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Infestation of Mangroves by the Invasive Moth *Hyblaea puera* (Cramer, 1777)(Lepidoptera: Hyblaeidae)

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HIGHLIGHTS

- We report the first known infestation by *Hyblaea puera* in mangroves of Paraná, Southern Brazil.
- Massive defoliation of *Avicennia schaueriana* was observed in a large portion of local mangroves.
- We visually estimated levels of impact, focusing on protected areas.

Abstract: We report the first known infestation of mangroves by the invasive moth *Hyblaea puera* in Paraná, Southern Brazil. The infestation caused massive defoliation of *Avicennia*

schaueriana trees, affecting approximately 20,000 hectares of mangroves. We discuss the implications for conservation and management, focusing on protected areas, the ecology of mangroves, and local livelihoods.
Keywords: pest quarantine, ecosystem services, insect-plant interactions, leaf consumption, litterfall**.**

INTRODUCTION

The teak defoliator moth *Hyblaea puera* (Cramer, 1777) (Lepidoptera: Hyblaeidae) is an invasive pest species [1,2] known to attack commercial teak (*Tectona grandis* L.f Lamiaceae) plantations and cause extensive damage [3,4]. Teak has been exploited in Brazil since 1925 [5]; the first commercial plantations started in the 1960's [6–8] and, by 2015, covered an estimated area of 87.4 K ha [9]. Despite its long history of commercial exploitation in Brazil, the first record of the teak defoliator moth in a commercial plantation did not occur until 1997, when an outbreak occurred in the State of Mato Grosso, in the west of the country [2,10,11]. Besides teak, the teak defoliator moth has been recorded on 45 other host tree species [2,12–14]. Among these other host species, the moth has been found on black mangroves (*Avicennia* sp.), and there is strong evidence that it has adapted its life-history traits to suit the micro-environmental conditions of the mangrove ecosystem [15].

In general, herbivory in mangrove forests is a minor route for organic matter transfer, and insect herbivores typically only cause moderate damage (not exceeding 5% of the leaf area) [16–18]. To date, there have been few studies of mangrove herbivory that have provided detailed information on the consequences of defoliation events [19–23]. Nevertheless, there is evidence that heavy defoliation caused by insects can negatively affect reproduction of mangrove trees [19], making invasion by the teak defoliator moth a major concern for this already threatened ecosystem. These fears have recently been realized, with reports of the teak defoliator moth causing severe and extensive defoliation of *Avicennia* trees in geographically dispersed mangrove forests on the Brazilian coast. The first report was from Pará state, northern Brazil (1°03'26"S, 46°45'45"W) where a severe defoliation of *A. germinans* (L.) L. was described [24–26]. Menezes and Peixoto [27] have also reported widespread defoliation and necrosis of *Avicennia schaueriana* Stapf & Leechman ex Moldenke trees in Rio de Janeiro State due to a *H. puera* population explosion.

In Paraná State (southern Brazil), mangroves cover around 30,800 ha of the coastline, being the predominant intertidal ecosystem around two estuarine systems: the Paranaguá Estuarine Complex and Guaratuba Bay (Fig. 1). Mangrove forests in this region are composed of three tree species: *Rhizophora mangle* L., *Laguncularia racemosa* (L.) C.F. Gaertn. and *A. schaueriana*. Most of these forests are protected by a variety of sustainable use and no-take protected areas, an indication of the overall importance of this ecosystem for biodiversity conservation. Indeed, the mangroves are contiguous with one of the largest remaining sections of the Atlantic Rainforest Biome, a global biodiversity hotspot (28).

MATERIAL AND METHODS

The onset of the Paraná infestation was first noticed by local fishermen, who reported, in February 2016, massive black mangrove defoliation to the Chico Mendes Institute for Biodiversity Conservation (ICMBio), responsible for management of federal protected areas. In Santa Catarina state (adjoining Paraná), an infestation was reported by representatives of Joinville municipality, who sent samples of adult moths to the Federal University of Paraná, also in February.

Between March and May 2016, we observed the consequences of the infestation and collected data on the distribution of *A. schaueriana* defoliation, as a direct indicator of the occurrence of the moth. During boat surveys, we observed massive and widespread

defoliation of *A. schaueriana* trees, and collected larvae and pupae from infected trees. Most individuals of *A. schaueriana* were completely defoliated, though no infestation was observed on the other two mangrove species. Identification of *H. puera* was confirmed by the Laboratório de Estudos de Lepidoptera Neotropical (Universidade Federal do Paraná, Zoology Department). Two adults and two pupae were deposited as vouchers in the Coleção Entomológica Padre Jesus Santiago Moure (DZUP).

On April 20, 2016, an aerial survey of the coast of Paraná and northern coast of Santa Catarina was conducted using a helicopter. We registered visual observations of defoliation in a GIS and estimated the size of the affected area. Intensity of the attack (high, medium, and low) was based on visual observation of the density of defoliated trees in each area. We evaluated the impact of the herbivory on mangroves, focusing on protected areas within Paraná State (Table 1).

RESULTS

An estimated 20,357.93 hectares of mangrove forest were affected at different levels according to the density of *Avicennia* trees and, possibly, to proximity to urban and harbor areas (Table 2 and Figure 1). This represents 66% of the total area of mangroves in Paraná. Two protected areas were particularly affected: the Guaraqueçaba Ecological Station (75.39% of area affected) and Boguaçu State Park (17.27% affected).

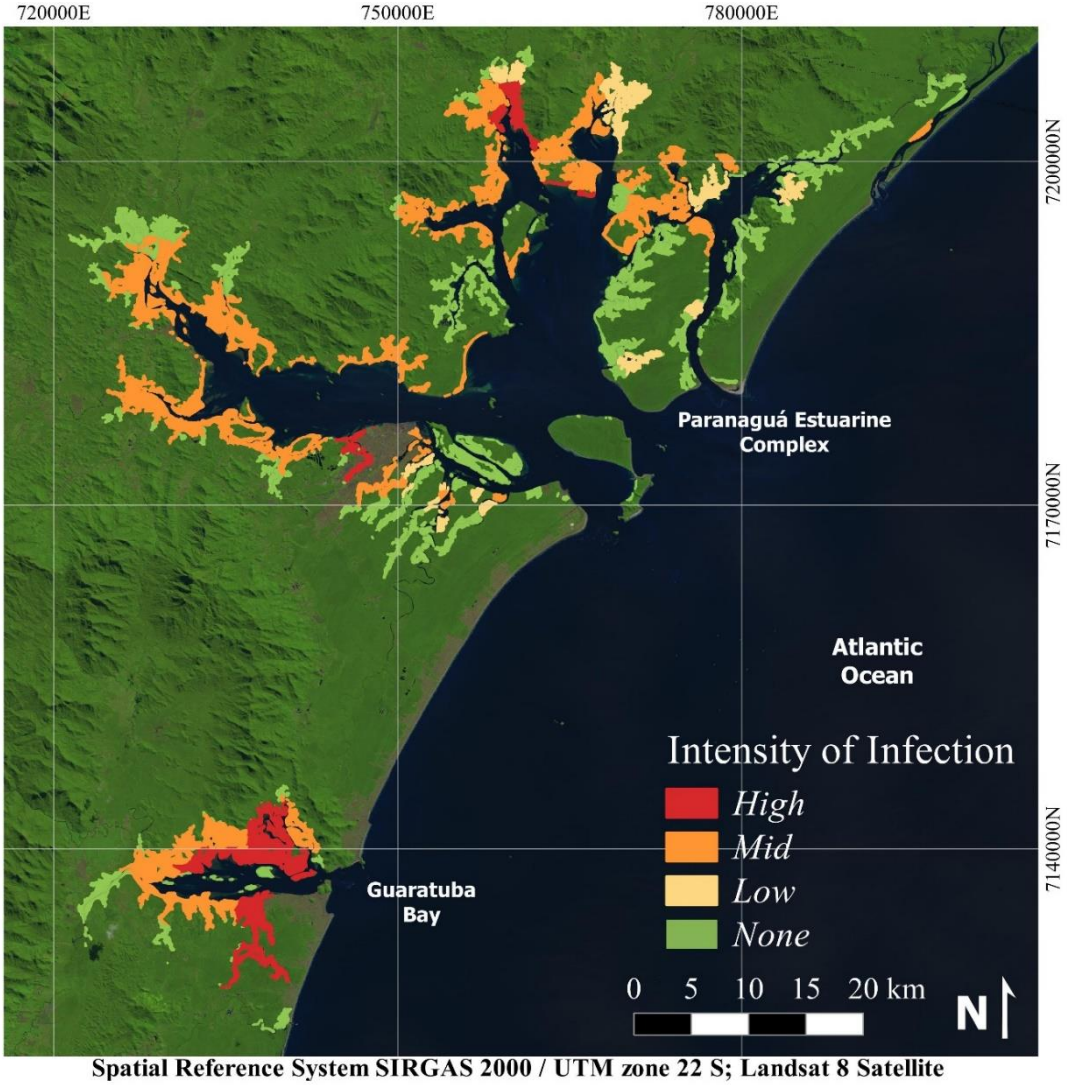

Figure 1. Intensity of infection by *H. puera* in mangroves of Paraná in 2016.

In June 2016, we revisited some of the infected areas and observed that most trees showed signs of recovery, with budding leaves. No dead trees were observed. We also found some empty puparia but no signs of larvae.

Table 1. Impact of the herbivory of the moth *H. puera* on *A. schaueriana* in Federal and State protected areas during the outbreak of 2016 in Paraná State, Brazil.

	Protected area	affected area (ha)[1]	Total PA area (ha)	% affected area
State level	Boguaçu State Park	1150.6	6660.8	17.3
	Guaraqueçaba State EPA[2]	8011.0	231802.2	3.5
	Guaratuba State EPA	5605.5	199455.2	2.8
National level	Guaraqueçaba Ecological Station	3294.4	4370.1	75.4
	Bom Jesus Biological Reserve	478.5	34179.0	1.4
	Superagui National Park	663.8	33860.6	2.0
	Guaraqueçaba Federal EPA	11054.6	282446.3	3.9

1. Some of these protected areas are zoned, with no-take PAs inside sustainable use areas. Therefore, the sum of affected areas in Table 1 is larger than the total affected area showed in Table 2.
2. EPA = Environmental Protection Area; a type of sustainable use protected area equivalent to IUCN Category VI. The other cited protected areas are no-take, equivalent to IUCN Categories Ia, Ib and II.

Table 2. Qualitative impact level of the moth *H. puera* on *A. schaueriana* during the outbreak of 2016 in Paraná State, Brazil.

Attack intensity	Affected area (ha)	Total mangrove area (ha)	%
Low	2262.9		7.3
Medium	14433.2	30884.4	46.7
High	3661.8		11.9
total	**20357.9**		**65.9**

DISCUSSION

Although measured under different environmental conditions, a study in Pernambuco State in tropical northeast Brazil reported a leaf formation rate of 48 days with a leaf life span of 13.1 months for healthy *A. schaueriana* [29]. This suggests that there may be a slower rate of leaf formation in infected sites, though further investigation is required to confirm this. Our observations corroborate others on northern populations of *A. germinans* [24,25,26]. Fernandes et al. [26] reported that *H. puera* larvae were able to deplete both young and senescent leaves within a short period of time, with a few trees not surviving the attack.

The outbreak in Paraná state occurred in synchrony with outbreaks in Santos (São Paulo State) and Joinville (Santa Catarina State). These regions host some of the largest and busiest ports in Brazil. Port regions have been implicated in the introduction of moth species in other parts of the world. For example, ship structures and cargos with egg masses of the gypsy moth *Lymantria dispar* L. (Lepidoptera: Noctuidae: Lymantriinae) have been noted on more than one occasion in North America [30]. Moth larvae have also been observed 'ballooning' from a superstructure and being carried downwind toward the shore

[30]. Therefore, despite assumptions that the teak moth was introduced with teak vegetative material, it is possible that ports have also contributed to the entry of new genetic material of *H. puera* into Brazil. Nonetheless, we cannot discard the hypothesis that teak plantations have played an important role in the infestation of mangroves by the teak defoliator moth. In this context, a genetic survey could potentially identify the invasion routes of the moth.

The introduction and spread of an invasive pest species inevitably raises concerns about ecological impacts. In the current example, herbivory by *H. puera* on *Avicennia* may influence energy transfer in the system. The moth infestation converts *Avicennia* leaves into particulate organic matter over a short period of time, favoring nutrient cycling in the mangroves and providing a nutrient supply for neighboring aquatic systems [26]. This can have short-term impacts, increasing secondary production and local fish catches [25,26]. Nevertheless, overall negative impacts on mangrove health are expected, especially if new outbreaks occur in short periods of time.

The creation of a permanent observation and monitoring area for this ecosystem is currently under discussion by state and federal research and management institutions, and we will continue to observe the impact of these infestations. A biannual pattern of moth outbreaks has been reported in Brazil and other countries [26], but, as late as June 2019, no new occurrences have been observed in the region. Attention should be especially focused on protected areas and on the possible impacts of moth outbreaks on the wider ecology of mangroves and estuaries. There may also be consequences for the livelihoods of local fishers, some of whom rely heavily on mangrove crabs and oysters as a supplementary source of income and food [31].

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Conflicts of Interest: The authors declare no conflict of interest.

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