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Analysis of the natural regeneration of the white mangrove (*Laguncularia racemosa* (L.) C.F. Gaertn. with dasometric variables during the drought season

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ABSTRACT
Objective: To analyze the natural regeneration of the white mangrove (*Laguncularia racemosa* L.) with dasometric variables, during the drought season, in the ejido La Solución Somos Todos in Paraíso, Tabasco, Mexico.
Design/Methodology/Approach: The structural variables of white mangrove —diameter at breast height (DBH), height, and canopy diameter— were measured in three sampling plots. A statistical analysis was performed with the resulting data and the mean data were determined for the three sampling plots.
Results: The following data were recorded for each sampling plot: DBH (0.34, 0.37, and 0.42 cm), height (134, 128, and 158 cm), and canopy (44.18, 38.56, and 39.83 cm).
Study Limitations/Implications: In the dry season, erosion can expose rocky and sandy substrates that are not suitable for mangrove growth.
Findings/Conclusions: The white mangrove —which undergoes its brinzal (seedling) stage during the dry season— recorded statistically significant differences in growth between sampling plots using the dasometric variables (DBH, height, and canopy diameter).

Keywords: mangroves, conservation, sustainability, water, salinity.

INTRODUCTION
The natural regeneration of mangroves is a vital process for the health of these ecosystems, but it can be severely hindered by various factors, especially alteration of environmental conditions (Vargas-Fonseca, 2014).

Laguncularia racemosa L. is a very attractive species for restoration programs, because of its better chances for survival. Furthermore, its rapid growth rate and its ability to colonize degraded areas makes it a promising species for natural regeneration (Guerra-Santos *et al.*, 2015).

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The relationship between allometric measurements and the evaluation of natural regeneration of *Laguncularia racemosa* during the drought season are crucial to understand and address its adaptation and growth difficulties (Flores-de-Santiago *et al.*, 2012). In this context, dasometric measurements (*e.g.*, height, canopy diameter, and breast height diameter) can help to evaluate the response of plants to drought conditions and the adaptation strategies that might be effective (Sobrado and Ewe, 2006). These strategies could provide information on which traits are of the utmost importance for the survival and growth of *Laguncularia racemose* under drought conditions, which in turn could provide management and conservation guidelines (Sánchez-Toruño *et al.*, 2022).

Given the crucial role of mangroves for ecosystem services and their importance in climate change mitigation, ongoing research and conservation efforts are essential. Measuring the dasometric variables in these ecosystems is fundamental to establish effective conservation and restoration policies and actions. Therefore, this research aims to analyze the natural regeneration of the white mangrove (*Laguncularia racemosa* L.) with dasometric variables, during the drought season in the ejido La Solución Somos Todos in Paraíso, Tabasco, Mexico.

During the drought season, conditions such as water level, salinity, and light availability are expected to significantly impact the growth, structure, and survival of the white mangrove (*Laguncularia racemosa* L.), which will be reflected in remarkably different the structural and dasometric variables of *Laguncularia racemosa* in different sample plots.

MATERIALS AND METHODS

Study site

The study was carried out at the UMA (Unit for the Conservation, Management and Sustainable Use of Wildlife) La Solución Somos Todos, located in the municipality of Paraíso, Tabasco, north of the state capital, in southeastern Mexico. The UMA is located in 18° 19’ 00” and 18° 23’ 00” N and 93° 04’ 00” and 93° 07’ 00” W (Figure 1).

Data collection

Field data collection was carried out during the drought season (February to June 2023), when no precipitation was recorded. During the drought season the solar radiation reaches its maximum point in the study area and, consequently, the mangrove canopy is in a dormant state and photosynthetic activity requires a careful use of water. Under these conditions, the temperature increase can affect or limit the growth of the white mangrove (Berlanga-Robles *et al.*, 2019). Three measurements were taken in February, April, and June. For this purposes, three 10×10 m plots were established (Fonseca *et al.*, 2007).

Measurements

Each mangrove plant was labeled at the beginning of the study. A 6” Truper® stainless steel analog vernier caliper (std and mm) was used to measure the diameter at chest height (30 cm above the soil level). The height of the mangroves was measured with a 3 m long graduated ruler, while the diameter of the canopy was recorded with a measuring tape. In total, 586 plants were monitored, out of which 207, 197, and 182 were located in plots

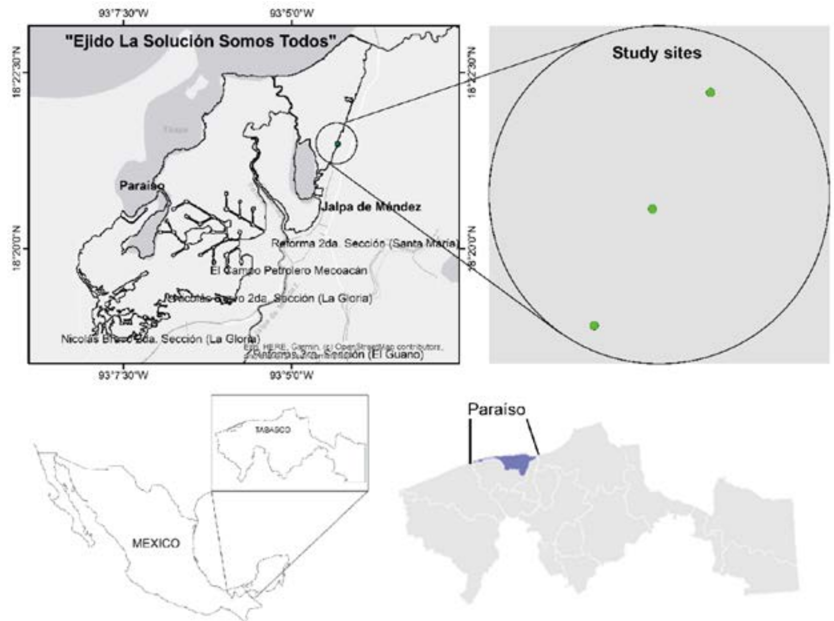

Figure 1. Geographical location of the UMA La Solución Somos Todos, Paraíso, Tabasco.

1, 2, and 3, respectively. The monitoring period was 6 months during the drought season (February to July); no precipitation was recorded during this period.

Dasometric variables

Allometric functions are used to estimate growth in relation to certain physical parameters of the tree, such as diameter at breast height, total height, and canopy diameter (Aye *et al.*, 2022). The dasometric analysis includes variables such as DBH, height and canopy diameter that are crucial to understand the structure and growth of individual trees.

Statistical analysis

The recorded data were analyzed using the non-parametric Kruskal-Wallis test to estimate the growth of the species during this period.

RESULTS AND DISCUSSION

White mangrove height

Statistically significant differences ($p<0.0001$) were recorded among the variables for the three plots. The height means for each of the plots were 134 cm, 128 cm, and 158 cm, respectively. The resulting data can be compared with the findings of other researchers. For example, Elster (2000) reported that the height of *L. racemosa* in the mangroves of Cénaga Grande de Santa Marta in Colombia during the drought season ranged from 109 cm (minimum) and 140 cm (maximum). Figure 2 shows the mean height of white mangrove brinzal in each of the three monitored plots: no statistically significant differences were reported in plots 1 and 2, but plot 3 had statistically

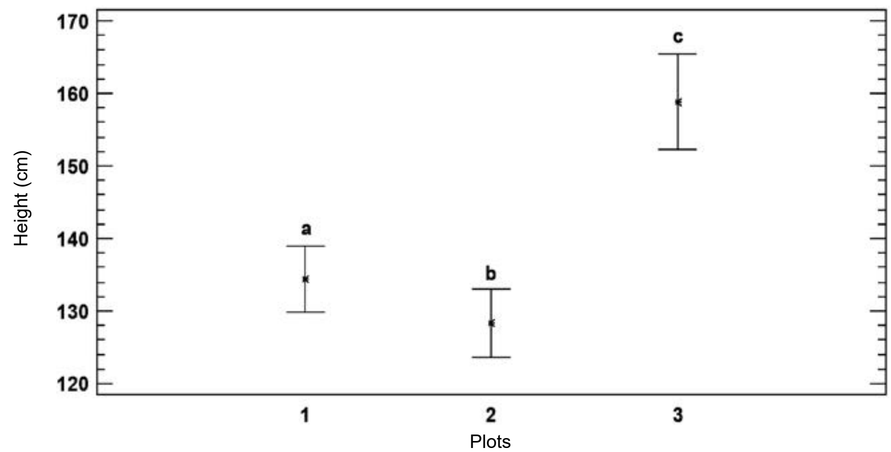

Figure 2. Statistical differences in mean *brinzal* height between white mangrove monitoring plots. Different letters indicate the average and significant statistical differences.

significant differences regarding the other two plots. According to the physiological requirements, light incidence and water availability may have influenced the growth of the plants during the evaluation period. Meanwhile, the database shows that the water depth on the same site reached 26 cm and 49 cm on May 5 and on May 22, respectively; comparatively speaking, the development of the roots of the plants was much slower and therefore the smallest were the least favored. Soil salinity and inter- and intra-specific competition are other factors that influence the growth of these species The site salinity data recorded 49 and 51 parts per thousand (ppt) on May 5 and 22, respectively; nevertheless, this is an acceptable range. The lack of water in the plant generates stress and, at a higher concentration of salt, the basal increase of white mangroves is negatively affected. Consequently, adult plants could have few expectations (Monroy-Torres *et al.*, 2014; Rodríguez-Rodríguez *et al.*, 2016).

Diameter of white mangrove at breast height

Statistically significant differences were recorded among the three plots ($p<0.0001$) regarding this variable. The values obtained per plot were 0.34, 0.37, and 0.42 m (Figure 3). The data obtained are comparable with other researches. For example, the *L. racemosa* mangroves from Samaná Bay, Los Haitises National Park, Dominican Republic, recorded a 0.46 cm DBH during the drought season (Sherman *et al.*, 2000). Meanwhile, the DBH of *L. racemosa* mangroves in Puerto Rico, during the drought season, was 0.56 cm (Branoff, 2020).

Canopy diameter of white mangrove

Statistically significant differences ($p=0.0009$) were recorded for this variable among the three plots. The canopy diameter values obtained per plot were 44.18, 38.56 and 39.83 cm (Figure 4). Increased soil temperature and decreased humidity during the drought season can lead to a reduction in the leaf area index (LAI) of white mangrove. This decrease in LAI may have implications for the health and productivity of the

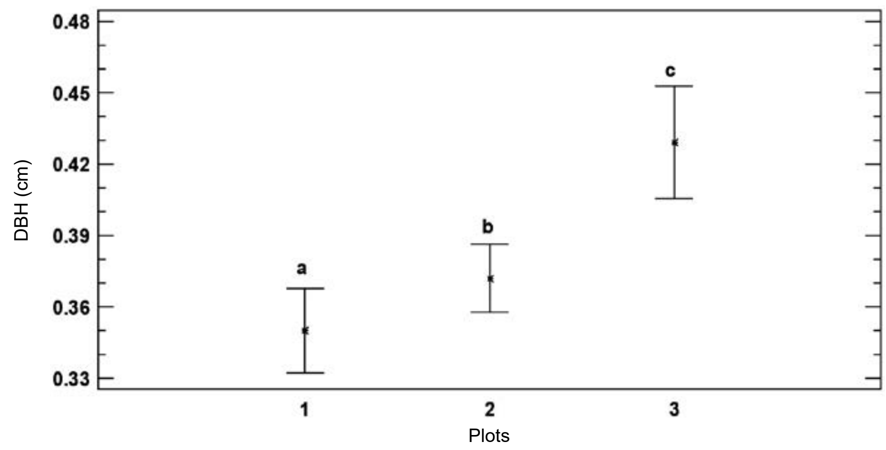

Figure 3. Mean diameter at breast height of white mangrove *brinzal* in the different plots. Different letters indicate the average and significant statistical differences.

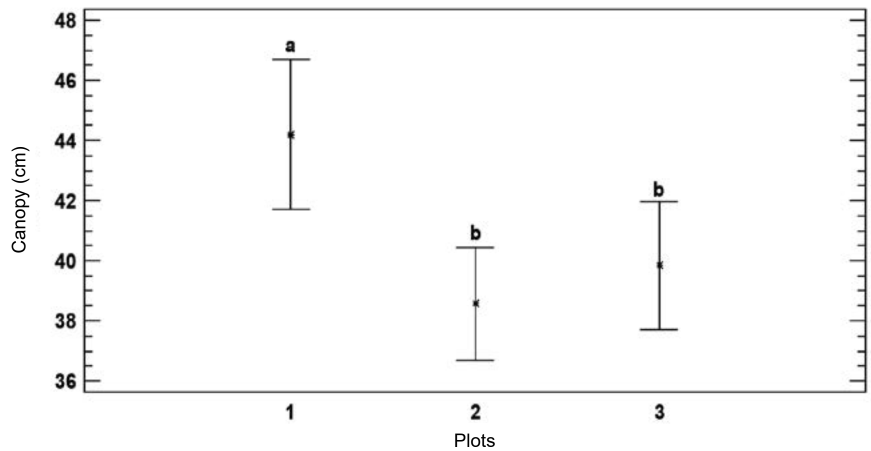

Figure 4. Mean canopy diameter of white mangrove *brinzal* in the different plots. Different letters indicate the average and significant statistical differences.

mangrove ecosystem, since the white mangrove is a key species in these coastal habitats (Flores-de-Santiago *et al.*, 2012).

CONCLUSIONS

The study recorded significant differences in the height, diameter at breast height (DBH), and canopy diameter among three monitoring plots of white mangroves. These differences indicate variations in environmental conditions such as light incidence, water availability, and soil salinity. These dasometric measurements are crucial for understanding the growth and adaptation of white mangroves, as they reveal the species' response to environmental stressors like drought and salinity. Understanding the complex nature of the mangrove ecosystems requires multiple variables, such as water level and salinity, to assess their health and survival. The study suggests that the death of seedlings might be a consequence of the increased salinity caused by a reduction in water intake, although this conclusion is not backed by any corroboration measurements. Further research into the structural variables of white mangroves during different growth stages and seasons is recommended. Additionally, incorporating factors like water level and salinity into growth studies can help to make informed decisions regarding sustainable mangrove use, ensuring viable harvesting practices and the long-term health of the species.

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