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Sudden appearance and population outbreak of *Eunica monima* (Lepidoptera: Nymphalidae) on Desecheo Island, Puerto Rico

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One of the greatest challenges in insect ecology is to determine the causes of population outbreaks; such causes are particularly difficult to identify on isolated islands where entomological and ecological surveys are infrequent or difficult to conduct. Insect population outbreaks can be defined as pulses of exceptionally high numbers of individuals. Forest Lepidoptera are among the most studied groups involved in outbreak events, partly because of their frequent stand-level herbivory on economically important species (Myers 1988). Explanations for lepidopteran population outbreaks have included environmental triggers such as rainfall or temperature events (Torres 1992; Harvey & Mallya 1995), release from predators or competitors (Berryman 1996), or a combination of factors (Mattson & Haack 1987; Myers 1988). Despite hypotheses explaining Lepidoptera population outbreaks, definitive evidence linking outbreaks to specific triggers is rare (Myers 1988).

In our study, we sought to identify the lepidopteran species experiencing outbreak conditions and causing heightened herbivory and defoliation of its host plant *Bursera simaruba* (L.) Sarg. (Burseraceae) shortly after island-wide removal of invasive rats (*Rattus rattus* L.; Muridae) on Desecheo Island, Puerto Rico. We discuss potential causes of the outbreak, and its similarity to a coincidental outbreak in southern and western Puerto Rico that involved a related lepidopteran species.

Desecheo (18.385437°N, 67.480044°W) is a small (1.5 km^2) uninhabited island approximately 27 km from the western shore of the main island of Puerto Rico that is administered by the U.S. Fish and Wildlife Service (USFWS) as a National Wildlife Refuge. The island is rugged, with a peak elevation of 218 m, and average annual rainfall of 1,020 mm (Seiders et al. 1972). Dryland vegetation includes *B. simaruba* dominated forest, shrubland, and grassland.

The non-native *R. rattus* is abundant on Desecheo, and this rat is deemed the world's top rodent pest (Capizzi et al. 2014), especially in island forests (Shiels et al. 2014). Lepidopteran larvae are frequently consumed by *R. rattus* (up to 33% of rats sampled) in island forests (Clark 1982; Shiels et al. 2013). The purpose of the visits to Desecheo associated with the current study (in Mar–Apr 2016) was to attempt rat eradication to help restore Desecheo's natural ecosystem. A restricted-use rodenticide, Brodifacoum 25-D Conservation (EPA Registration 56-22837), was applied island wide on 2 application dates, 18 Mar and 9 Apr 2016.

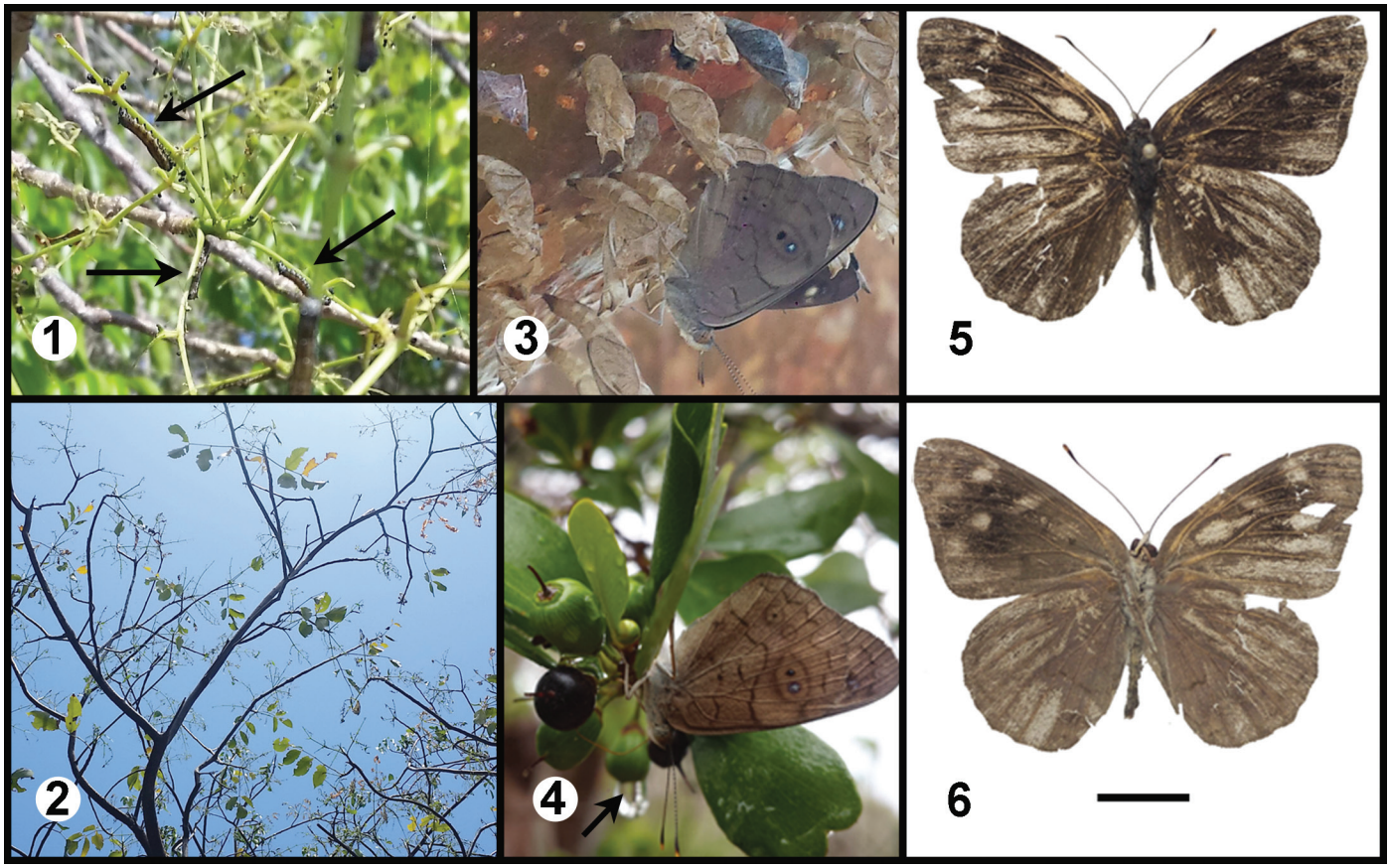
Prior to the first survey and monitoring trip on 7 Apr 2016, which began 20 d after the first rodenticide application, no *Eunica monima* (Stoll) (Lepidoptera: Nymphalidae) larvae were observed. However, during the 7–16 Apr survey, we observed several hundred to thousands of larvae of a single size class per *B. simaruba* tree (Figs. 1 and 2), and the sound of falling frass could be heard as it hit leaf litter beneath host trees. Larvae and adults were photographed and collected from the western part of the island during the 7–16 Apr visit; samples were kept frozen or in 95% ethanol. During the 26–27 Apr visit to Desecheo, larval abundance had decreased, but adults (Figs. 3–6) were very abundant.

Adults were initially identified as *E. monima* from photographs using internet resources (e.g., http://www.butterfliesandmoths.org/species/eunica-monima) and descriptions in Pérez-Asso et al. (2009). We confirmed the identity of larvae and adults by extracting DNA from both life stages, and sequencing the "barcode" region of the mitochondrial gene *CO1* (624 bp) with universal primers LCO1490 (5′-GGTCAACAAATCATAAAGATATTGG) and HCO2198 (5′-TAAACTTCAGGGTGACCAAAAAATCA) (Folmer et al. 1994). Sequences of larvae (GenBank sequence ID: KX268732) and adults (KX268731) were identical, and were 99.5 to 100% similar to voucher sequences of *E. monima* (50 specimens) in the Barcode of Life Database (BOLD) (Ratnasingham & Hebert 2007). The next closest match in BOLD was *Eunica tatila* (Herrich-Schäffer) at 94% similarity. Based on this molecular confirmation that supplemented our morphological assessment, as well as known host plant affiliations, we are confident that the specimens collected were *E. monima*. Additionally, an adult butterfly specimen (Figs. 5 and 6) was sent to the United States Department of Agriculture Systematic Entomology Laboratory, whose experts confirmed the identification as *E. monima* (Stoll).

Eunica monima is native to Puerto Rico, but it is uncommon (Pérez-Asso et al. 2009). Its native distribution includes the Caribbean (Bahamas to Greater Antilles), northern South America, Central America,

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Figs. 1 and 2. *Eunica monima* outbreak on *Bursera simaruba* trees on Desecheo Island, Puerto Rico, Apr 2016, following island-wide invasive rat removal. Note that the level of damage from herbivory by larvae has left the majority of the tree canopy branches leafless (both photos). Photos by Aaron B. Shiels, 8–10 Apr 2016. **Figs. 3–6.** *Eunica monima* adults collected during their outbreak (Apr 2016) in a *Bursera simaruba* dominated forest on Desecheo Island, Puerto Rico, following island-wide invasive rat removal. **3.** Adult and abundant empty chrysalises on the trunk of *B. simaruba*. **4.** Adult feeding on juices from fruit of *Sideroxylon obovatum* Lamarck (Sapotaceae) (photos by Juan G. García-Cancel, 14–16 Apr 2016). **5 and 6.** Voucher specimen (dorsal and ventral aspects) collected from Desecheo and genetically analyzed to confirm species identification (specimen was unfortunately rubbed and tattered when received). Collection data: USA, Puerto Rico, Desecheo Island, 18.385437°N, 67.480044°W, 8 Apr 2016; collector: A. B. Shiels (photos by William P. Haines).

Mexico, Florida, Arizona, and Texas; it is only considered common in northern South America (Schwartz 1989; Jenkins 1990; Hall et al. 2013). This species is known to experience population outbreaks and mass migrations elsewhere, and Jenkins (1990) summarized observations of outbreaks in Costa Rica going back as far as 1912. The most commonly recorded host plant for *E. monima* is *B. simaruba,* and outbreaks can cause defoliation of entire trees (DeVries 1986; Jenkins 1990). Although these outbreaks have been documented, we could not find any discussion of their environmental triggers.

We reviewed previous records of *E. monima* in Puerto Rico, including those describing its rarity there (Ramos 1982; Pérez-Asso et al. 2009), as well as its periodic abundance in Mona Island (1986–1991; Smith et al. 1988, 1994) and Guánica (13–17 Jul 1915; Comstock 1944; Wolcott 1948). Three specimens were found at the Entomology and Tropical Biodiversity Museum (METB) at the University of Puerto Rico at Mayagüez, with only one specifying location (Mona Island). *Eunica* species were not recorded during what appears to be the only formal insect surveys of Desecheo, which occurred from 1914 to 1971 (García-Tudurí et al. 1974).

Although our evidence is circumstantial, and we cannot determine for certain the cause of the *E. monima* population outbreak on Desecheo, we present two possible explanations: a rat-suppression hypothesis, and an abiotic environmental trigger hypothesis. The timing of the larval population outbreak immediately followed rat removal from Desecheo. Although we could not find detailed information on the life cycle of *E. monima*, such data exist for other Neotropical *Eunica* species. Freitas & Oliveira (1992) studied the life history of *Eunica bechina* Hewitson, and found that after 5 d as an egg, the larval stage (5 instars) lasts about 17 d, followed by a pupal stage of about 9 d. On Desecheo, rodenticide was applied on 18 Mar, and rodent mortality was observed within 5 d, with no evidence of living rats 8 d after application. Late-instar larvae were noted upon return to the island from 7 to 16 Apr, 20 d after rodenticide application. Assuming that the life cycle of *E. monima* is similar to that of *E. bechina*, this timeline fits well with a scenario in which larval survival increased due to a sudden release from rat predation. Because *R. rattus* feeds preferentially on large insects (St Clair 2011), it is likely that this release would mainly decrease mortality of late instars. Additionally, a pupal stage of about 9 d is consistent with observations of very abundant adults on Desecheo during a follow-up visit from 26 to 27 Apr.

An alternative explanation for the cause of the *E. monima* population outbreak on Desecheo is a non-predator environmental factor. Although long-term environmental data from Desecheo are lacking, much of Puerto Rico was in severe drought during the latter half of 2015, and heavy rain (3.1 cm) on Desecheo on 27 Feb and noticeable *B. simaruba* leaf flush and overall canopy greening were documented during 17 Mar to 10 Apr (D. W. unpublished data). Causes of lepidopteran population outbreaks are often difficult to identify and

may involve complex interactions (Mattson & Hack 1987; Berryman 1996), yet the time sequence of drought followed by heavy rain and *B. simaruba* leaf flush seems to be associated with the *E. monima* population outbreak on Desecheo. Additionally, approximately 1 mo following the Desecheo outbreak of *E. monima*, an outbreak or local migration of *E. tatila* adults was observed in south and west Puerto Rico where rat control did not occur. Although the 2 lepidopteran species are closely related and both considered imperiled in Florida (Minno 2011), their larvae feed on unrelated host plants in different families (Jenkins 1990). The cause and exact timing of this *E. tatila* population outbreak is unknown, but outbreaks have apparently occurred periodically over the last few decades (Miguel Canals, retired Guánica State Forest Manager, personal communication). The coincidental timing of these 2 outbreaks is striking, and it is possible that both *E. tatila* and *E. monima* populations responded to a common environmental cue.

Our study has resulted in a first-time record of *E. monima* for the island of Desecheo, and an observation of a population outbreak of this species in Puerto Rico. *Eunica monima* larvae in Desecheo were observed consuming only the host plant *B. simaruba*, which is one of the most important dry forest species in Puerto Rico (Brandeis & Turner 2013). Whether the triggers associated with *Eunica* population outbreaks in Desecheo and Puerto Rico were biotic or abiotic remains unresolved. Nevertheless, documentation of insect population outbreaks such as documented here should facilitate future experiments in which causal effects could be studied explicitly.

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Summary

We documented the appearance and elevated abundance of the uncommon dingy purplewing butterfly, *Eunica monima* (Stoll) (Lepidoptera: Nymphalidae), and pronounced herbivory on its host plant *Bursera simaruba* (L.) Sarg. (Burseraceae) shortly after island-wide rat (*Rattus rattus* [L.]; Muridae) removal from Desecheo Island, Puerto Rico. We confirmed the species as *E. monima* by using both molecular and morphological analyses of larvae and adults. This is a first-time record of *E. monima* for the island of Desecheo, one of relatively few documented appearances in Puerto Rico during the last 100 yr, and an uncommon documentation of an outbreak of this species in the Caribbean. Although experimental manipulation would be needed to identify the cause of the *E. monima* population outbreak, we discuss possible cause-and-effect scenarios.

Key Words: *Bursera simaruba*; caterpillar–butterfly irruption; *Eunica tatila*; insect herbivory; *Rattus rattus* eradication; predator–prey interaction

Sumario

Documentamos la aparición y elevada abundancia de la mariposa poco común Dingy Purplewing, *Eunica monima* (Stoll) (Lepidoptera: Nymphalidae), y la pronunciada herbivoría en su planta hospedera *Bursera simaruba* (L.) Sarg. (Burseraceae), poco después de una erradicación de ratas (*Rattus rattus* [L.]; Muridae) en la isla de Desecheo, Puerto Rico. Confirmamos la especie como *E. monima* mediante análisis tanto moleculares como morfológicos de las orugas y adultos. Este es el primer registro de *E. monima* para la isla de Desecheo, una de las relativamente pocas apariciones documentadas en Puerto Rico durante los últimos 100 años y también se documentó un brote poco común para esta especie en el Caribe. Aunque la manipulación experimental sería necesaria para identificar la causa del brote de *E. monima*, discutimos los posibles escenarios de causa y efecto.

Palabras Clave: *Bursera simaruba*; irrupción de mariposa-oruga, *Eunica talita*, herbivoría de insectos, erradicación de *Rattus rattus*, interacción depredador-presa

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