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Scientific papers

Evaluation of *Coccotrypes rhizophorae* on propagules of species of the genus *Rhizophora* on the Ecuadorian coast

Evaluación de *Coccotrypes rhizophorae* en propágulos de especies del género *Rhizophora* en la costa ecuatoriana

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Abstract

Coccotrypes rhizophorae (Coleoptera), an insect native to Indonesia, has been introduced to several American countries, including Ecuador and the Galapagos Islands. *C. rhizophorae* is the principal pest of mangrove species in the genus *Rhizophora*. Here, we examine the damage caused by *C. rhizophorae* infestations in a mangrove forest at eleven locations along the Ecuadorian coast throughout one year. We collected 13 200 *Rhizophora* spp. propagules in total (1200 individuals per site per year). The total *C. rhizophorae* infestation rate was 45%. The total prevalence of *Rhizophora* spp. propagules infested by *C. rhizophorae* was significantly higher during the rainy season (55%) compared to the dry season. Bellavista Island, Corazón and Fragatas Island, and Guayaquil Historical Park showed higher damage prevalence compared to other sites. In all sites and in both seasons, the prevalent location of damage in affected propagules was in the basal area (59.81%). There was an inverse relationship between the population size inside the propagule (larvae and adults) and rainfall. The number of holes created by *C. rhizophorae* in *Rhizophora* spp. propagules was associated with the damage intensity. These results are critical for the management, conservation, and restoration of mangrove forests in Ecuador and other countries where *C. rhizophorae* is present.

Keywords: biological cycle, Coleoptera, damage, infestation, mangroves, wetland.

Resumen

Coccotrypes rhizophorae (Coleoptera), un insecto originario de Indonesia, se ha introducido en varios países de América, incluidos Ecuador y las Islas Galápagos. *C. rhizophorae* es la principal plaga de las especies de manglares del género *Rhizophora*. Aquí, se examinó el daño causado por las infestaciones de *C. rhizophorae* en un bosque de manglares en once lugares a lo largo de la costa ecuatoriana durante un año. Se recolectaron 13 000 propágulos de *Rhizophora* spp. en total (1200 individuos por sitio por año). La tasa total de infestación por *C. rhizophorae* fue de 45%. La prevalencia total de propágulos de *Rhizophora* spp. infestados por *C. rhizophorae* fue significativamente mayor durante la estación lluviosa (55%) en comparación con la estación seca. La isla Bellavista, las islas Corazón y Fragatas y el Parque Histórico de Guayaquil mostraron una mayor prevalencia de daños en comparación con otros sitios. En todos los sitios y en ambas épocas, la localización predominante del daño en los propágulos afectados fue en el área basal (59.81%). Hubo una relación inversa entre el tamaño de la población dentro del propágulo (larvas y adultos) y la precipitación. El número de agujeros creados *por C. rhizophorae* en propágulos de *Rhizophora* spp. se asoció con la intensidad del daño. Estos resultados son críticos para el manejo, conservación y restauración de los manglares en Ecuador y otros países donde está presente *C. rhizophorae*.

Palabras clave: ciclo biológico, Coleptera, daño, parásito, manglar, humedales.

Introduction

Pest insects are a threat to mangroves worldwide (Jenoh at al., 2016; Souza et al., 2003b). One of the pest insects that affects the propagules of *Rhizophora* genus is *Coccotrypes rhizophorae,* Coleoptera: Curculionidae, Scolytinae (Martínez-Zacarías *et. al*., 2017; Arias de López & Molina Moreira, 2019; Carmona-Diaz et al., 2020). *C. rhizophorae* is native to Indonesia, and through dispersal by marine currents, it has invaded sites on the American continent; infestations have been reported in Florida, United States (Woodruff, 1970); Mexico (Gerónimo-Torres et al., 2015; Martínez-Zacarías et. al., 2017; Carmona-Díaz et al., 2020); Belize (Feller, 2002); Panama (Rabinowitz, 1977), Cuba (Vasquez-Moreno et al., 2003); Santa Cruz and Isabela in the Galapagos Islands and the Gulf of Guayaquil in Ecuador (Wood, 1982; Bright & Peck, 1998); Peru (Castillo, 2001) and Brazil (Souza & Sampaio, 2011).

Coccotrypes rhizophorae has strong and adverse effects on mangrove regeneration dynamics (Devlin, 2004). *C. rhizophorae* larvae and adults feed on the propagule tissue of *Rhizophora* and other mangrove species such as *Avicennia germinans* and *Laguncularia racemosa* (Onuf et al., 1977). The characteristics of damage generated by *C. rhizophorae* in mangrove propagules include perforations and gallery formation (Onuf et al., 1977; Carmona-Diaz et al., 2020; Cassinelli et al., 2023;). *C. rhizophorae* infestation typically begins with boring in the propagule basal area— the area preferred by the insect (Menéndez et al., 2006; Mendoza-Zambrano et al., 2020; Vasquez-Moreno et al., 2003). When *C. rhizophorae* infests a propagule, it consumes large amounts of plant tissue, significantly reducing establishment probability (Onuf et al., 1977; Devlin, 2004). When only the basal area is affected, propagule survival remains high (Menéndez et al., 2006); however, mortality rates significantly increase when *C. rhizophorae* infests the apical area of propagules (Carmona-Diaz et al., 2020). Propagule mortality associated with *C. rhizophorae* infestations is highly variable — about 1% in open habitats but 72% - 89% under the closed canopy of mangrove forests (Devlin, 2004). When an infested propagule survives, the growth rate of the established seedling is lower compared to seedlings originating from uninfected propagules (Onuf et al., 1977). Additionally, the negative relationship between *C. rhizophorae* gallery volume and propagule establishment is aggravated by the presence of other insect species in the galleries (Baena et al., 2020; Uribe et al., 2023).

Coccotrypes rhizophorae infestation is a major threat to mangroves in Ecuador, as evidenced by several recent studies (e.g., Mendoza-Zambrano et al., 2020; Pazmiño et al., 2021; Cassinelli et al.,2023; Rueda-Ajoy et al., 2023). In Manabí province, infestations in mangrove forests were up to 37% (Mendoza-Zambrano et al., 2020). Infestations by *C. rhizophorae* were observed in mangrove forests at four locations in the Gulf of Guayaquil, infestation rates were variable between sites (28% - 60%), and the basal area of the propagule was the most frequently damaged area (Cassinelli et al., 2023). Additionally, a comparison between mangrove infestation levels in the mainland Ecuadorian coast (Santa Elena Province) and the Galapagos Islands revealed that, in both locations, *C. rhizophorae* infestation had a greater effect on more highly disturbed mangroves (Rueda-Ajoy et al., 2023; Uribe et al., 2023). However, these studies were geographically isolated and short-term, limiting our knowledge of the spatial and temporal dynamics of *C. rhizophorae* infestations in Ecuador.

In this study, we assessed the damage caused by *Coccotrypes rhizophorae* infestation in mangrove forests at eleven locations along the Ecuadorian coast throughout one year to compare the level of damage caused by *C. rhizophorae* among locations and between seasons (rainy and dry). We estimated the relative abundance of the insect stages that cause mangrove propagule damage (larvae and adults) and identified other organisms associated with *C. rhizophorae* infestation. We also examined the most affected propagule sections (apical, basal, and/or medial).

Objectives

To determine the factors that affect the level of damage caused by *C. rhizophorae*, such as propagule length and the number of holes bored. Collectively, the results of this study are critical for the management, conservation, and restoration of mangrove forests in Ecuador and other countries where *C. rhizophorae* is present.

Materials and methods

Area of study

Ecuador is a tropical country where the cold Humboldt current and the warm El Niño current converge, influencing climatic conditions, especially the annual precipitation regimes (Cai et al., 2020). We conducted fieldwork at 11 sites among four provinces throughout the Ecuadorian coast, from north to south (Fig. 1): 1) Ecological Reserve Cayapas-Mataje (Majagual-San Lorenzo-Esmeraldas (01°18'07" N, 78°54'19" W); 2) Corazón and Fragatas Island Wildlife Refuge, between San Vicente and Sucre-Bahía de Caráquez-Manabí (00°39'08" S, 80°22'12" W); 3) Guayaquil Historical Park, Samborondón-Guayas (02°08'43" S, 79°52'12" W); 4) Santay Island National Recreation Area, Durán-Guayas (02°13'60" S, 79°52'00" W); 5) Puná Island (Guayaquil-Guayas, 2°50'00"S, 80°08'00"W); 6) Churute Mangrove Ecological Reserve (02°30'32" S, 79°44'38" W); 7) Nuevo Porvenir, Naranjal-Guayas (02°40'22" S, 79°36'54" W); 8) Puerto Pitahaya, (03°24'00" S, 80°05'00" W); 9) Bellavista Island (03°26"30" S, 78°5730" W,); 10) Pongalillo Island (3°22'22" S, 80°07'42" W); and 11) Las Huacas Island, Jambelí archipelago, Santa Rosa-El Oro (03°20'41" S, 80°09'41" W).

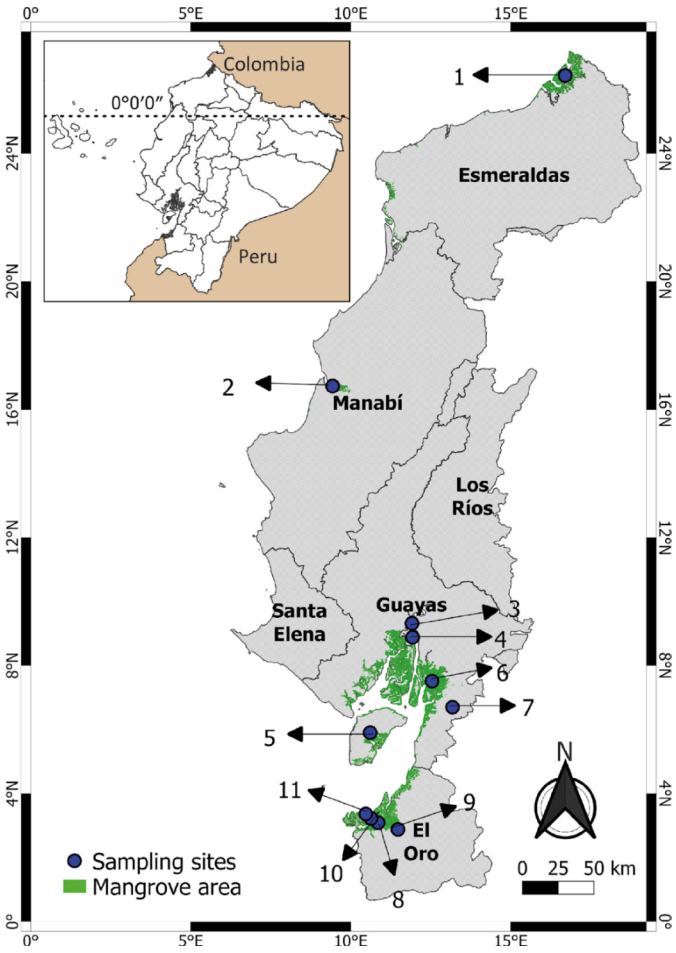


Figure 1. Location of the eleven study sites and the distribution of mangrove forest throughout the Ecuadorian coast.

Damage caused by *C. rhizophorae* in *Rhizophora* propagules

Mangrove, *Rhizophora* spp. (*R. mangle; R. racemosa R. samoensis*, and *R. harrisonii*), propagules were sampled at Guayaquil Historical Park from July 2018 to June 2019 and in the other sites from March/April 2019 to February/March 2020 for a total of 12 sampling months at each of the 11 sites. To standardize the methodology and reduce sampling bias, we randomly chose 100 mangrove propagules, collecting 13 200 propagules in total (1200 per site per year). We collected freshly fallen (on the ground/ trails or on the water, such that it was impossible to differentiate propagules to the species level) or imminently falling (still on the plant) propagules. After collection, we examined propagules in the laboratory. Each propagule was measured longitudinally and then classified as healthy or infested. Infested propagules can be recognized by the presence of holes and light-brown sawdust. We counted the number of holes in each infested

propagule and vertically cut each propagule to assess their degree of infestation according to a scale designed by the authors of this study: 0%, 25%, 50%, 75%, and 100% (0 = healthy propagule; 25% quarter-damaged; 50% half-damaged; 75% three-quarters damaged; 100% completely damaged) (Fig. 2).

Damaged propagule area

We adapted a method that only considers three propagule areas: Basal (B), Medial (M), Apical (A) (Cassinelli et al., 2023). Due to the large propagule sizes and observed variation in infestation areas, we characterized the area of damage in each propagule at a finer scale. We included the different combinations of the three main propagule components (Basal-Medial (BM), Basal-Medial-Apical (BMA), Medial-Apical (MA), and Basal-Apical (BA) (Fig. 3).

Stage of the insect causing damage to propagules and associated organisms

We recorded the insect populations in the infested propagules among the 11 sites and throughout the year using an Olympus SZ51 stereomicroscope. We identified and counted individuals in the egg, larva, pupa, and adult life-stages). We also determined the life cycle *C. rhizophorae* (Arias de López & Molina-Moreira, 2019) (Fig. 4).

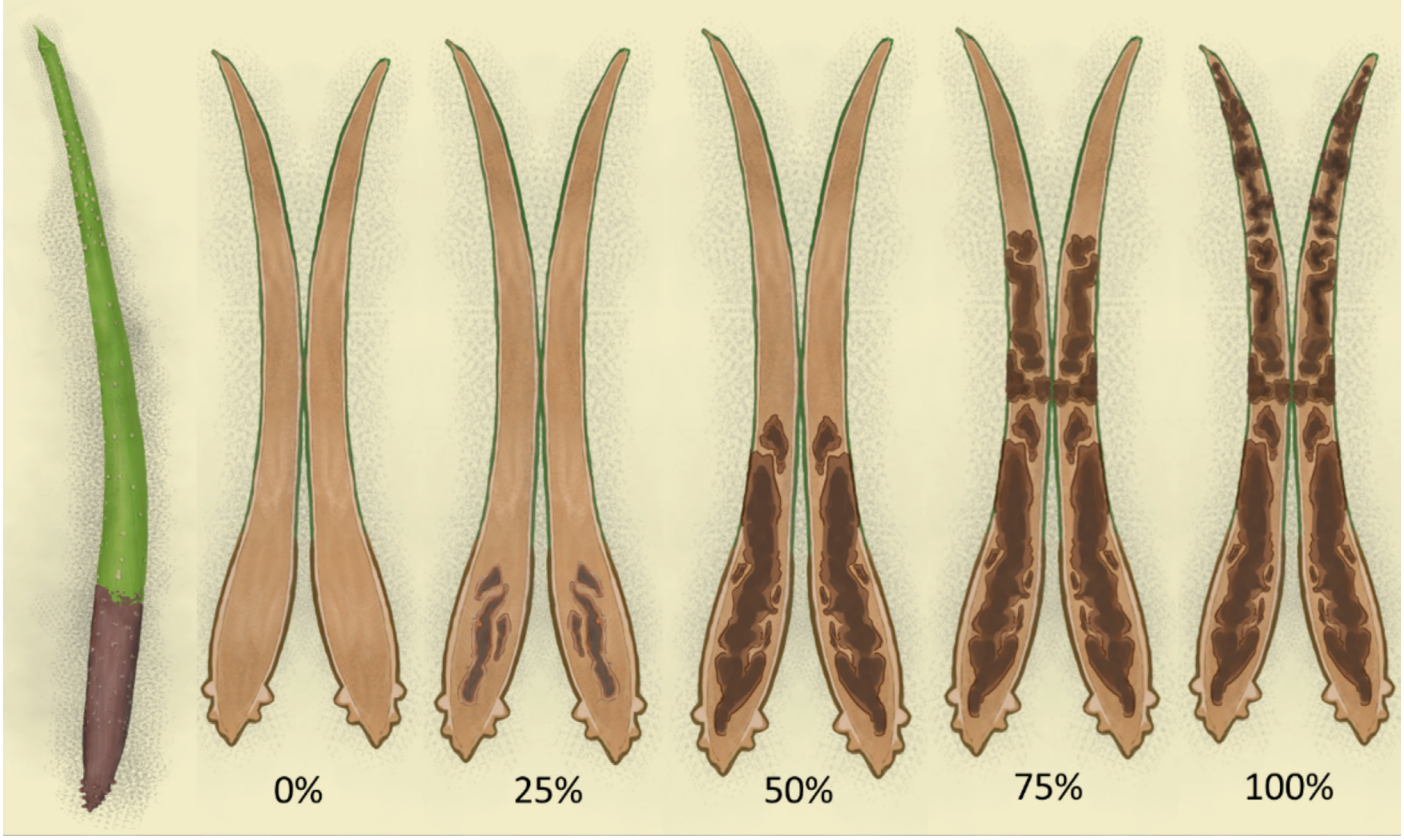


Figure 2. Scale (0%, 25%, 50%, 75%, 100%) of damage caused to *Rhizophora* propagules by *C. rhizophorae*.

Illustration by Mauricio Macias Tulcán.

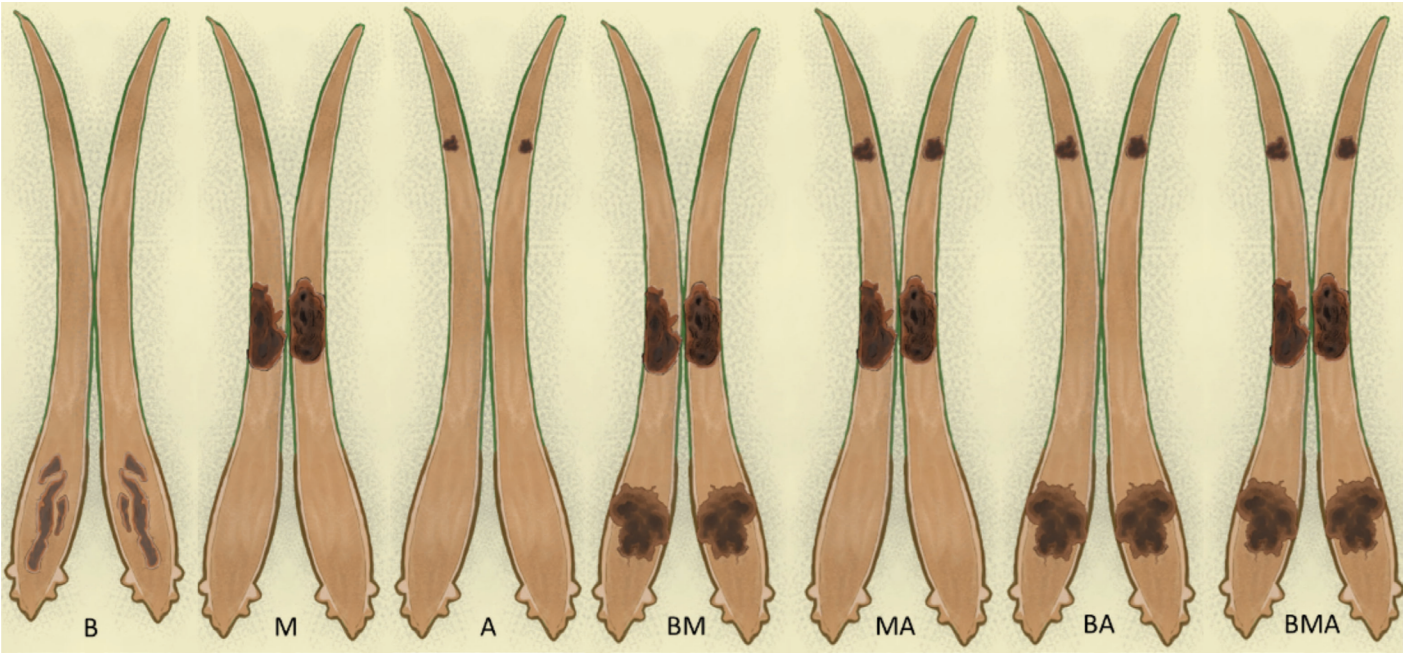


Figure 3. Area of the propagule affected by *C. rhizophorae*.

B: Basal; M: Medial; A: Apical; BM: Basal-Medial; MA: Medial-Apical; BA: Basal-Apical; BMA: Basal-Median-Apical. Design by Arias de López and Molina Moreira.

Illustration by Mauricio Macias Tulcán.

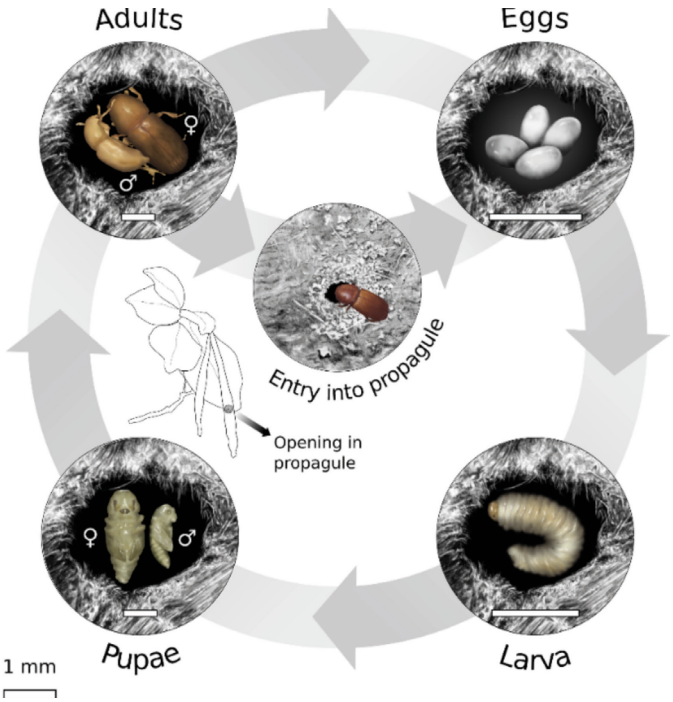


Figure 4. Biological cycle of *Coccotrypes rhizophorae* (Arias de López and Molina-Moreira, 2019).

Illustration by Jagoba Malumbres-Olarte.

Data Analysis

We calculated the incidence index of propagule damage caused by *C. rhizophorae* at each site by averaging the percentage values of all sample units. The prevalence index of the damage caused by *C. rhizophorae* was determined by calculating the proportion of affected propagules in relation to the total collected, multiplied by 100.

After inspecting the variables for normality and homoscedasticity assumptions according to the Kolmogorov-Smirnov and Breusch-Pagan tests, we tested if there were any differences between the percentages of prevalence and incidence of damage caused by *C. rhizophorae* between sites. We performed homogeneity tests on qualitative variables using a Pearson's Chi-square test and the likelihood ratio (G-test), applying a correction to improve the estimation of the G-test (Sousa et al., 2003).

We estimated the population size of *C. rhizophorae* that infested the interior of each propagule by summing the number of larval and adult specimens. Next, we performed a principal component analysis to inspect the

level of association and statistical significance between the following variables: prevalence, incidence, rainfall, propagule size, population of *C. rhizophorae* inside the propagule (larvae plus adults), and the number of holes on the surface of the propagule. We also performed a linear regression analysis with the variables with the highest correlation and significance. The autocorrelation between variables was verified according to the Durbin-Watson test.

All data analysis was conducted using the R statistical program (Version 3.6.3), via the interface RWizard v3.4 (Guisande et al., 2013). All the tests were made assuming a value of probability below 5% ($p < 0.05$), to reject the null hypothesis. Voucher specimens used in this study were deposited in INABIO-Quito, Código (code): MAAE-CMARG-2022-0492.

Results

Damage caused by *Coccotrypes rhizophorae* in *Rhizophora* propagules

Among the 13 200 *Rhizophora* spp. propagules analyzed at the eleven sampling sites, the total *C. rhizophorae* infestation rate was 45%. Other organisms (fungi, bacteria, mites, and nematodes) associated with damage caused by *C. rhizophorae* were identified based on microscopic observations. The most affected sites were Corazón and Fragatas island (72%), Santay Island (69%), Guayaquil Historical Park (64%), and Bellavista Island (60%; X-squared = 1730.5, df = 10, p-value < 0.001) (Fig. 5).

The total prevalence of *Rhizophora* spp. propagules infested by *C. rhizophorae* (combining all sites) was significantly higher during the rainy season (55%) than in the dry season (35%; X-squared = 485.25, df = 1, p-value < 0.001). When distinguishing the seasonality of infestation rate between sites, the proportion of infestations was significantly higher (p-value < 0.001) during the rainy season in most of the sites. However, there was a higher infestation rate in the dry season in Bellavista Island (Fig. 6).

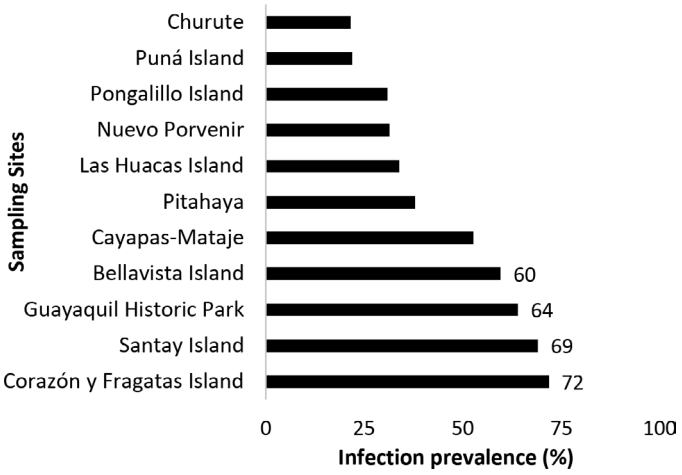


Figure 5. Prevalence of damage caused by *C. rhizophorae* infestation in *Rhizophora* spp. propagules between 2018 – 2020 in 11 sampling sites (N = 100/ site) throughout the coastal strip of continental Ecuador.

Shaded bars represent the largest proportions that were significant according to the Pearson's Chi-squared test, X-squared = 1730.5, df = 10, p-value < 0.001. Log likelihood ratio test of independence with Williams' correction (1976): G-test = 1785.2, X-squared df = 10, p-value < 0.001.

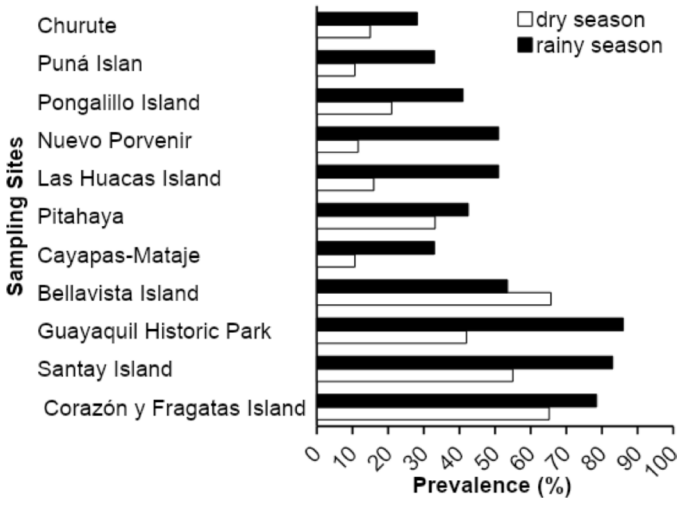


Figure 6. Comparison of *C. rhizophorae* infestation rate in *Rhizophora* spp. propagules between in rainy and dry seasons from 2018 – 2020 at 11 sampling sites (N = 600/ site/ season) along the coastal strip of mainland Ecuador.

Bellavista Island, Corazón y Fragatas Island and Guayaquil Historical Park showed the higher prevalence of damage (Table 1) (X-squared = 3651.6, df = 40, p-value < 0.001, log likelihood ratio test of independence with Williams' correction (1976): G-test = 3316.4, X-squared df = 40, p-value < 0.001).

Table 1. Prevalence of damage caused by *C. rhizophorae* in *Rhizophora* spp. propagules from 2018 – 2020 in 11 sampling sites along the coastal strip of continental Ecuador (N = 1200/ Site).

Sampling Sites	*Incidence (%)*				
	0	25	50	75	100
Pitahaya	•				
Pongalillo Island	•				
Las Huacas Island	•				
Puná Island	•				
Nuevo Porvenir	•				
Churute	•				
Cayapas-Mataje		•			
Santay Island		•	•		
Guayaquil Historical Park			•	•	
Corazón y Fragatas Island			•	•	•
Bellavista Island					•

Cells whith • represent the incidence proportions that were significant according to the Pearson's Chi-squared test.

Damaged propagule area

The basal area was the prevalent damage location in affected propagules in all sites sampled and, in both seasons, (59.81%). N: 1200; Shaded cells represent the incidence proportions that were significant by the Pearson's Chi-squared test, X-squared = 3651.6, df = 40, p-value < 0.001. Log likelihood ratio test of independence with Williams' correction (1976): G-test = 3316.4, X-squared df = 40, p-value < 0.001 (Fig. 7).

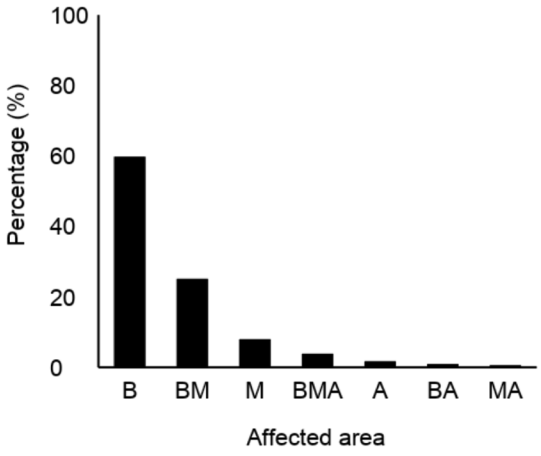


Figure 7. Location of the propagule area with tissue affected by *Coccotrypes rhizophorae* infestation.

B: basal; M: Medial; A: Apical (A); BM: Basal-Medial; MA: Medial-Apical; BA: Basal-Apical; BMA: Basal-Medial-Apical.

Stage of the insect causing damage to propagules and associated organisms

The average number of eggs, larvae, pupae and adults found within all the infested propagules at each site collected in the dry and rainy season was obtained. (Table 2) There was a negative relationship between the population size (larvae and adults) inside the propagule and rainfall. Larger propagules were the least affected by holes on their surface and had the lowest population of *C. rhizophorae* (Table 3).

The number of orifices created by *C. rhizophorae* on the surface of *Rhizophora* spp. propagules was significantly related to the damage intensity in the propagules (coefficient of determination equal = 84%) (Fig. 8). During the mangrove propagule evaluation, we observed that these holes allow the entry of predators of *C. rhizophorae* larvae and pupae, such as: ants of the subfamilies Myrmicinae and Ponerinae (Hymenoptera. Formicidae); flies of the families Cecidomyidae and Phoridae (Diptera); and mycelia of fungi in adults.

Table 2. Average number of different life stages of C. rhizophorae observed in affected propagules of Rhizophora spp., during the rainy and dry seasons between 2018 and 2020 along the coastal strip of continental Ecuador.

Sampling Sites	*Season*	*N*	*Eggs*	*Larva*	*Pupae*	*Adults*
Churute	rainy	39	5.03	4.05	1.18	4.00
	dry	46	3.26	5.22	1.28	3.81
Puná Island	rainy	61	2.10	2.85	2.62	4.47
	dry	15	2.40	0.53	11.13	5.27
Pongalillo Island	rainy	33	2.21	1.48	0.91	1.45
	dry	50	8.10	1.74	1.48	3.59
Nuevo Porvenir	rainy	130	4.10	1.35	1.40	2.67
	dry	52	2.81	3.88	4.29	3.56
Las Huacas Island	rainy	51	1.80	0.20	0.71	2.94
	dry	51	1.12	4.27	1.29	2.44
Pitahaya	rainy	87	1.59	3.74	3.08	3.73
	dry	161	2.80	8.13	2.85	5.27
Cayapas-Mataje	rainy	140	5.05	2.09	0.81	3.08
	dry	165	2.48	3.47	1.88	1.69
Bellavista Island	rainy	84	1.52	1.82	4.29	2.34
	dry	275	2.70	9.20	5.35	6.60
Guayaquil Historic Park	rainy	268	2.42	4.16	2.16	2.45
	dry	153	0.10	3.55	1.51	2.72
Santay Island	rainy	213	1.77	0.97	0.92	3.16
	dry	192	2.49	4.71	2.31	3.39
Corazón y Fragatas Island	rainy	175	3.31	4.09	2.30	5.03
	dry	229	4.19	6.25	2.72	4.40

Table 3. Correlation matrix between the damage indicators and the variables orifices, propagule length, and rainfall.

	Rainfall	*Length*	*Incidence*	*Prevalence*	*Population*	*Orifices*
Rainfall	*****	0.103	0.101	0.344	-0.065	0.080
Length	<0.001	*****	-0.148	-0.107	-0.030	-0.079
Incidence	<0.001	<0.001	*****	0.576	0.344	0.728
Prevalence	<0.001	<0.001	<0.001	*****	0.233	0.538
Population	<0.001	<0.001	<0.001	<0.001	*****	0.324
Orifices	<0.001	<0.001	<0.001	<0.001	<0.001	*****

*Upper diagonal part contains correlation coefficient estimates; lower diagonal part contains corresponding p-values.

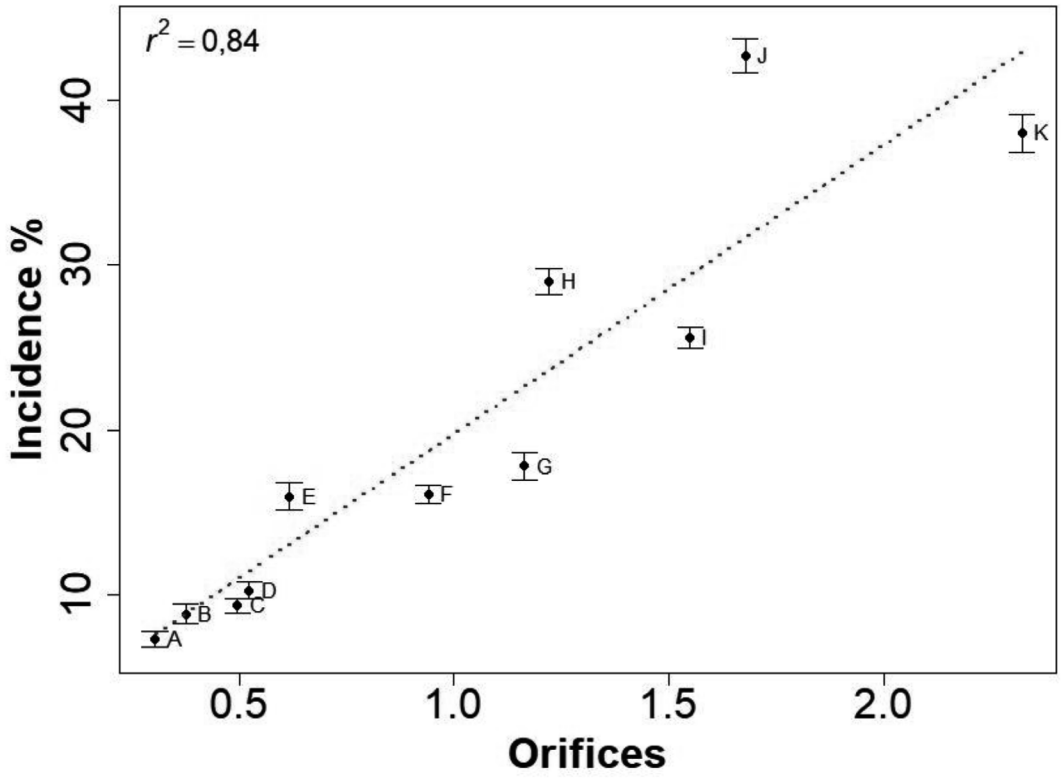


Figure 8. Location of the propagule area with tissue affected by *Coccotrypes rhizophorae* infestation.

B: basal; M: Medial; A: Apical (A); BM: Basal-Medial; MA: Medial-Apical; BA: Basal-Apical; BMA: Basal-Medial-Apical.

Discussion

The prevalence of the damage caused by *C. rhizophorae* in propagules of *Rhizophora* spp. was higher in the rainy season than in the dry season, similar to a study conducted in Cuba which also reported greater propagule damage by *C. rhizophorae* in the rainy season (Vasquez-Moreno et al., 2003; Menéndez et al., 2006). Why is the damage greater in the rainy season? *C. rhizophorae* initiates damage by boring holes in the early stages of propagule development (Pazmiño et al., 2021). These holes allow the entry of predators of *C. rhizophorae* larvae and pupae, such as: ants; flies and mycelia of fungi in adults that control and reduce the population of *C. rhizophorae*

The chambers and galleries built by this beetle favor the colonization of other organisms such as borer larvae of lepidoptera of the family Pyralidae and decomposers such as fungi, bacteria, mites and nematodes, which increase the level of damage. This explains why the population of *C. rhizophorae* (larvae and adults) causing damage is low during the rainy season.

If the population of *C. rhizophorae* in the stages that cause damage (larvae and adults) in the dry season is higher, why is there less damage? Because the *C. rhizophorae* life cycle is very short (20 days), copulation is carried out by the teneral adults as soon as they emerge from the pupae (Rueda-Ajoy et al., 2023). The absence of rain favors *C. rhizophorae* reproduction and the several generations of the insect complete development within the propagules. Consequently, the damage to each propagule is greater, such that the insects do not need to damage other propagules. Therefore, the proportion of the number of damaged propagules was higher according to the scale of damage. Our results agree with those of other authors who recorded higher average numbers of bored propagules in the dry season (November to May) in Veracruz México (Carmona-Diaz et al., 2020).

What is the most damaged part of the propagule? Is there any relation with the size of the propagule?

The basal area of the propagule was the most affected. Other authors (Carmona-Diaz et al. (2020); Mehlig and Menezes, (2005); Menéndez et al. (2006); Rueda-Ajoy et al. (2023) have also reported that the basal area of the propagule is the most affected by infestations; but *C. rhizophorae* prefers this part of the propagule because the propagule begins development at the basal area (Pazmiño et al., 2021). The adult female perforates the propagule and digs a brood chamber in which she oviposits more than 20 eggs, preferring to oviposit in the basal area because it is the widest part of the propagule and the one that develops first (Rueda-Ajoy et al., 2023).

Although propagules die when the apical zone is infested (Carmona-Diaz et al., 2020), in this study we found that the percentage of damage in the apical area and their combinations was minimal. Therefore, the damage caused by *C. rhizophorae* may not be a determining factor for the survival of propagules (Menéndez et al., 2006). On the other hand, sediment and hard soil prevent the anchorage essential for the growth and development of the propagules, so soil characteristics may be more important for their establishment Mendoza-Zambrano et al. (2020); Menéndez et al. (2006). Although the damage caused by the insect destroyed 100% of the basal area, the propagule can still grow roots and survive, evidence of the high resilience of the species of the genus *Rhizophora* (Menéndez et al., 2006).

There was no relationship between infestation and propagule size. This is likely because infestation influences propagule growth when mangroves have high levels of sedimentation caused by human settlements (Mendoza-Zambrano et al., 2020). However, our principal component analysis showed that larger propagules were less affected by holes on their surface and had lower populations of *C. rhizophorae*, results that agree with other studies (Wood, 1977; Wood,

1982) that have reported that larger propagules are less prone to infestations (Onuf et al., 1977).

What are the stages of the insect that cause damage to the propagules?

Adult females and larvae of *C. rhizophorae* are the stages that cause damage to the propagules. Adult females initiate damage when they bore a hole through which they enter to build the brood chamber and oviposit. The adult females also dislodge the sawdust produced by the feeding of the larvae feed and cause the most damage when they make their galleries along the propagule (Rueda-Ajoy et al., 2023). Associated organisms that increase the damage have also been recorded. In this study, we recorded populations of other organisms besides *C. rhizophorae* that occupy the chambers and galleries. We saw in the laboratory that fungi, bacteria, mites and nematodes often increase the damage, and accelerate the decomposition of the propagule.

The number of holes in the propagules was higher during the rainy season (up to 27). The adult females of *C. rhizophorae* make holes both when boring into a propagule to infest it and when boring an exit hole in order to infest other propagules; the adult males do not die after copulation inside the propagule (Rueda-Ajoy et al., 2023). This would explain why there are more orifices during the rainy season; the females abandon the propagules in order to avoid drowning by the entry of water.

Study limitations

Because *Rhizophora* propagules were randomly collected from the water, soil, and plant and propagule morphology changes according to environmental conditions, it was not possible to identify propagules to the species level. However, collecting the same number of propagules every month during a year and at each study location necessitated this collection method because there is only one flowering and fruiting season per year.

The prevalence of the damage caused by *Coccotrypes rhizophorae* in propagules of *Rhizophora* spp. was higher in the rainy season than in the dry season, in the same way that the number of holes in the propagules was higher during the rainy season. Adult females and larvae of *C. rhizophorae* are the stages that cause damage to the propagules of *Rhizophora* spp. The basal area of the propagule of *Rhizophora* spp was the most affected. There was no relationship between infestation and propagule size. We consider that *C. rhizophorae* can be a good indicator of mangrove health, and that knowledge of its prevalence in the rainy season, the state in which it causes the most damage and the area of the propagule that affects the most, contributes to the management of the species in the mangrove genus *Rhizophora* for the implementation of mangrove restoration actions.

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