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SHORT COMMUNICATION

Geographic Origin and Taxonomic History of *Delphastus* spp. (Coleoptera: Coccinellidae) in Commercial Culture

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Most of the published studies of Delphastus pusillus *biology and behavior on* Bemisia *spp. actually refer to* D. catalinae*. Similarly,* Delphastus *species in commercial insectary cultures are probably* D. catalinae *and not* D. pusillus*. We discuss the historical reasons for the clouded identity of these native coccinellid beetles.*

Keywords: *whitefly predator,* Delphastus catalinae*,* Delphastus pusillus*,* Bemisia tabaci*,* Bemisia argentifolii

The proper identification of mass-produced natural enemies is of constant concern to commercial insectaries and their clients. Correct identification of a biological control agent is essential to ensure quality control and to validate biological studies and efficacy trials. During the early 1990s there were severe problems managing outbreaks of invasive *Bemisia* species in Florida and elsewhere in North America, a trend that has continued in other regions of the world. This situation stimulated a search for new biological control agents of whitefly (Hoelmer *et al.,* 1994a; Henneberry *et al.,* 1998). One of those discovered, the native coccinellid beetle *Delphastus catalinae* (Horn), is a valuable predator that has been cultured and sold commercially worldwide for the past decade as a whitefly-specific predator under the name *D. pusillus* (le Conte). In this communication we address questions that have arisen concerning the origin and proper nomenclature of the species (Booth & Polaszek, 1996).

Substantiated records of prey for *Delphastus* species are limited to whiteflies (Homoptera: Aleyrodidae), especially those species occurring on citrus [see Gordon (1994) for a summary]. *Delphastus pusillus* and *D. pallidus* (le Conte) have been commonly found in surveys of predators attacking citrus whitefly in central Florida (c.f. Muma, 1955; Muma *et*

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al., 1961; Cherry & Dowell, 1979). *Delphastus catalinae* was first noted as a predator of *Bemisia tabaci* (Genn.) biotype 'B' (= *B. argentifolii* Bellows & Perring) in certain greenhouses in central Florida (Apopka) during the late 1980s by L.S. Osborne (University of Florida). He subsequently established a culture of *Delphastus* from individuals collected on whitefly-infested papaya in order to evaluate its potential as a predator of *B. tabaci*. Specimens from the culture were originally identified as *D. pusillus* (le Conte) based on the descriptions and keys for the genus that were available at the time (Gordon, 1970, 1985). This determination was supported by the view that *D. pusillus* was widely distributed across the southern U.S. from east to west coasts, very common in the southeastern U.S., with a tendency to be morphologically variable. However, it was readily distinguished from the only other species of *Delphastus* then known from Florida, *D. pallidus*. In contrast, *D. catalinae* was recorded only from a small section of southern California coastline (Gordon, 1970).

A number of biological studies and greenhouse evaluations were conducted that demonstrated the efficacy of *D. catalinae* (as *D. pusillus*) against *B. tabaci* and provided basic information necessary for the successful culture and use of the predator (Hoelmer *et al*., 1993, 1994b; Heinz & Parrella, 1994; Heinz & Nelson, 1996; Liu *et al*., 1997). Beetles from the central Florida culture were distributed to various researchers and eventually to commercial insectaries throughout North America and internationally in response to requests for new natural enemies of *Bemisia*.

The genus *Delphastus* is native to the Nearctic (Gordon, 1994; Booth & Polaszek, 1996). In a major revision of the genus, Gordon (1994) amended the original descriptions of several species, described new species, and updated the known geographic distributions. Two species, *D. dejavu* Gordon and *D. sonoricus* Casey, previously considered conspecific with *D. pusillus,* have western U.S. distributions. As a result, the distribution of *D. pusillus* is now restricted to the eastern half of the U.S., and that of *D. catalinae* is recorded as extending from Colombia north through Mexico into coastal southern California, and to the east to the island of Trinidad in the West Indies. *Delphastus catalinae* is known to have been introduced deliberately for purposes of biological control into Hawaii (from Trinidad), into Fiji (possibly from Hawaii), and (perhaps unintentionally) to the Canary Islands (Booth & Polaszek, 1996). Gordon's revision raised questions regarding the actual identity of the central Florida *Delphastus* species. Between 1994 and 1996, a number of specimens from the U.S., Israel, The Netherlands, and the UK were examined which were identified as *D. catalinae* (Booth & Polaszek, 1996; KAH & CHP). The central Florida *Delphastus* population was very likely the origin of the majority of cultures that produced these specimens. Other releases of material from commercial cultures reported to be *D. pusillus* (e.g., Fransen, 1994; Halperin *et al*., 1995, as cited in Booth & Polaszek, 1996) are also likely to have been *D. catalinae*. We re-examined specimens from our own voucher collections and determined that all specimens from cultures were *D. catalinae.* Wild specimens collected on various host plants at several sites in central Florida in 1989 were also *D. catalinae.* However, specimens of *Delphastus* collected on *Hibiscus mutabilis* L. in LaBelle (southern Florida) by T.–X. Liu in 1993 were *D. pusillus*.

Concurrently, new information became available to us regarding field releases of *D. catalinae* obtained from the western U.S. that were made early in the 20th century in Florida. In September 1916, 12 individuals of *D. catalinae* were imported from California for insectary rearing. The following year more beetles were imported and were released in the Clearwater and Bradenton areas along Florida's Gulf coast against citrus whitefly, *Dialeurodes citri* Ashmead. By 1918, many individuals of *Delphastus* were found at one of the release sites. These were thought to be *D. catalinae* and some of these were redistributed to other sites in western Florida (Watson, 1918; summary in Frank & McCoy, 1993). According to the early reports, the beetles increased their numbers at many locations across Florida and were thought to have established along the western coast of Florida, and to have reduced citrus whitefly populations in the areas of release. However, it was reported that they

became scarce again as citrus whitefly became less abundant, and there was no attempt subsequently to document their spread or establishment (Watson, 1923). *Delphastus catalinae* was not found during a comprehensive 10-year survey of citrus pest natural enemies in Florida (Muma, 1955; Muma *et al*., 1961) and no recent records have been reported, so it was assumed that *D. catalinae* had since become very rare or disappeared completely from citrus groves (Muma, 1953; Browning, 1994). Frank and McCoy (1993) reported that no vouchers from the original introductions could be found. Specimens of *Delphastus* collected in west Florida in 1918 were identified as *D. catalinae* by the collector, H.B. Swartsel, but these same specimens were later re-identified as *D. pusillus* by A.J. Mutchler (Am. Mus. Nat. Hist.). As of 1992, there were no specimens identified as *D. catalinae* in the Florida State Collection of Arthropods (Frank & McCoy, 1993). These authors suggested that the coccinellids recovered in the release areas and thought to be *D. catalinae* were, in fact, *D. pusillus.*

In 1917, another *Delphastus* species, *D. sonoricus* Casey, was imported from California by J.R. Watson for release against citrus whitefly (Merrill, 1922). Although Frank and McCoy (1993) stated that Merrill's report did not specify whether this species was actually released, Merrill wrote "this *Delphastus* has not, as yet, become of great importance in controlling the whiteflies" which clearly implies that it was released. The species was synonymized with *D. pusillus* by Gordon (1970) but was reinstated as a distinct species in his more recent revision. Ironically, *D. pusillus* from Florida was also introduced, many years later, into southern California against citrus whitefly, where it was recovered initially but was not thought to be effective (Rose & de Bach, 1981).

One of us (CHP) visited Florida in October 2000 to re-examine the specimens of *Delphastus* in the Florida State Collection of Arthropods (Gainesville, FL). Twenty-six collections of individual or series of beetles with collection dates from 1918 to 1988 were examined (Table 1). Identification was based on the presence or absence of coarse punctation on the prosternum of both sexes, an easily determined and unambiguous key character in Gordon's revised *Delphastus* key (Gordon, 1994). All of the specimens examined were found in specimen drawers labelled as *D. pusillus* except for two collections in a drawer marked 'unidentified' specimens. Based on the punctation character alone, all specimens collected prior to 1960 (eight collections) that had been identified originally as *D. pusillus* were, in fact, *D. pusillus.* This includes the specimens from 1918, originally called *D. catalinae* but re-identified by Mutchler as *D. pusillus.* The oldest specimen of *Delphastus* in the Florida State Collection now identified as *D. catalinae* by CHP was collected in Tampa, Florida in May 1960. There were 19 additional collections (one or more specimens per date and site) made between 1960 and 1988. Of these, five had been identified as *D. pusillus,* but were actually *D. catalinae*. One of the previously unidentified collections, from *Dialeurodes citri* on citrus, included both *D. pusillus* and *D. catalinae* specimens from the same site on the same day.

During the October 2000 trip, although it was late in the season, a field survey was made to collect additional *Delphastus* adults at various locations (from north to south: Gainesville, Apopka, Orlando, Vero Beach, Ft. Pierce, Bradenton/Palmetto). Infestations of various whiteflies (*Aleurodicus dugesii* Cockerell on hibiscus*, Aleurothrixus floccosus* (Maskell) on citrus, magnolia and seagrape, and *Trialeurodes variabilis* (Quaintance) on papaya) were located at nine sites. Coccinellids feeding on the whiteflies were found at four sites, including two sites where *Nephaspis oculatus* (Blatchley) was identified, but no *Delphastus* species were found at any site.

Today, three species of *Delphastus* occur in Florida (*catalinae*, *pallidus*, and *pusillus*). Based on the discussion above, we propose two possible origins for how the *D. catalinae* which established the cultures used for research in Florida on *B. tabaci* strain 'B', and which have been widely disseminated for biological control purposes during the past decade, came to be present in Florida. The first explanation is that *D. catalinae* became permanently established in Florida following its purposeful introduction against *D. citri* early in last

TABLE 1. Florida Dept. Agriculture collection (Gainesville, FL) specimens of *Delphastus* spp. collected in Florida examined by C.H. Pickett in 2000. All specimens came from trays labelled as *Delphastus pusillus,* or were, in a few cases, unidentified specimens

Collection date	Location	Host plant, if indicated	Host whitefly, if indicated	Collector/identifier named on label	No. examined/total in series	New identification by CHP
Sept. 14, 1918	Manatee Co.			Mutchler	3/18	*pusillus*
Oct. 24, 1921	Oakland				4/8	*pusillus*
Aug. 7, 1953	Dade Co., Miami			Link	1/1	*pusillus*
Oct. 16, 1953	Alachua Co., Gainesville	*Gardenia*		Frost	5/8	*pusillus*
Jun. 5, 1954	Dade Co.	*Callicaspa americana*		Merrill	1/1	*pusillus*
Jan. 26, 1955	Sarasota Co., F.W. Mead Stn.	Lychee			1/1	*pusillus*
Aug. 2, 1955	Santa Rosa Co.	*Prunus carolina*		F. W. Mead	1/1	*pusillus*
Jan. 12, 1957	Dade Co., Miami	Trema		Weems	1/1	*pusillus*
May 10, 1960	Tampa			C. W. Hale	1/1	*catalinae*
May 27, 1964	Alachua Co., Gainesville			R. White	1/1	*pusillus*
Oct. 1, 1964	Apopka	Citrus			1/1	*pusillus*
Sept. 18, 1967	Edgewater				1/1	??
May 2, 1974	Alachua Co., Gainesville		whitefly		1/1	*pusillus*
Sept. 20, 1974	Alachua Co., Gainesville		Citrus whitefly	R. Gordon	1/1	*catalinae*
July 10, 1975	Alachua Co., Gainesville?	Citrus?	*Dialeurodes citri*		3/3	*pusillus*
July 10, 1975	Alachua Co., Gainesville?	Citrus?	*Dialeurodes citri*		2/2	*catalinae*
Feb. 9, 1976	Dade Co., Miami				2/2	*pusillus*
Feb. 24, 1976	Broward Co.				2/2	*pusillus*
Jun. 22, 1977	Broward Co., Ft. Lauderdale	Citrus		R. Schimmel	1/1	*pusillus*
April 7, 1978	Highland Co., Archibold Biol. Stn.			H. W. Weems Jr. & L.L. Lampert Jr.	2/2	*pusillus*
Aug. 29, 1979	Broward Co., Ft. Lauderdale			R. Gordon	1/1	*pusillus*
Sept. 10, 1982	Broward Co., Hollywood	Guava		B. Harrell	1/1	*catalinae*
Dec. 16, 1982	Dade Co., Homestead	Black olive		R. Gordon	1/1	*catalinae*
Aug. 30, 1987	Alachua Co., Gainesville		Dialeurodes	F. Bennett	1/1	*pusillus*
April 15, 1988	Manatee Co., Ellenton	Citrus	Citrus black fly	R. Nguyen	2/2	*pusillus*
July 24, 1988	Manatee Co., Palmetto	Citrus	*Aleurocanthus woglumi*	F. Bennett	2/2	*catalinae*
Oct. 7, 1988	Pinellas Co., Clearwater	Carica			3/3	*pusillus*

century, although its widespread occurrence was not evident for more than half a century. This seems unlikely, given the extensive surveys of beneficial insects in citrus and among other whiteflies found in Florida, but it cannot be ruled out. The second explanation is that *D. catalinae* was reintroduced into Florida sometime during the latter half of the past century. This could have happened in several ways, with a few individual beetles (perhaps as eggs, larvae or pupae) hitchhiking on infested plant material entering Florida from elsewhere, or the beetles may have arrived naturally from other parts of their current distribution. *D. catalinae* has been reported from Trinidad and Mexico, and its historical distribution may have been close to Florida, and possibly within range of dispersal by exceptional weather conditions. Gordon (1994) suggested that the species is native to Colombia and expanded from that origin, possibly due to increased trade in plant material. Arrival on plant material seems to us the most probable means for its arrival in Florida, just as many new invasive pests have been introduced, sometimes with their natural enemies. Repeated introductions by any of these mechanisms may have occurred more than once until a population became widely established.

The central Florida culture of *Delphastus* from which shipments were sent to other researchers a decade ago conceivably could have included both *D. catalinae* and *D. pusillus*, although the limited number of voucher specimens from this culture in the possession of KAH are all *D. catalinae*. In 1993, the California Department of Food and Agriculture (CDFA) Biological Control Program obtained some of these beetles for a mass-rearing program and eventually released 33 000 beetles at urban and rural home sites in Imperial County, CA, and Mexicali, Baja California (Mexico) for control of *Bemisia tabaci* strain 'B' (Roltsch *et al.,* 1994). Voucher specimens from the CDFA rearing that have been identified have all been *D. catalinae.* Although the beetles reproduced when they were confined in cages on infested host plants, they apparently failed to establish after their release.

Also in 1993, 1000 beetles from the CDFA rearing were released at two home sites on mulberry whitefly, *Tetraleurodes mori* (Quaintance), on mulberry trees in Tulare County, CA, in the hope they would establish in the San Joaquin Valley (Pickett & Roltsch, 1996; Pickett *et al.*, 1997). Specimens recovered in 1996 and 1997 from mulberry trees were identified as predominantly *D. dejavu*, a species whose western distribution extends into California. However, some beetles recovered ca. 50 km from one of these release sites in 1997 were identified as *D. pusillus*. Since voucher specimens of the CDFA culture and its parent culture in Florida were all *D. catalinae*, it is not likely that the beetles released by CDFA in 1993 included both *D. catalinae* and *D. pusillus*, but with only *D. pusillus* surviving after field release. A more likely possibility, given the similarity between them, is that the specimens identified as *D. pusillus* may be attributed to one of the closely related western species previously considered conspecific, *D. dejavu* or *D. sonoricus*.

It is reasonable to suppose that *Delphastus* species from different geographic regions might vary significantly in their biological traits and capabilities as predators, thus it is important to note that most if not all of the published studies of *D. pusillus* biology and behavior on *Bemisia* species actually pertain to *D. catalinae.* We propose the following studies to confirm the identity and origin of *Delphastus* populations in Florida: (1) new field surveys should be made of whitefly-infested host plants in various regions in Florida, including Central Florida near the original field source, and *Delphastus* specimens collected from these areas for taxonomic studies; (2) specimens identified as *Delphastus pusillus* that were collected in recent years should be reexamined, and (3) molecular characterizations using population-specific markers could be helpful in determining the ultimate origin of commercially maintained populations and explaining the most likely paths and mechanisms of dispersal of these predators.

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