage, in the states of Veracruz and Nayarit, respectively. On the other hand, Vidal et al. (2014) reported that *O. palmaris* uses *Annona squamosa* L. (Annonaceae) as a host, whereas Castañeda (2011) reported the occurrence of *O. palmaris* on *A. muricata* during the mo of Nov and Dec in the municipality of Compostela, Nayarit, quantifying the resulting damage. Hernández et al. (2015) mentioned that *G. pyrgo* could be abundant and cause up to 40% of defoliation in mature trees, which causes a reduction in the quality and production of soursop fruits in the state of Nayarit.

In the soursop-producing areas in this study, *Aphytis* sp., *Coccophagus* sp., *Encarsia* sp., *A. kamali*, and *G. indica* occurred as parasitoids of *Pinnaspis* sp., *S. nigra*, *Aulacaspis* sp., and *M. hirsutus*. Hernández et al. (2013) and Ceballos et al. (2016) mentioned that the parasitoids *A. kamali* and *G. indica* are used in the biological control programs of the pink hibiscus mealybug in Mexico and Cuba, respectively. On the other hand, Gaona et al. (2006) noted that the species of the genus *Anagyrus*, *Aphytis*, *Coccophagus*, and *Encarsia*, have the ability to exercise a natural control over the Coccoidea in Ciudad Victoria, Tamaulipas, and

Table 3. Number of specimens collected of parasitoids and predators associated with insect pests in soursop cultivation in orchards of the municipalities of Compostela and San Blas, Nayarit, Mexico.

		Compostela								San Blas							
Order: Family Genus / species	Host or prey	Altavista 1	Altavista 2	Altavista 3	Chacala 1	Chacala 2	Chacala 3	Divisadero	Subtotal	Tecuitata 1	Tecuitata 2	Tecuitata 3	El Llano	Palmas 1	Palmas 2	Subtotal	Total
Parasitoids	Host																
Hymenoptera: Aphelinidae																	
Aphytis sp.	*Pinnaspis* sp.	9	4	7	15	8	10	—	53	5	3	6	3	1	4	22	75
Coccophagus sp.	*Saissetia nigra*	16	11	1	—	—	—	—	28	2	—	—	—	19	3	24	52
Encarsia sp.	*Aulacaspis* sp.	7	7	9	6	4	6	—	39	2	2	3	2	2	9	20	59
Hymenoptera: Encyrtidae																	
Anagyrus kamali (Moursi)	*M. hirsutus*	18	—	7	—	10	—	23	58	5	6	4	—	20	—	35	93
Gyranusoidea indica (Shafee)	*M. hirsutus*	29	—	6	—	16	—	13	64	2	1	—	—	7	—	10	74
No. species		5	3	5	2	4	2	2	5	5	4	3	2	5	3	5	5
Subtotal		79	22	30	21	38	16	36	242	16	12	13	5	49	16	111	353
Predators	Prey																
Coleoptera: Coccinellidae																	
Azya orbigera (Mulsant)	Aphids	—	—	—	—	1	—	2	3	—	—	—	—	—	—	0	3
Chilocorus sp.	Aphids	—	—	—	—	—	—	—	0	—	—	—	—	1	—	1	1
Cryptolaemus montrouzieri (Mulsant)	*M. hirsutus*	—	—	—	—	—	—	—	0	—	—	—	—	6	—	6	6
Cycloneda sanguinea (Linnaeus)	Aphids	7	4	—	—	5	—	6	22	—	—	—	—	9	5	14	36
Cycloneda sp.	Aphids	—	—	—	—	—	—	—	0	—	—	—	—	3	3	6	6
Hippodamia convergens (Gue-Men)	Aphids	—	—	—	—	—	—	—	0	—	—	—	—	7	4	11	11
Olla v-nigrum (Mulsant)	Aphids	—	—	—	—	—	—	—	0	—	—	—	—	4	—	4	4
Paraneda pallidula (Mulsant)	Aphids	—	—	—	—	—	—	—	0	—	—	—	—	1	—	1	1
Stethorus pinachi (Gordon y Chapin)	Aphids	11	—	—	—	1	—	—	12	—	—	—	—	—	2	2	14
Neuroptera: Chrysopidae																	
Ceraeochrysa valida (Banks)	Aphids	2	—	—	—	—	—	—	2	—	—	—	—	—	—	0	2
Ceraeochrysa sp.	Aphids	5	—	—	—	—	—	—	5	—	—	—	—	—	—	0	5
Chrysoperla externa (Hagen)	Aphids	3	—	—	—	—	—	—	3	—	—	—	—	—	—	0	3
No. species		5	1	0	0	3	0	2	6	0	0	0	0	7	4	8	12
Subtotal		28	4	0	0	7	0	8	47	0	0	0	0	31	14	45	92
Total		107	26	30	21	45	16	44	289	16	12	13	05	80	30	156	445

Table 4. Number of insect specimens collected in association with soursop cultivation in orchards of the municipalities of Compostela and San Blas, Nayarit, Mexico.

	Compostela								San Blas							
Order: Family Genus / species	Altavista 1	Altavista 2	Altavista 3	Chacala 1	Chacala 2	Chacala 3	Divisadero	Subtotal	Tecuitata 1	Tecuitata 2	Tecuitata 3	El Llano	Palmas 1	Palmas 2	Subtotal	Total
Coleoptera: Chrysomelidae																
Disonycha glabrata Fabricius	1	—	—	5	3	2	—	11	—	—	—	—	6	5	11	22
Coleoptera: Curculionidae																
Chalcolepidius silbermanni Chevrolat	—	3	—	—	—	—	—	3	—	—	—	—	2	—	2	5
Rhodobaenus 13-punctatus	2	—	—	—	—	—	—	2	—	—	—	—	11	2	13	15
Coleoptera: Nitidulidae																
Lobiopa insularis Castelnau	6	—	2	—	—	—	7	15	—	—	—	—	18	2	20	35
Diptera: Blephariceridae																
Agathon sp.	—	2	—	—	—	—	—	2	—	—	—	—	—	—	—	2
Diptera: Drosophilidae																
Drosophila icteroscuta Wheeler	7	—	—	11	5	8	—	31	—	—	—	—	—	—	—	31
Diptera: Pipunculidae																
Nephrocerus scutellatus Macquart	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Hemiptera: Coreidae																
Anasa armigera Say	—	—	3	—	—	—	—	3	—	—	—	—	1	—	1	4
Hemiptera: Lygaeidae																
Ochrimnus lineoloides Slater	3	1	—	1	—	—	—	5	—	—	—	—	2	—	2	7
Hemiptera: Tropiduchidae																
Kallitaxila granulata Stål	2	—	—	—	—	—	—	2	—	—	—	—	2	—	2	4
Total	22	6	5	17	8	10	7	75	—	—	—	—	42	9	51	126

could be used as an alternative to biological control in ornamental and fruit plants of that state.

With respect to predators, 9 species of ladybug and 3 species of lacewing were observed, among which *C. sanguinea*, *H. convergens*, and *S. pinachi* (Coccinellidae) and *Ceraeochrysa* sp. (Chrysopidae) were the most abundant. These results are similar to what was recorded by Rodríguez et al. (2017), who reported the presence of these species in the jackfruit plantations in the municipalities of Compostela and San Blas, Nayarit, Mexico.

In this study, the ladybird beetle *P. pallidula guticolli* Mulsant was recorded for the first time in the state of Nayarit. Previously it had been recorded in the states of Puebla and Veracruz (as *Cycloneda rubida* L.) (Coleoptera: Coccinellidae) by Gorham (1887–1899) and later by Trejo and Néstor (2012) for the state of Morelos. It is also noteworthy that 9 species were observed feeding on soursop in Mexico for the first time, because they are not included in the lists of previous authors (MacGregor & Gutiérrez 1983; Sánchez & Franco 2001; Ruiz et al. 2014; Vidal et al. 2014; Hernández et al. 2013, 2015; Cambero et al. 2017).

The entomofauna associated with soursop cultivation in the principal production area of Nayarit, Mexico, is very diverse, having a large number of phytophagous insects (20), as well as natural enemies such as parasitoids (5 species) and predators (12 species) that have the potential to naturally regulate the pest organisms associated with the crop. However, these natural enemies should be given more attention, because they could be part of biological control programs implemented for the management of the soursop pests.

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References Cited

Blackman RL, Eastop VF. 2000. Aphids on the World's Crops. An Identification and Information Guide. 2nd edition. John Wiley & Sons, Chichester, United Kingdom.

Blackwelder RE. 1944. (Elateridae, Cebrionidae, Melasidae, Trixagidae). Checklist of the Coleopterous insects of Mexico, Central America, The West Indies and South America. US National Museum Bulletin 185: 275–276, 280–305.

Blake DH. 1933. Revision of the beetles of the genus *Disonycha* occurring in America north of Mexico. Proceedings of the United States National Museum 82: 1–66.

Cambero CB, Rodríguez PM, Cambero CJ, Cham AK, Cambero CN. 2017. *Euphoria leucographa* (Gory & Percheron, 1833) (Coleoptera: Melolonthidae) en frutos de guanábana (*Annona muricata* L.) en Nayarit, México. Revista Gaditana de Entomología 3: 223–227.

Castañeda GM. 2011. Ciclo de vida y hábitos del picudo de las Annonaceas *Optatus palmaris* Pascoe: observaciones en campo y laboratorio. Bachelor thesis. Universidad Tecnológica de la Costa, Santiago Ixcuintla, Nayarit, México.

Ceballos VM, Lellani BH, Chico R, Martínez MA. 2016. Presencia en Cuba de enemigos naturales de la chinche rosada del hibisco (*Maconellicoccus hirsutus* Green). Revista de Protección Vegetal 31: 77—80.

COFEPRIS (Comisión Federal para la Protección Contra Riesgos Sanitarios). 2018. En línea. Consultada 19 de abril de 2018. (online) http://siipris03.cofepris.gob.mx/Resoluciones/Consultas/ConWebRegPlaguicida.asp (last accessed 8 Jan 2019).

Coto DA, Saunders JL. 2001. Insectos plaga de la guanábana (*Annona muricata*) en Costa Rica. Manejo Integrado de Plagas 61: 60–68.

Curran CH. 1965. The Families and Genera of North American Diptera. 2nd edition. Henry Tripp, Woodhaven, New York, USA.

Gaona GG, Cancino ER, Myartseva SN, Trjapitzin VA, Coronado JM, Mora OA. 2006. Himenópteros parasitoides (Chalcidoidea) de Coccoidea (Homoptera) en Cd. Victoria, Tamaulipas, México. Acta Zoológica Mexicana (n.s.) 22: 9–16.

Gibson GP, Humber JT, Woolley JB. 1997. Annotated keys to the Genera of Nearctic Chalcidoidea (Hymenoptera). NCR Research Press, Ottawa, Canada.

Godoy CC, Garnier XM, Nishida K. 2006. Treehoppers of tropical America. Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica.

González G. 2006. Los Coccinellidae de Chile. http://www.coccinellidae.cl/paginasWebChile/PaginasOriginal/generos.php (last accessed 3 Jan 2019).

Gordon RD. 1985. The Coccinellidae (Coleoptera) of America North of Mexico. Journal of the New York Entomological Society 93: 1–912.

Gorham HS. 1887–1899. Insecta Coleoptera. Erotylidae, Endomychidae and Coccinellidae. Biología Centrali-Americana 7: 150–246.

Gutiérrez RA, Robles BA, Santillán OC, Ortiz CM, Cambero OJ. 2013. Control biológico como herramienta sustentable en el manejo de plagas y su uso en el estado de Nayarit, México. Revista Bio Ciencias 2: 102–112.

Hernández FLM, Bautista MN, Carrillo SL, Cibrián T, Urías MA. 2006. *Bephratelloides cubensis*: comportamiento diurno y selección de frutos en guanábana (*Annona muricata*). Entomología Mexicana 5: 696–699.

Hernández FLM, Bautista MN, Carrillo SL, Urías MA. 2008. Control de *Bephratelloides cubensis* (Hymenoptera: Eurytomidae) en guanábana, *Annona muricata*. Acta Zoológica Mexicana 24: 199–206.

Hernández FLM, Gómez JR, Andrés AJ. 2013. Importancia, plagas insectiles y enfermedades fungosas del cultivo de guanábano. Libro técnico núm. 1. Campo Experimental Santiago Ixcuintla, Nayarit, México.

Hernández FLM, Valdéz CJM, Urías LMA, Gómez JR. 2015. Identificación y fluctuación poblacional de *Godonta pyrgo* (Lepidoptera: Noctuidae) en *Annona muricata*. Revista Mexicana de Ciencias Agricolas 6: 1001–1012.

Jiménez JO, Balois MR, Alia TI, Juárez LP, Sumaya MMT, Bello LJE. 2017. Caracterización de frutos de guanábana (*Annona muricata* L.) en Tepic, Nayarit, México. Revista Mexicana de Ciencias Agrícolas 7: 1261–1270.

Lasoń A, Przewoźny M. 2009. *Lobiopa insularis* (Castelnau, 1840) (Coleoptera: Nitidulidae), an introduced beetle species new for the Palaearctic fauna. Polish Journal of Entomology 78: 347–350.

MacGregor R, Gutiérrez O. 1983. Guía de insectos nocivos para la agricultura en México. Alhambra Mexicana, México.

Rodríguez PM, Cambero CJ, Luna EG, Robles BA, Cambero NKG. 2017. Entomofauna asociada al cultivo de yaca (*Artocarpus heterophyllus* Lam.) en Nayarit, México. Entomología Mexicana 4: 220–225.

Ruiz MC, Domínguez PE, Flores PR, Illescas RC. 2014. Insectos asociados al guanábano (*Annona muricata* L.) en Veracruz, México. Southwestern Entomologist 39: 367–374.

Sánchez SS, Franco MO. 2001. Presencia de *Bephratelloides cubensis* (Ashmead) (Hymenoptera: Eurytomidae) en Tabasco, México. Folia Entomológica Mexicana 40: 140. https://www.researchgate.net/publication/262014656_Presencia_de_Bephratelloides_cubensis_Ashmead_Hymenoptera_Eurytomidae_en_Tabasco_Mexico (last accessed 3 Jan 2019).

SIAP (Servicio de Información Agroalimentaria y Pesquera). 2016. http://www.siap.gob.mx/cierre-de-la-produccion-agricola-por-estado/ (last accessed 13 May 2017).

Slater JA, Baranowski RM. 1978. How to Know the True Bugs (Hemiptera-Heteroptera). Brown, Dubuque, Iowa, USA.

Stange LA. 2015. Green Lacewings of Florida (Insecta: Neuroptera: Chrysopidae). University of Florida IFAS document EENY-534. http://edis.ifas.ufl.edu/in965 (last accessed 3 Jan 2019).

Trejo LAG, Néstor JI. 2012. New records of Coccinellidae from Morelos, Mexico. Acta Zoológica Mexicana (n.s.) 28: 640–643.

Valencia LJ, Romero JN, Valdés JL, Carrillo SV, López M. 2006. Taxonomía y registros de Chrysopidae (Insecta: Neuroptera) en el estado de Morelos, México. Acta Zoológica Mexicana 22: 17–61.

Vidal HL, López MH, Vidal MNA, Ruíz BR, Castillo RDG, Chiquito CRG. 2014. La situación de las Anonáceas en México: principales plagas, enfermedades y su control. Revista Brasileira de Fruticultura 36: 44–53.

Williams DJ, Granara de Willink MC. 1992. Mealybugs of Central and South America. CAB International, Wallingford, Oxfordshire, United Kingdom.

Williams DJ, Watson GW. 1988. The Scale Insects of the Tropical South Pacific Region. Part 2: The Mealybugs (Pseudococcidae). CAB International, Wallingford, Oxfordshire, United Kingdom.

Williams DJ, Watson GW. 1990. The Scale Insects of the Tropical South Pacific Region. Part 3: The Soft Scales (Coccidae) and Other Families. CAB International, Wallingford, Oxfordshire, United Kingdom.