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A Lepidopteran defoliator attack on Brazil nut trees (*Bertholletia excelsa*) in Central Amazonia, Brazil

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ABSTRACT

This paper describes a severe outbreak of a Lepidopteran defoliator, *Lusura altrix* (Stoll 1782), on Brazil nut trees in Central Amazonia. The pest outbreak appeared to succeed abnormal weather conditions, and defoliation was sufficient to disrupt normal phenological patterns.

Key words: Caterpillars; climate change; defoliation; drought; insect outbreak; Neotropical forest; notodontidae; phenology.

LEPIDOPTERAN LARVAE ARE RECOGNIZED AS MAJOR DEFOLIATORS of tropical forest trees (Nair 2007). In Amazonia, for example, Lepidopteran defoliators now represent one of the main pests in monoculture *Eucalyptus* plantations (*e.g.*, Zanuncio *et al*. 1994, 2000) and other commercially important plantation species such as cupuaçu (*Theobroma grandiflorum*; Lourido *et al*. 2007). In contrast, observations of major insect outbreaks in Neotropical primary forests remain scarce, although there are now a growing number of reports of severe defoliation events in various species of Neotropical forest trees (Wolda & Foster 1978; Janzen 1981, 1985; Wong *et al*. 1990; Nascimento & Proctor 1994). To my knowledge, however, there have been no reported outbreaks of Lepidoptera on economically important plant species from undisturbed Amazonian forest.

In this paper, I describe an outbreak of a Lepidopteran defoliator on the Brazil nut tree (*Bertholletia excelsa*—Lecythidaceae, Humb. & Bonpl.) in a relatively intact Central Amazonian forest. Brazil nut trees grow in natural clusters or stands (but see Wadt *et al*. 2005), and provide one of the most socioeconomically important tropical nontimber forest products (NTFP)—-the Brazil nut. The local and regional economies throughout Amazonia strongly depend on collecting and processing Brazil nuts and these nuts have emerged as an important export industry, particularly for Bolivia and Brazil, following the demise of the rubber trade. In 1998, the world trade in Brazil nuts amounted to US$ 57 million (Zuidema 2003). These nuts are the only internationally traded seed crop collected exclusively from natural forests (Clay 1997). Serious pest outbreaks on the Brazil nut tree may therefore carry significant implications for the rural population in Amazonia as well as for the regional and global Brazil nut market.

The pest outbreak was observed at Lago Uauaçu, which is located in the lower Rio Purús region (04°20′ S, 62°28′ W) of Central Amazonia, Brazil. Lago Uauaçu is a large, crescent-shaped blackwater lake surrounded by upland terra firme forest that supports extensive natural stands of Brazil nut trees. A previous floristic study based on three 1-ha terra firme plots shows that *B. excelsa* is the dominant species in terra firme forest in the area, representing 12.0 and 21.8 percent of the total basal area and biomass, respectively (Haugaasen 2004). The 30 extractive *caboclo* households inhabiting the lake rely primarily on the collection of Brazil nuts, in addition to small-scale fishing and hunting, for their subsistence and annual income.

Extensive defoliation was recorded during systematic monthly phenological observations of Brazil nut trees from five different Brazil nut stands (comprising a total of > 900 trees distributed across *ca.* 600 ha). Lepidopteran infestations were observed on two occasions; a minor attack on a small number of trees (< 10 individuals) was observed during the last week of March 2007, and a more severe attack in the subsequent dry season in June–August 2007. The latter attack affected a large number of Brazil nut trees across the entire Uauaçu region, including independent stands located on the north and south sides of the lake. Phenological observations showed that each stand succumbed to an infestation rate of 80–95 percent of all adult individuals. The worst-affected area was the stand in which the initial outbreak was observed. In this stand *ca.* 97 percent of trees were infested. An unstructured inspection of stands in which phenological monitoring was not carried out suggested that the level of infestation was similarly high in other areas surrounding the lake. The pest species was collected and subsequently identified at the National Institute for Amazonian Research (INPA) as *Lusura altrix* (Stoll 1782), a moth belonging to the Notodontidae (Fig. 1A).

Caterpillars of *L. altrix* have a distinctive red head, with yellow bodies displaying brownish-black stripes along the sides and on the back (Fig. 1B). The dorsal surface of the caterpillars also exhibits a number of defensive spores on the anterior and posterior body segments (Fig. 1B). The color of the caterpillars faded visibly with time inside the cocoon, finally producing a brown pupa (Fig. 1C). Cocoons were exclusively found inside deep furrows in the tree bark (Fig. 1D) and tree trunks often appeared white due to the vast number of cocoons produced. Almost all cocoons observed were located on Brazil nut trees. A small number of cocoons were also observed on nearby trees that have a similar deeply furrowed

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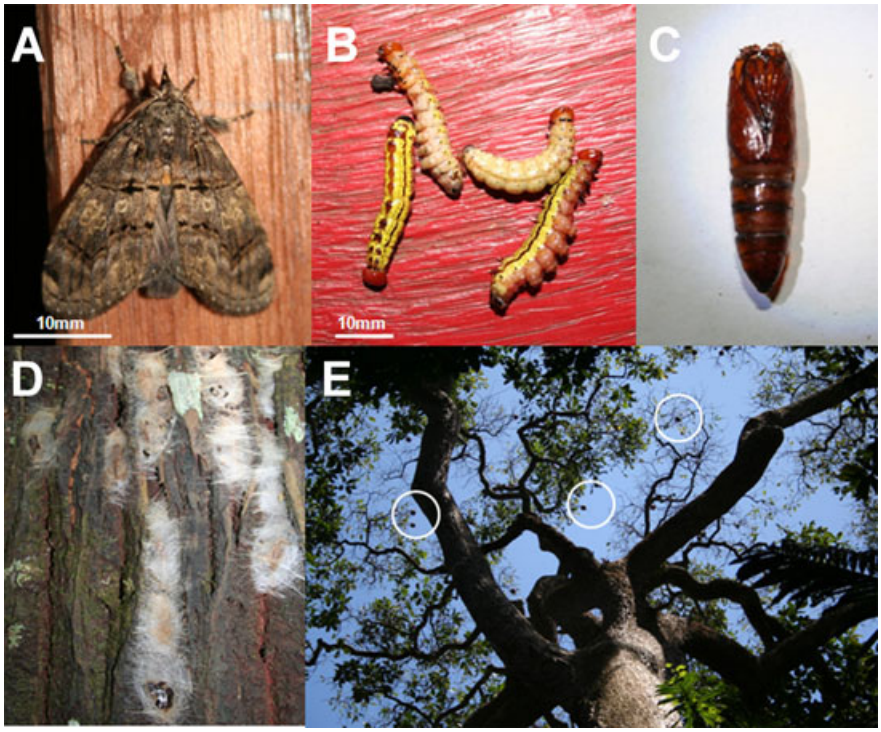

FIGURE 1. The (A) adult, (B) caterpillar, (C) pupa, and (D) cocoon of *Lusura altrix*. Heavily defoliated Brazil nut trees (E) did not appear to abort their crops as shown by the large Brazil nut fruits on the heavily defoliated branches.

bark, although these trees were not defoliated. Several pupae were collected, and adult moths were recorded emerging between 1930 h and 2300 h 3 d after collection. However, the life cycle of the species was not monitored.

Defoliation by *L. altrix* was exclusive to large *B. excelsa* trees with deeply furrowed bark. Smaller Brazil nut trees were not affected; it appeared that their smooth bark prevented cocoon attachment. This was the case even where young *B. excelsa* trees were found in close vicinity of infested adults. In most cases, observed defoliation was severe, with a continuous rain of caterpillar frass falling from the canopy of infested trees. Visual estimates showed that all trees affected lost at least 50 percent of their total foliage (Fig. 1E). Some trees were virtually stripped of all their leaves. The leaves were mature at the time of the defoliator attacks as the annual leaf-changing event normally occurs synchronously in September–October (T. Haugaasen, unpublished data).

The lack of caterpillars and defoliation on other tree species suggests that *L. altrix* is host specific. The fact that smaller trees with smooth bark escaped attack further suggests that the species is also restricted to trees on which they are able to produce a cocoon and undergo metamorphosis. According to local Brazil nut collectors (*castanheiros*), infestations by this species of moth have occurred sporadically for decades. However, this is the first report of an infestation of this magnitude in the study area. Previously, attacks have generally been restricted to one stand, or even part of a stand.

Subsequent to the defoliator attack, phenological observations show that both flowering and leaf-changing events were affected. As the outbreak declined, some trees flushed new leaves. This leaf flush did not match usual phenological patterns with respect to timing, and appeared to only replace lost leaves. The flowering phenophase was also affected in several individuals. Flowering in *B. excelsa* normally occurs synchronously between October and February in the study area (T. Haugaasen, unpublished data). However, subsequent to being infested, 25 trees were observed to flower well outside the normal flowering season between May and July. Although such phenological outliers may occur occasionally, no trees were observed to flower during these months in the previous year (T. Haugaasen, unpublished data). Another 23 trees flowered as early as August (15 trees) and as late as April (eight trees) compared to only a single individual in the year before, and a few trees bore flowers on some branches in September–October with the remaining branches flowering several months later (February–March). Ongoing phenological observations show that Brazil nut trees that were attacked did not appear to abort their fruits, although *castanheiros* that were interviewed stated that trees that have experienced severe defoliation will not produce seed crops in the subsequent 4 yrs. This observation remains unconfirmed, but appears unlikely since unripe fruits have been observed in the canopy following the irregular flowering (T. Haugaasen, unpublished data). Nevertheless, it remains to be seen how the defoliation event described here will affect crop sizes in subsequent years and the time necessary to recover normal

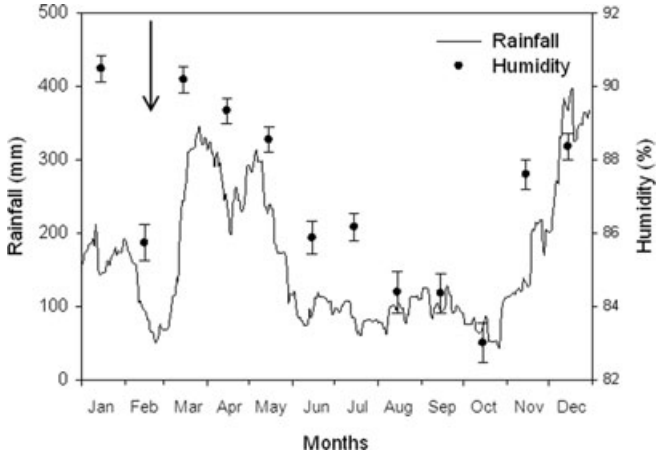

FIGURE 2. Patterns of rainfall and humidity in 2007 at Lago Uauaçu, Central Amazonia, Brazil. Following Brearley *et al.* (2007), rainfall is portrayed as a sliding 30-d total calculated by summing the rainfall in a given day with the rainfall on the preceding 29 d. The arrow shows the dramatic decrease in rainfall and humidity during February 2007.

phenological patterns. Previous studies have also shown that severe defoliation may unbalance regular phenological patterns in Neotropical forest trees and dramatically reduce reproductive outputs (*e.g.*, Wong *et al.* 1990, Van Bael *et al.* 2004).

Lepidopteran outbreaks in tropical forests often follow an El Niño/Southern Oscillation (ENSO) related drought. This has been observed in Central America (Janzen 1985, Aiello 1992, Van Bael *et al.* 2004), Indonesia (Whitten & Damanik 1986), Borneo (Itioka & Yamauti 2004), and Australia (McKillup & McKillup 1997). In the current study, the outbreak did not succeed a serious drought. Indeed, there were no observations of an outbreak of *L. altrix* during the recent severe drought, which affected the region in 2005 (T. Haugaasen, pers. obs.). However, climatic data from Lago Uauaçu show that there was an unexpected and dramatic decrease in precipitation accompanied by a simultaneous drop in humidity and increase in temperature during February 2007 (Fig. 2), the month prior to the first observed outbreak. February generally receives a lot of rain (250–300 mm) in the study area (Haugaasen & Peres 2006) and it is therefore possible that the abnormal weather conditions triggered the initial, smaller, outbreak seen in March. This outbreak may in turn have precipitated the larger outbreak observed in the subsequent dry season (June–August), in which rainfall is normally very low (Fig. 2). Indeed, all the trees attacked in March were also infested in the subsequent outbreak. A similar large-scale outbreak of *L. altrix* was recently reported in the Bolivian Amazon. In this report, changes in temperature and a disappearance of Tachinidae flies, whose larvae are endoparasites of butterfly and moth caterpillars, were proposed as potential triggers for the outbreak (Anon 2008). Further studies are therefore clearly needed to investigate the factors underlying spatial-temporal occurrence patterns of *L. altrix,* and the combination of abiotic and biotic factors that may initiate outbreaks of this species on Brazil nut trees. Nevertheless, if outbreaks of *L. altrix* can be triggered by profound changes to normal precipitation or temperature patterns, this may have serious implications for the future sustainability of this crucial NTFP. Future climate change scenarios predict ENSO events to occur at greater frequency and severity (Timmermann *et al.* 1999), consequently producing more erratic precipitation patterns across the Amazon basin. Regardless of the specific factors and/or their interactions that initiated the outbreak described here, serious outbreaks of Lepidopteran defoliators on the Brazil nut tree may carry enormous implications for the rural population in Amazonia and, in turn, the global Brazil nut market. This can be underlined by the recent severe outbreak of *L. altrix* in Bolivia (Anon 2008), which by 1998 had become the largest exporter of shelled Brazil nuts (Zuidema 2003). Similarly, these outbreaks show that the occurrence of *L. altrix* is widespread and that the potential damage caused by the species may affect large parts of central and western Amazonia. The potential significance of these outbreaks therefore clearly demands further investigations. Careful monitoring of the occurrence and spread of insect outbreaks on Brazil nut trees and other economically important species in Amazonia may be imperative to safeguard the future economic viability of the region.

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