First New World Documentation of an Old World Citrus Pest, the Lime Swallowtail *Papilio demoleus* (Lepidoptera: Papilionidae), in the Dominican Republic (Hispaniola)

Kelvin A. Guerrero, Denia Veloz, Sarah Lyn Boyce, and Brian D. Farrell

Abstract. *Papilio demoleus* L., a well-known citrus pest in the Old World, is documented from eastern Dominican Republic on the Caribbean island of Hispaniola. **Resumen.** Se registra la especie *Papilio demoleus*, una reconocido plaga de los citricos en el Mundo Viejo, para la Hispaniola Republica Dominicana. **KEY WORDS**: West Indies, Hispaniola, distribution, Lepidoptera, Papilionidae, *Papilio demoleus*, invasive species, citrus pest.

Papilio demoleus L., commonly known as the lemon, lime, citrus, or chequered swallowtail, is found throughout southern Asia (Corbet and Pendlebury 1992), extending from Iran (Larsen 1977) and the Middle East to India, and from the Indo-Pacific (Vane-Wright and de Jong 2003) to New Guinea and Australia (Parsons 1998, Braby 2000), in parallel with the native or introduced range of its principal host plants in the genus *Citrus* (Rutaceae).

In this article, we present a new record for *P. demoleus* from the Dominican Republic; this is only the second report of this species in the Americas. There is an unconfirmed record of a specimen allegedly collected in San Jose, Calif., that was turned in as part of a student collection for a course at San Jose State University (Tilden 1968).

During a spring break field trip associated with the Harvard University course in tropical insect systematics offered by BDF, DV and SLB collected two male specimens of *P. demoleus* on 29 March 2004 in an area commonly known as "Hoyo Azul" (N 18°33.528', W 68°26.807') located in the municipality of El Veron in Higuey Province in the southeast region of the Dominican Republic (Fig. 1). This an area where many citrus trees, primarily lemon and orange, are grown.

Because of the potential economic importance of this butterfly in the hemisphere, in June 2004 we gave an early draft of this article to Carolyn Cohen of the USDA in Santo Domingo for circulation to USDA staff. An international team, including Wayne Wehling of the USDA in Maryland, was assembled in late September to investigate the distribution of *P. demoleus* in the Dominican Republic. The USDA/Departamento de Sanidad Vegetal de la Secretaría de Estado de Agricultura team confirmed the presence of dozens of butterflies in and around the citrus groves in Villa Altagracia (Province San Cristobal), ≈200 km from the original Punta Cana sites, as well as in Cotui (Province Sachez Ramirez) and Mata Santiago Bayaquana (Province Monte Plata), though no butterflies were found in citrus nurseries or groves in Jarabacoa (Province La Vega) or Hato Mayor. In every site where *P. demoleus* was found, it was more abundant than the native citrus-feeding *Papilio* spp. (W. Wehling, personal communication).

Fig. 1. Location of Hoyo Azul Natural Monument in the eastern Dominican Republic where specimens of *Papilio demoleus* L. were captured.

Figure 2. Male specimen of *Papilio demoleus* captured in the Dominican Republic: (left) ventral habitus; (right) dorsal.

P. demoleus cannot be confused with any other butterfly known to occur on Hispaniola. It does superficially resemble several swallowtail species (*Heraclides* spp., Papilionidae), all of which have distinctive tails on the hind wings, and to a lesser extent the nymphalid butterfly *Siproeta stelenes* (L.) (Nymphalidae).

P. demoleus is similar to the African species *P. demodocus* Esper from which it can be distinguished by the characteristic form of the blue and red eyespots on the hindwing as well as the rounded outlines of cream spots on the forewing. We and expert Rod Eastwood compared high-resolution digital photographs (Fig. 2) of both specimens to more than 100 specimens of each species in the collections of the Harvard Museum of Comparative Zoology. The specimens do not appear to be of the strongly yellow Australian subspecies *P. demoleus sthenelus* Macleay (R. Eastwood, personal communication), but resemble populations of *P. demoleus* malayanus Wallace from Southeast Asia. J. Rawlins, Carnegie Museum of Natural History (Pittsburgh), and A. Sourakov, University of Florida (Gainesville), made independent comparisons with specimens in their respective collections and came to the same conclusion. The identification was further confirmed by *P. demoleus* expert Wehling in the field (personal communication). Genetic analyses will be performed using DNA sequences from the Dominican specimens and others from Southeast Asia (Zakharov et al., in press) to further localize the origin of the individuals found in the Dominican Republic.

The discovery of this butterfly species in the West Indies may be of some importance as this vagile butterfly species is an important citrus pest throughout much of its Old World range, which is rapidly expanding. *P. demoleus* is known to plague citrus groves in Saudi Arabia and Iran (Badawi 1981), as well as India. Narayayanamma et al. (2001) reported up to 83% defoliation of young grove trees in Andra Pradesh, and Thakare and Borle (1974) reported an outbreak severe enough to skeletonize entire citrus gardens. The larvae prefer young nursery plants 1–2 feet high and are capable of completely defoliating nursery groves (Yunus and Munir 1972; Thakare and Borle 1974; Singh 1993a; Matsumoto 1996, 2001; Narayayanamma et al. 2001). Yunus and Munir (1972) reported that *P. demoleus* larvae will accept leaves of at least 19 citrus species or varieties, but show some differences in larval consumption rates, development times, and mortality.

A brief review of the biology of the species, including biological control studies, is given here because of the potential impact of this butterfly species could have on the citrus industry of the Dominican Republic and Haiti, the remaining countries in the Caribbean region, as well as Florida and other citrus-producing states in the United States. The potential economic impact of this invasive pest species is not trivial. In 2002, the value of the Florida citrus crop exceeded $1.5 billion; the U.S. total (Florida, California, Arizona, and Texas) was more than $2.6 billion (National Agricultural Statistics Service 2004). The Dominican citrus crop is valued at $30 million annually and supports 3000–4000 families (Carlos Suarez, USDA FAS, personal communication).

Atluri et al. (2002) documented larval development through to the adult stage using larvae reared on leaves of *Citrus limon* (L.) Burm. in the laboratory. They noted that eggs are laid singly, but may accumulate to 8–10 over a 2–3-day period, on the surface of young leaves and twigs. After eggs hatch in 4–5 days, there are five instars over 27–35 days, followed by 10–12 days in pupation and an adult lifespan of 7–12 days. Atluri et al (2002) also summarized the results of a survey of eggs, larvae, and pupae on 12 plants of *Citrus limon* in India. They reported peak abundances in October following monsoons from June to October and concluded that the species is capable of producing up to six generations per year. Chatterjee et al. (2000) showed a positive correlation of *P. demoleus* abundance with seasonal increases in temperature and relative humidity in West Bengal, India, and Singh (1993a) reported apparent polymorphism in facultative pupal diapause.

Studies of natural sources of mortality include Singh (1993b), who reported the effectiveness of an entomophagous nematode (*Steinernema* sp., Nematoda: Rhabditida: Steinernematidae) in control of caterpillars of *P. demoleus* in India (mean mortality 45% within 48 hrs of treatment), and Badawi (1981), who reported pupal mortality caused by application of a *Bacillus* infusion. Thakare and Borle (1974) published photographs of unidentified podisine predators (Hemiptera: Pentatomidae: Asopinae), which along with some unidentified dipteran parasitoids, are suggested to regulate local populations of *P. demoleus*.

The recent arrival of *P. demoleus* into a new tropical region with favorable climatic conditions in conjunction with the presence of its preferred host plant and the potential lack of population-controlling predators has led to the establishment of this species in the Dominican Republic. It could easily spread throughout the West Indies and surrounding areas, including the United States where the impact could be very high. *P. demoleus* is a successful invasive species, recently spreading throughout an Old World island system very much like that in the Caribbean. Beginning in the 1970s, this species invaded the islands of Java, Borneo, Philippines, and Sumatra, apparently facilitated by deforestation and the increased availability of citrus groves (Matsumoto 1996, 2001).

In conclusion, the circumstances surrounding the introduction(s) to the Dominican Republic remain unknown, but the establishment of the species seems certain. Spread throughout the island of Hispaniola should be documented and used to predict the rate of spread elsewhere. The potential agricultural and economic impact this known citrus pest also should be evaluated because it is possible that native parasitoids may shift from other native, but less abundant, citrus-using *Papilio* spp.

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Kelvin Guerrero is a systematic entomologist with el Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) and is associated with the Punta Cana Center for Sustainable Tourism and Biodiversity. He is a specialist in cerambycid beetles and holds a master's degree from Montana State University. **Denia Veloz** is a systematic entomologis associated with the Punta Cana Center for Sustainable Tourism and Biodiversity. She is a specialist in Orthoptera and holds a bachelor's degree from the Universidad Autonoma de Santo Domingo. **Sarah Lyn Boyce** is an invertebrate systematist and assistant to **Brian D. Farrell** in the Museum of Comparative Zoology at Harvard University. She holds a master's degree from Florida State University. **Brian D. Farrell** is a systematic entomologist and professor of biology in the Department of Organismal and Evolutionary Biology, and curator in entomology in the Museum of Comparative Zoology, at Harvard University. He earned a Ph.D.at the University of Maryland, and was a Sloan Postdoctoral Fellow at Cornell University. For more infromation on Caribbean insects see: http://insects.oeb.harvard.edu