REPORT OF *Erpetogomphus sabaleticus* WILLIAMSON, 1918 (ODONATA: GOMPHIDAE) FEEDING ON *Diaphorina citri* KUWAYAMA (HEMIPTERA: LIVIIDAE)

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RESUMEN

La libélula *Erpetogomphus sabaleticus* Williamson, 1918 (Odonata: Anisoptera: Gomphidae) se reporta por primera vez depredando a *Diaphorina citri* Kuwayama (Hemiptera: Liviidae). Se provee una lista compilada de más de 63 especies de enemigos naturales de *D. citri* distribuidos en siete órdenes y diecisiete familias de artrópodos (insectos y arañas).

Palabras clave. Anisoptera, depredador, enemigos naturales, libélula, listado.

SUMMARY

The dragonfly *Erpetogomphus sabaleticus* Williamson, 1918 (Odonata: Anisoptera: Gomphidae) is for the first time reported preying on *Diaphorina citri* Kuwayama (Hemiptera: Liviidae). A compiled list of more than 63 species distributed in seven orders and seventeen families of arthropod (insects and spiders) natural enemies of *D. citri* is provided.

Key words. Anisoptera, checklist, dragonfly, natural enemies, predator.

INTRODUCTION

The Asian citrus psyllid, *Diaphorina citri* Kuwayama, 1908 (Hemiptera: Liviidae) is an insect vector of the phloem-limited bacteria (*Candidatus Liberibacter* spp.) which cause citrus greening disease (Huanglongbing) or HLB, one of the world's most serious diseases of citrus (Aubert 1990, McClean & Schwartz 1970, Halbert & Manjunath 2004, Mead & Fasulo 2010). Apart from being a vector of HLB, *D. citri* can cause direct damage to its host plant by sucking large amounts of sap, injecting toxins that cause malformation of leaves and shoots and by inducing sooty molds that grow on the honeydew they excrete (Michaud 2004). The Asian citrus psyllid *D. citri* is an economically important citrus pest in many citrus growing regions of the world (Halbert & Manjunath 2004, Manjunath *et al.* 2008). *Diaphorina citri* has a worldwide distribution, and has been recorded from Asia (Afghanistan, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Japan, Lao, Macau, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam), Africa (Mauritius, Réunion), the Caribbean (Bahamas, Belize, Cayman Islands, Cuba, Dominican Republic, Guadeloupe, Jamaica, Puerto Rico, and St. Thomas), Central America (Honduras, Mexico) and from South America (Argentina, Brazil, Colombia,

Paraguay, Uruguay and Venezuela) (Augier *et al.* 2006, Cermeli *et al.* 2007, EPPO 2005, ICA 2010, Kondo & Simbaqueba 2014, Kondo *et al.* 2012). The Asian citrus psyllid was reported in the New World for the first time in Brazil in 1942 (Costa-Lima 1942), and it was only until fairly recently that it was reported from Colombia in 2007. Since then, *D. citri* has been recorded in Colombia from the Departments of Antioquia, Atlántico, Bolívar, Caldas, Cauca, Cesar, Córdoba, Cundinamarca, Magdalena, Meta, Norte de Santander, Quindio, Risaralda, Santander, Sucre, Tolima, and Valle del Cauca (ICA 2010, Ebratt-Ravelo *et al.* 2011a, b, Kondo & Simbaqueba 2014, Kondo *et al.* 2012). In Colombia, *D. citri* is commonly found on *Citrus* spp., *Murraya paniculata* (L.) Jack and *Swinglea glutinosa* (Blanco) Merr. (Rutaceae) (T. Kondo, pers, obs.).

In recent years, populations of *D. citri* have increased in citrus orchards in rural areas and house gardens in urban areas in Colombia. In order to find biological control options to control *D. citri*, natural enemies of *D. citri* were searched in the department of Valle del Cauca, Colombia. During this study, a dragonfly of the family Gomphidae (Odonata: Anisoptera) was captured preying upon an adult *D. citri* in a citrus grove. The adults of some odonate species visit field crops such as cotton and rice in search of prey, helping to control pests of these crops (Rathod *et al.* 2012), including species in the Gomphidae family (Rathod *et al.* 2012, Ghahari *et al.* 2009). This is the first report of an insect belonging to the order Odonata preying on *D. citri*.

MATERIALS AND METHODS

Field trips were carried out in the Department of Valle del Cauca, between February and May 2014, in the municipalities of Candelaria, El Cerrito, Florida, Palmira, Pradera and Zarzal, in order to collect natural enemies of *D. citri* in citrus (*Citrus* spp.) orchards, and hedges of *M. paniculata* and *S. glutinosa*. Flying insects were collected with an insect net through sweeping, preserved in 70 % ethyl alcohol and labeled with their collecting data. The dragonfly was identified using the keys by Garrison (1994) and Garrison *et al.* (2006).

RESULTS

The dragonfly was identified as *Erpetogomphus sabaleticus* Williamson, 1918 (Odonata: Anisoptera: Gomphidae) (Fig. 1), a species found in Colombia, Panama and Venezuela (Paulson 2009). In Colombia, *E. sabaleticus* has been recorded from the Departments of Antioquia, Magdalena, Tolima and from Valle del Cauca (present study). *Erpetogomphus sabaleticus* has been found in streams and adjacent forests (Williamson 1918, Garrison 2004), but this is the first record of this species in a cultivated area, namely, a citrus orchard. This is the first report on the eating habits of *E. sabaleticus*, and also the first report of a dragonfly feeding on *D. citri* (Fig. 1).

Specimen Repository. MCUB-He: Museo de Ciencias Universidad El Bosque, Bogotá, Colombia.

Natural enemies of *Diaphorina citri*. Despite the importance of *D. citri* as a vector of HLB, very few studies on natural enemies of *D. citri* have been carried out in Colombia, with the exception of those that report the presence of the ectoparasitoid *Tamarixia radiata* Waterston (Hymenoptera: Eulophidae) in various regions of mainland Colombia (Ebratt *et al.* 2011a, b, Kondo *et al.* 2012). Herein we have compiled a list based on records of natural enemies of *D. citri* from the literature plus a gomphid dragonfly collected in the present study. The bulk of natural enemies of *D. citri* are generalist predators. With the addition of *E. sabaleticus*, the list of natural enemies of the class Arthropoda is increased to more than 63 species, distributed in seven orders and seventeen families, namely, Araneae [Anyphaenidae (1 sp.), Miturgidae (1 sp.), Oxyopidae (1 sp.), Salticidae (2 spp.)], Coleoptera [Carabidae (1 sp.), Coccinellidae (28 spp.), Histeridae (1 sp.)], Diptera [Syrphidae (6 spp.)], Hemiptera [Anthocoridae (2 spp.), Geocoridae (1 sp.), Reduviidae (2 spp.)], Hymenoptera [Encyrtidae (1 sp.), Eulophidae (1 sp.), Formicidae (2 spp.)], Neuroptera [Chrysopidae (11 spp.), Hemerobiidae (1 sp.)] and Odonata [Gomphidae (1 sp.)] (Table 1). Of the 63 species of arthropods that have been reported preying on *D. citri*, 7.9 % (5 spp.) are spiders and 92.1 % (58 spp.) are insects.

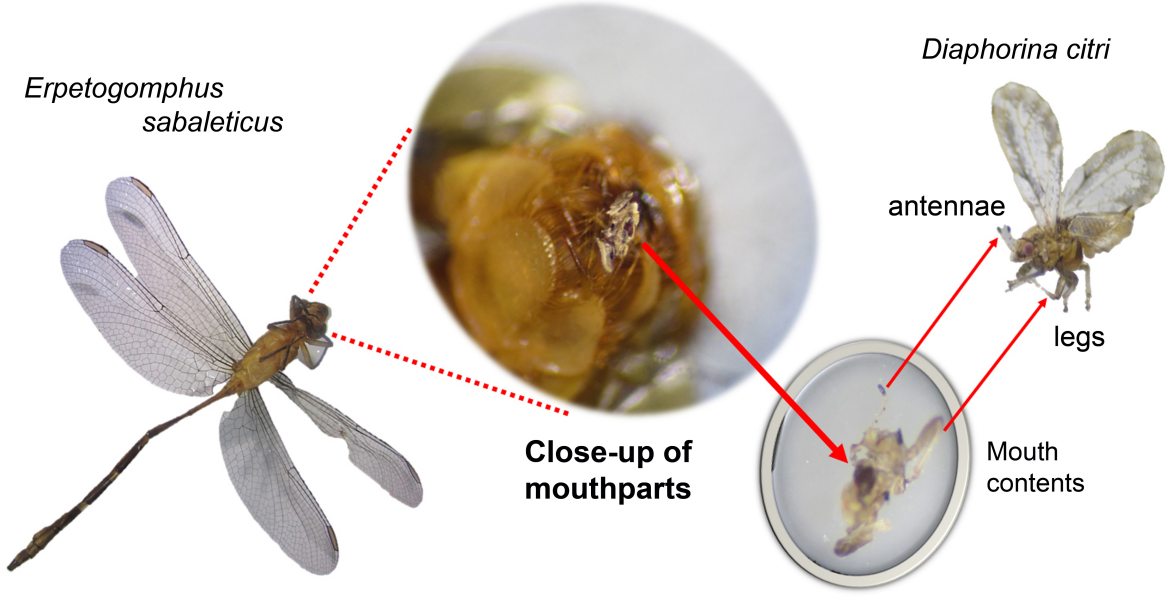

Figure 1. Remains of *Diaphorina citri* (Hemiptera: Liviidae) found inside mouthparts of the gomphid dragonfly *Erpetogomphus sabaleticus* (Odonata: Anisoptera: Gomphidae).

Material studied. *Erpetogomphus sabaleticus* Williamson, 1918 (Odonata: Anisoptera: Gomphidae), 1 adult male (♂). Colombia: Valle del Cauca, Candelaria, 26.iii.2014, coll. Richard D. Peña Cuellar, collected while feeding on Asian citrus psyllid, *Diaphorina citri*.

Of the 58 species of insects, almost half (48.3 %; 28 spp.) are lady beetles (Coleoptera: Coccinellidae), with the most commonly cited species being *Cycloneda sanguinea* (Linnaeus) (Chong *et al.* 2010, González *et al.* 2001, 2002, González-Cárdenas *et al.* 2012, Hall *et al.* 2008, Lozano-Contreras *et al.* 2012, Michaud 2002, 2004, Miranda-Salcedo & López-Arroyo 2010, Rodríguez-Palomera *et al.* 2012, Rodríguez-Toledo *et al.* 2008), *Olla v-nigrum* (Mulsant) (Hall *et al.* 2008, Lozano-Contreras *et al.* 2012, Michaud 2002, 2004, Miranda-Salcedo & López-Arroyo 2010, Rodríguez-Palomera *et al.* 2012), *Chilocorus cacti* (Linnaeus) (González *et al.* 2001, 2002, Lozano-Contreras *et al.* 2012, Rodríguez-Palomera *et al.* 2012, Rodríguez-Toledo *et al.* 2008) and *Harmonia axyridis* (Pallas) (Chong *et al.* 2010, Hall *et al.* 2008, Michaud 2002, 2004). The multicolored Asian lady beetle, *H. axyridis* was recently reported from Colombia (Brown *et al.* 2011, Amat-García *et al.* 2011, Kondo & Gonzalez 2013) where it has become well established (Kondo & Gonzalez 2013). Based on museum insect specimens, Kondo & Gonzalez (2013) estimated the introduction of *H. axyridis* in Colombia to have occurred in 1989 or earlier, making it the second oldest record of *H. axyridis* in South America after it was deliberately released in Argentina in 1986. The next group of abundant natural enemies are the lacewings (Neuroptera: Chrysopidae) with 20.7 % (12 spp.). Amongst the lacewings *Chrysoperla rufilabris* (Burmeister) (Lozano-Contreras *et al.* 2012, Michaud 2002, 2004, Miranda-Salcedo & López-Arroyo 2010) is the most cited species followed by *Mallada boninensis* (Okamoto) (Chien & Chu 1996, Lin *et al.* 1973, Yang *et al.* 2006) and *Chrysopa* spp. (González *et al.* 2001, 2002, Hall *et al.* 2008, Lozano-Contreras *et al.* 2012, Rodríguez-Toledo *et al.* 2008). On the third place are the hover flies (Diptera: Syrphidae) with 10.3 % (6 spp.), with members of the genera *Allograpta* Osten Sacken (Aubert 1987, Hall *et al.* 2008, Michaud 2002, 2004) and *Ocyptamus* Macquart (González *et al.* 2001, 2002, Michaud 2004, Rodríguez-Toledo *et al.* 2008) being the most common according to the number of bibliographical citations. The rest of natural enemies include the carabid beetle *Egaploa crenulata* (Dejean) (Coleoptera: Carabidae) (Al-Ghamdi 2000), a histerid beetle *Saprinus*

chalcites (Illiger) (Coleoptera: Histeridae) (Al-Ghamdi 2000), two species of minute pirate bugs, *Anthocorus* sp. and *Orius* sp. (Hemiptera: Anthocoridae) (Michaud 2002), a bigeyed bug *Geocoris* sp. (Hemiptera: Geocoridae) (Chien & Chu 1996), two species of assassin bugs, *Zelus longipes* (Miranda-Salcedo & López-Arroyo 2010, Hall *et al.* 2008) and *Zelus* sp. (Michaud 2002) (Hemiptera: Reduviidae), two species of parasitoid wasps *Diphorencyrtus aligarhensis* Shafee, Alam & Agarwal (Hymenoptera: Encyrtidae) (Aubert 1987, Aubert & Quilici 1984, Chien & Chu 1996, Chu & Chien, 1991, García-Darderes 2009, Hoy & Nguyen 1998, Michaud 2002, Yang *et al.* 2006) and *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae) (Baños-Díaz *et al.* 2013; Chien & Chu, 1996, Chu & Chien 1991, Ebratt-Ravelo *et al.* 2011a, b, García-Darderes 2009, González *et al.* 2001, 2002, Hoy & Nguyen 1998, Kondo *et al.* 2012, Michaud 2002, 2004, Miranda *et al.* 2011, Miranda-Salcedo & López-Arroyo 2010, Rodríguez-Toledo *et al.* 2008, Yang *et al.* 2006), two ant species, namely *Dorymyrmex bureni* (Trager) and *Pseudomyrmex gracilis* (Fabricius) (Hymenoptera: Formicidae) and a brown lacewing *Micromus posticus* (Walker) (Neuroptera: Hemerobiidae) (Table 1).

Table 1. Arachnids and insects reported as natural enemies of *Diaphorina citri*.

Taxonomy (Order/Family/Species)	Country and reference
Araneae	
Anyphaenidae	
Hibana velox (Becker, 1879)	USA (Michaud 2002, 2004)
Miturgidae	
Cheiracanthium inclusum (Hentz, 1847)	USA (Michaud 2002)
Oxyopidae	
Oxyope sp.	USA (Michaud 2002)
Salticidae	
Hentzia palmarum (Hentz, 1832)	USA (Michaud 2002)
Marpissa tigrina Tikader, 1965	India (Sanda 1991)
Coleoptera	
Carabidae	
Egaploa crenulata (Dejean, 1829)	Saudi Arabia (Al-Ghamdi 2000)
Coccinellidae	
Arawana sp.	Mexico (Lozano-Contreras *et al.* 2012)
Azya orbigera Mulsant, 1850	Mexico (Lozano-Contreras *et al.* 2012)
Brachiacantha dentipes (Fabricius, 1801)	USA (Michaud 2004)
Brumus suturalis (Fabricius, 1798)	India (Husain & Nath 1927, Pruthi & Mani 1945)
Cheilomenes sexmaculata (Fabricius, 1781)	China (Lin *et al.* 1973), Taiwan (Chien & Chu 1996), India (Husain & Nath 1927, Pruthi & Mani 1945)
Chilocorus cacti (Linnaeus, 1767)	Cuba (González *et al.* 2001, 2002, Rodríguez-Toledo *et al.* 2008), Mexico (Lozano-Contreras *et al.* 2012, Rodríguez-Palomera *et al.* 2012)
Chilocorus nigrita (Fabricius,1798)	India (Husain & Nath 1927, Pruthi & Mani 1945)
Chilocorus stigma (Say, 1835)	Mexico (González-Cárdenas *et al.* 2012), USA (Chong *et al.* 2010).
Coccinella repanda Thunberg, 1781	India (Husain & Nath 1927, Pruthi & Mani 1945)
Coccinella septempunctata (Linnaeus, 1758)	India (Husain & Nath 1927, Pruthi & Mani 1945)
Coelophora inaequalis (Fabricius, 1775)	USA (Michaud 2002, 2004)
Coleomeguilla maculata (De Geer, 1775)	USA (Michaud 2002)
Curinus coeruleus (Mulsant, 1850)	Mexico (González-Cárdenas *et al.* 2012), USA (Chong *et al.* 2010, Hall *et al.* 2008, Michaud 2002, 2004)
Cycloneda devestita (Mulsant, 1850)	Venezuela (Solano *et al.* 2014)

Cycloneda sanguinea (Linnaeus, 1763)	Cuba (González *et al.* 2001, 2002, Rodríguez-Toledo *et al.* 2008), USA (Chong *et al.* 2010; Michaud 2002, 2004), Mexico (González-Cárdenas *et al.* 2012, Hall *et al.* 2008, Lozano-Contreras *et al.* 2012, Miranda-Salcedo & López-Arroyo 2010, Rodríguez-Palomera *et al.* 2012)
Delphastus sp.	Mexico (Lozano-Contreras *et al.* 2012)
Exochomus childreni Mulsant, 1850	USA (Michaud 2002, 2004)
Exochomus cubensis Dimmock, 1906	Cuba (González *et al.* 2001, 2002)
Harmonia axyridis (Pallas, 1773)	USA (Chong *et al.* 2010, Hall *et al.* 2008, Michaud 2002, 2004)
Hippodamia convergens (Guérin-Méneville, 1842)	Mexico (González-Cárdenas *et al.* 2012, Miranda-Salcedo & López-Arroyo 2010)
Nephus sp.	Mexico (Rodríguez-Palomera *et al.* 2012)
Olla v-nigrum (Mulsant, 1866)	USA (Hall *et al.* 2008, Michaud 2002, 2004), Mexico (Lozano-Contreras *et al.* 2012, Miranda-Salcedo & López-Arroyo 2010, Rodríguez-Palomera *et al.* 2012)
Pentilia sp.	Mexico (Rodríguez-Palomera *et al.* 2012)
Rodolia cardinalis (Mulsant, 1850)	USA (Michaud 2004)
Scymnus distinctus Casey, 1924	Cuba (González *et al.* 2001, 2002)
Scymnus spp.	Brazil (Gravena *et al.* 1996)
Serangium sp.	Taiwan (Chien & Chu 1996)
Zagloba sp.	Mexico (Lozano-Contreras *et al.* 2012)
Histeridae	
Saprinus chalcites (Illiger, 1807)	Saudi Arabia (Al-Ghamdi 2000)
Diptera	
Syrphidae	
Allograpta obliqua (Say, 1823)	USA (Michaud 2002, 2004)
Allograpta sp. (probably *A. obliqua* Say)	USA (Hall *et al.* 2008)
Allograpta spp.	Nepal (Aubert 1987), Reunion island (Aubert 1987)
Ocyptamus sp.	Cuba (González *et al.* 2001, 2002, Rodríguez-Toledo *et al.* 2008)
Ocyptamus fuscipennis (Say, 1823)	USA (Michaud 2004)
Pseudodorus clavatus (Fabricius, 1794)	USA (Michaud 2002)
Hemiptera	
Anthocoridae	
Anthocorus sp.	USA (Michaud 2002)
Orius sp.	USA (Michaud 2002)
Geocoridae	
Geocoris sp.	Taiwan (Chien & Chu 1996)
Reduviidae	
Zelus sp.	USA (Michaud 2002)
Zelus longipes (Linnaeus, 1767)	Mexico (Miranda-Salcedo & López-Arroyo 2010), USA (Hall *et al.* 2008)
Hymenoptera	
Encyrtidae	
Diphorencyrtus aligarhensis Shafee, Alam & Agarwal, 1975	Argentina (García-Darderes 2009), China (Yang *et al.* 2006), India, Philippines (Aubert 1987), Reunion island (Aubert & Quilici 1984), USA (Hoy & Nguyen 1998, Michaud 2002), Taiwan (Chien & Chu 1996, Chu & Chien 1991), Vietnam (Aubert 1987)
Eulophidae	
Tamarixia radiata (Waterston, 1922)	Argentina (García-Darderes 2009); Colombia (Ebratt-Ravelo *et al.* 2011a, b, Kondo *et al.* 2012), China (Yang *et al.* 2006), Cuba (Baños-Díaz *et al.* 2013, González *et al.* 2001, 2002, Miranda *et al.* 2011, Rodríguez-Toledo *et al.* 2008), USA (Hoy & Nguyen 1998; Michaud 2002, 2004), Mexico (Miranda-Salcedo & López-Arroyo 2010), Taiwan (Chien & Chu 1996; Chu & Chien 1991)
Formicidae	
Dorymyrmex bureni (Trager, 1988)	USA (Michaud 2004)

Pseudomyrmex gracilis (Fabricius, 1804)	USA (Michaud 2004)
Neuroptera	
Chrysopidae	
Ceraeochrysa claveri (Navás, 1911)	Mexico (Lozano-Contreras *et al.* 2012)
Ceraeochrysa cubana (Hagen, 1861)	Mexico (Lozano-Contreras *et al.* 2012)
Ceraeochrysa everes (Banks, 1920)	Mexico (Lozano-Contreras *et al.* 2012)
Ceraeochrysa sp. nr. *cincta* (Schneider, 1851)	Mexico (Lozano-Contreras *et al.* 2012)
Ceraeochrysa spp.	USA (Michaud 2002, 2004), Mexico (Rodríguez-Palomera *et al.* 2012)
Ceraeochrysa valida (Banks, 1895)	Mexico (Lozano-Contreras *et al.* 2012)
Chrysopa septempunctata Wesmael, 1841	China (Yang *et al.* 2006)
Chrysopa spp.	Cuba (González *et al.* 2001, 2002, Rodríguez-Toledo *et al.* 2008), Mexico (Lozano-Contreras *et al.* 2012), USA (Hall *et al.* 2008)
Chrysoperla rufilabris (Burmeister, 1839)	USA (Michaud 2002, 2004), Mexico (Lozano-Contreras *et al.* 2012; Miranda-Salcedo & López-Arroyo 2010)
Chrysoperla spp.	USA (Michaud 2004), Mexico (Lozano-Contreras *et al.* 2012)
Mallada boninensis (Okamoto, 1914)	China (Lin *et al.* 1973, Yang *et al.* 2006), Taiwan (Chien & Chu 1996)
Hemerobiidae	
Micromus posticus (Walker, 1853)	USA (Michaud 2002)
Odonata	
Gomphidae	
Erpetogomphus sabaleticus Williamson, 1918	Present study

DISCUSSION

A general characteristic of arthropods reported as natural enemies of *D. citri* is that all recorded species are generalist predators, for the exception of the parasitoids *T. radiata* and *D. aligarhensis*. Michaud (2004) reported eight different ant species that were observed on *D. citri* infested terminals, usually harvesting honeydew, of which only two species, namely *Dorymyrmex bureni* and *Pseudomyrmex gracilis* were observed carrying away *D. citri* nymphs. Thus, in Table 1, we only listed these two ant species that had some evidence of predation (i.e., carrying away *D. citri* nymphs), as the other six species listed by Michaud (2004) were only observed nearby the psyllids or tending them (i.e., feeding on the honeydew).

Very few studies have looked into the importance of dragonflies as natural enemies of plant pests, although they may be mentioned as having some degree of predatory role. For example, in a study carried in the Philippines, insects in the order Odonata are listed as being recorded feeding on the brown planthopper, *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae), a well-known pest of rice plants (*Oryza sativa* L.) (Chiu 1979). However, most studies on dragonflies as natural enemies deal with controlling mosquito larvae. Sebastian *et al.* (1990) reported a great reduction on a population of *Aedes aegypti* (L.) (Diptera: Culicidae) through augmentative releases of nymphs of a dragonfly, *Crocothemis servilia* (Drury, 1773) (Odonata: Libellulidae) during the rainy season in Yangon (Rangoon), Myanmar. Furthermore, in a study carried out in the suburbs of Omiya City, Japan, during June-July 1979, Urabe *et al.* (1990) reported that nymphs of the Autumn Darter, *Sympetrum frequens* (Selys 1883) (Odonata: Libellulidae) plays an important role as a natural enemy of the larvae of the mosquito, *Anopheles sinensis* Wiedemann, 1828 (Diptera: Culicidae).

Although, hitherto dragonflies have not been listed as natural enemies of *D. citri*, these generalist predators may contribute to the reduction of populations of *D. citri* in orchards that are found near marshes, lakes, ponds, streams, and wetlands. Beneficial insects may help control insect pest populations by enhancing their efficacy and local abundance through modification of the environment or existing management practices, a practice known as conservation biological control (Barbosa 1998). This pest

management method using dragonflies as natural enemies may be efficient in such areas near water bodies where there is little use of pesticides.

CONCLUSIONS

With the addition of *E. sabaleticus*, the number of known arthropod natural enemies is increased to more than 63 species. Further studies are needed to determine the predation rate of *E. sabaleticus* on *D. citri* populations in areas where the distribution of the two species overlap.

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