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Population structure and distribution of Critically Endangered *Cycas sancti-lasallei* Agoo & Madulid (Cycadaceae) in northern Mindanao, Philippines

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ABSTRACT

Cycas sancti-lasallei Agoo & Madulid is a Critically Endangered (CR) cycad endemic to Mindanao. Its population structure, sex ratio, and distribution remain poorly understood; therefore, this study aims to provide a more comprehensive characterization of these parameters. Fieldwork was conducted across five plots in Mapawa Nature Park, Barangay Cugman, and one plot in Barangay F.S. Catanico, collectively covering 25,000 ha. Individual locations were mapped using QGIS and GeoCAT. A total of 1,015 individuals were recorded, with the population dominated by juvenile plants with reproductive adults comprised only 4.93% of the total population. This pattern suggests active recruitment but limited progression to reproductive maturity. Reproductive adult density was low (20 plants/ha), with nearly half of these individuals concentrated in a secondary forest site, whereas youngest stage juveniles exhibited the highest density (125.6 plants/ha). The sex ratio was skewed toward females (0.72:1), which may reflect differences in detectability between sexes during a single survey period rather than a true demographic imbalance. Spatial analysis indicated an aggregated distribution pattern influenced by terrain, soil properties, and vegetation structure. Secondary forests with loamy soils acted as reproductive hubs, supporting nearly half of all coning individuals. In contrast, areas with steep rocky slopes, invasive vegetation, or dense canopy cover supported fewer individuals and showed limited reproductive activity. The skewed stage structure, low abundance of reproductive

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adults, and spatially constrained distribution suggest potential limitations to the long-term viability of *C. sancti-lasallei*. These findings highlight the need for targeted conservation strategies and habitat protection.

Keywords: aggregated spatial distribution, endemic gymnosperm, population survey, sex ratio

INTRODUCTION

Cycads (Cycadaceae) are evergreen, palm-like, dioecious gymnosperms characterized by a robust, unbranched trunk, pinnately compound leaves with petiolar spines, and sexually dimorphic reproductive structures. Male plants bear cylindrical cones composed of numerous microsporophylls, while female plants produce megasporophylls that bear ovules rather than true cones (Simpson, 2010; Lindstrom *et al.*, 2008). Although commonly referred to as sago palms due to their superficial resemblance to palms, cycads are taxonomically distinct (Stein, 2004). Globally, cycads represent one of the most threatened plant lineages, with approximately 70% of species facing extinction risk due to habitat loss, illegal collection, and environmental degradation (Hoffmann *et al*., 2010; Ogwal, 2017). Their typically small and geographically restricted populations further increase vulnerability to stochastic and anthropogenic disturbances (Matthies *et al*., 2004).

The genus *Cycas* comprises thirteen species in the Philippines, six of which occur in Mindanao (Pelser *et al*., 2011). In the country, *Cycas* exhibits high levels of endemism and pronounced island-based biogeographic structuring, with most species confined to narrow ranges within Luzon, Palawan, or Mindanao and several taxa described only in recent decades. Many Philippine cycads occupy specialized habitats such as coastal forests, limestone areas, or disturbed lowland vegetation and persist as small, fragmented populations, underscoring the archipelago as an important center of cycad diversity but also one of high conservation concern (Agoo *et al*., 2018; Calonje *et al*., 2023). *Cycas sancti-lasallei* Agoo & Madulid is a site-endemic species confined to disturbed lowland evergreen forests and reforestation areas in Cugman, Cagayan de Oro City, Misamis Oriental (Agoo and Madulid, 2012). This species is distinguishable from other *Cycas* species by its elongated leaves, undulating leaflets, and a megasporophyll lamina characterized by a semi-orbicular to orbicular base and a triangular apex bearing few but well-defined spines (Agoo and Madulid, 2012). It is currently listed as Critically Endangered under the IUCN Red List criteria B1ab (i, iii, v); C2a(ii) (IUCN, 2022), with an estimated population of approximately 100 individuals at the time of assessment (Agoo and Lindstrom, 2022), and is protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Despite its high conservation priority, fundamental information on the population structure, sex ratio, density, and spatial distribution remains lacking, including the absence of a mapped distribution necessary for estimating its extent of occurrence. Small-population dynamics in cycads are still poorly understood (Donaldson, 2003), limiting the formulation of evidence-based conservation actions. This study therefore aims to characterize the population structure and document the spatial distribution of *C. sancti-lasallei* in Northern Mindanao, Philippines, to provide a scientific basis for targeted conservation and management strategies.

MATERIALS AND METHODS

Entry Protocol

Gratuitous Permit (GP) no. R10-2025-57 was secured from the Department of Environment and Natural Resources (DENR) Region 10 office, Cagayan de Oro City in compliance with R.A. 9147, known as the Wildlife Resources Conservation and Protection Act of 2001, and E.O. 247 for the authorized collection of specimens.

Study Area

The study was conducted in Barangay Cugman and Barangay F.S. Catanico in Cagayan de Oro City. Most of the populations of *C. sancti-lasallei* are found in Mapawa Nature Park within Barangay Cugman, Cagayan de Oro City, Misamis Oriental (Figure 1) with minimum elevation of 111 m to maximum elevation of 510 m. Mapawa Nature Park occupies 2,500 hectares positioned geographically with close proximity to the Mapawa stream and is claimed as a protected, conserved and sustainably managed area by E. Pelaez Ranch Incorporated (Parreno *et al.*, 2020). Barangay F.S. Catanico is adjacent to Barangay Cugman. This barangay is notable for F.S. Catanico Falls, a local tourist attraction. Similar to Mapawa Nature Park, Barangay F.S. Catanico is located near a water body, the Cugman River.

Environmental Parameters

HTC-2 Digital LCD Temperature and Humidity Meter was utilized to record temperature and relative humidity (RH) during outdoor sampling. During sampling, the calibrated device was positioned in a shaded, well-ventilated location to minimize interference from direct sunlight. Placement was above ground level, and away from surfaces that emit heat or

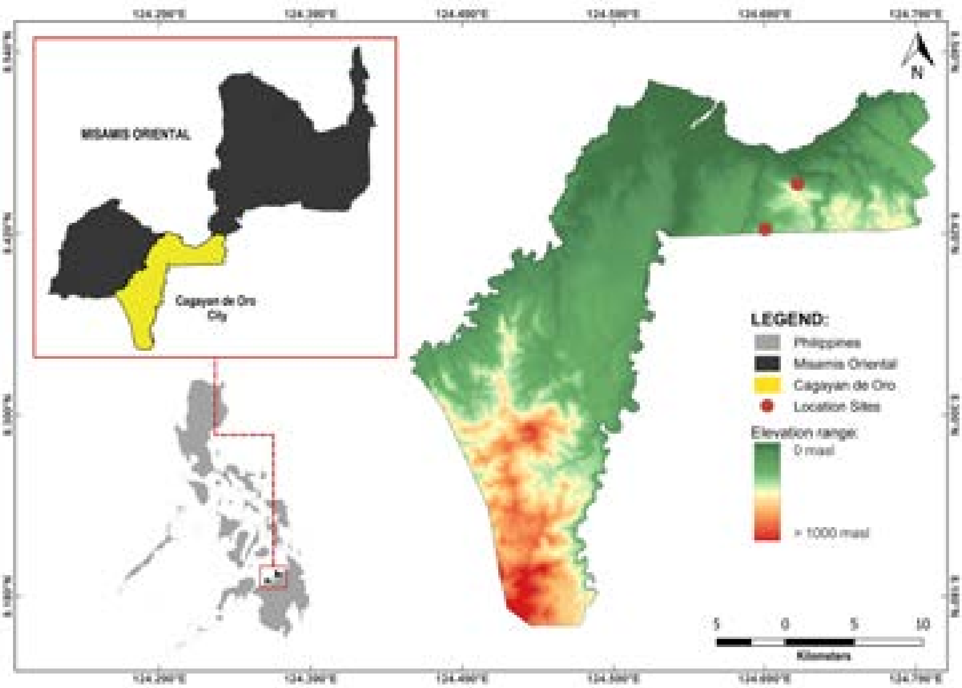

Figure 1. Map of the Philippines showing Misamis Oriental and Cagayan de Oro City with location sites in Barangay Cugman and Barangay F.S. Catanico.

moisture. Gaia mobile application and GPS device were utilized to record the coordinates of each individual. The RH and temperature were recorded when the readings are stabilized. Rainfall data was obtained from PAGASA, and any disturbances observed in the area where the population were found were documented.

Establishment of Sampling Plot

Following a preliminary survey, the study area was divided into five transects across all known population where *C. sancti-lasallei* were observed, representing the range of habitat types (Figure 2). Each transects possesses distinct environmental characteristics and vegetation composition. Sites 1 to 4 were established at Mapawa Nature Park: site 1 is a secondary forest with the densest canopy cover; site 2 is a bamboo-associated site; site 3 is a reforestation/grassland area exhibiting significant invasion by introduced *Acacia mangium* Willd.; site 4 is a reforestation/grassland site dominated by *Imperata cylindrica* (L.) Raeusch. (cogon grass) and located perpendicular to the secondary forest site; and site 5 is located in a coastal hill reforested site in Barangay F.S. Catanico characterized by steep slopes among all sites and a high potential for erosion.

The study employed the sampling method used by Ogwal (2017) with modifications to suit the current objectives. A stratified random sampling approach was employed to collect data, as this method is effective for estimating populations that are both rare and localized (Krebs, 1972). Given that the cycad population is distributed within a limited range, stratified random sampling is deemed suitable for capturing the spatial patterns of occurrence (Ogwal, 2017).

Following the method used by Ogwal (2017) each transects covered a total of 5,000 m² (0.5 hectare) and was divided into two blocks of 50 m x 50 m along each transect, resulting in ten blocks across all transects. Additionally, to achieve greater sampling granularity, each block was further divided into two blocks of 50 m x 25 m, resulting in 20 blocks across all transects. Therefore, the total area that was sampled per block is 1,250 m^2 multiplied by 20 blocks. Hence, the total number of blocks in all sampling sites (20 blocks) is 25,000 m^2 or 2.5 hectares. This design allows for enhanced resolution in data collection across varying population densities.

Sampling plots were established across all known populations using five transects representing distinct habitat types: the first plot was located within secondary forest with the densest canopy cover; the second is within a bamboo-associated site; the third in a reforestation/grassland area exhibiting significant invasion by introduced *Acacia mangium* Willd.; the fourth in a reforestation/grassland site which is dominated by cogon grass (*Imperata cylindrica* (L.) Raeusch.) and is perpendicular to secondary forest site or site 1; lastly, the site is at Barangay F.S. Catanico which is characterized as coastal hill reforested site with steepest slopes among all sites with high potential to erosion. All plots were carefully delineated using calibrated rope to ensure consistency in plot size and positioning. Lastly, opportunistic sampling was carried out for individuals observed outside the sampling plots and coordinates were documented for mapping.

Stage Class Determination

Stage classes were determined within stratified random sampling to assess the population structure of *C. sancti-lasallei*. The classification method outlined by Swart et al. (2019) was applied to differentiate among various stage classes namely seedlings, juveniles, and adults.

Seedlings were divided into two categories based on leaf length and developmental stage. Seedlings 1 (S1) includes the youngest individuals, with leaf lengths ranging from 5

Figure 2. Portion of Sampling Sites in Cagayan de Oro City, Misamis Oriental. A, Site 1 or Secondary Forest Site; B, Site 2 or Bamboo Associated Site; C, Site 3 or Acacia Associated Site; D, Site 4 or Grassland Site; E, Site 5 or Coastal Hill Reforested Site. Sites 1-4 are located at Barangay Cugman while site 5 is located at Barangay F.S. Catanico.

to 20 cm, characterized by their smaller leaf size and distinct shape (Figure 3A). Seedlings 2 (S2), considered older, was identified by leaf lengths of 21 to 80 cm (Figure 3B), indicating the development of larger true leaves, with each plant bearing between one and seven leaves.

Juvenile plants were categorized by stem height. Juvenile 1 (J1) plants have measurable stems between 1 and 9 cm (Figure 3C), while Juvenile 2 (J2) plants exhibit stem heights between 10 and 34 cm (Figure 3D).

Figure 3. Stage classes of Cycas sancti-lasallei. A, Seedling 1 or S1; B, Seedling 2 or S2; C, Juvenile 1 or J1; D, Juvenile 2 or J2; E, Adult 1 or A1; F, Coned Male or A2; G, Coned Female or A2.

Adults were distinguished based on the presence and maturity of reproductive structures. Adult 1 (A1) plants have stems of 35 cm or more but lack reproductive structures (Figure 3E). Adult 2 (A2) plants were identified by the presence of cones or reproductive structures, as well as any prior reproductive traces found at the base of the plants (Figure 3F, G).

Population Density

Population density was based on stage classes (seedlings, juvenile, and adult). To determine the population density, a total area of 25,000 m^2 or 0.025 km^2 as the total area of sampling sites, was used as land area. Furthermore, stage class structure was constructed by computing the mean density of *C. sancti-lasallei*. The density of the population was calculated as:

$$D=S/A$$

Where: *D* - Density of species. *S* – Total number of individuals per sampling unit. *A* – Land area.

Sex Ratio Distribution

The gender of adult *C. sancti-lasallei* plants was determined by examining their reproductive structures (Swart et al., 2019; Watkinson and Powell, 1997). Female plants bear megasporophylls, which are fertile sporophylls that bear ovules and subsequently develop seeds (Figure 3G) while male plants were distinguished for their elongated cone structures bearing pollen grains. Gender composition was computed as follows:

Distribution of *C. sancti-lasallei*

The geospatial distribution of *C. sancti-lasallei* was analyzed using QGIS software. Geographic coordinates of all recorded individuals, including seedlings, juveniles, and adults, were collected in the field using the GAIA mobile application and subsequently imported into QGIS for spatial mapping and analysis.

RESULTS AND DISCUSSION

Stage Class Determination

A total of 1,015 *C. sancti-lasallei* individuals were recorded across all sampling sites. The population structure was characterized by six stage classes, ranging from seedlings to reproductive adults. Among these, juvenile 1 (J1) comprised the largest proportion of the population, with 314 individuals, representing 30.93% of the total. This was followed by Seedlings 1 (S1), with 246 individuals (24.29%), indicating a relatively high rate of early recruitment within the population (Figure 4). The Juvenile 2 (J2) stage accounted for 163 individuals (16.06%), the same number recorded for adult 1 (A1) plant (16.06%), which are mature in size but non-reproductive. Seedlings 2 (S2), representing slightly older seedlings, comprised 79 individuals, or 7.78% of the population.

Reproductive adults (Adult 2) were the least represented in the dataset. A total of 50 individuals exhibited reproductive structures, comprising only 4.93% of the population. Of these, 21 were identified as male plants (2.07%), and 29 as female plants (2.86%). Mast coning events in *Cycas* can influence the number of individuals observed in reproductive condition. It is also important to note that data collection was conducted between February and March. Majority of reproductive adults or A2 is present in Site 1 (24/50 or 48%) explains the richest population among all sites especially seedlings (Figure 4). Comparatively, sites 3 and 4 only housed female adult individuals, with one and three female adults. This may explain the low population in the sites.

Many of the seedling stage class are clumped around the base of female adult plants and majority of the seedlings bear only one or two leaves. Juvenile plants (J1 and J2) were more evenly distributed, with Secondary Forest Site (Site 1) having the highest count (Figure 4). Among the adult plants, individuals without reproductive structures (A1) showed variable distribution across sites, with Site 1 having the highest count with 66 individuals. Coning individuals (A2) were less abundant, and the secondary forest site (Site 1) again recorded the highest count listing 24 individuals.

This skewed distribution, characterized by a greater proportion of juveniles and fewer mature adults, is comparable to the pattern reported by Ogwal (2017), who noted that an abundance of juveniles relative to adults in cycad populations may be associated with ecological disturbance, including habitat conversion for plantations, reforestation using exotic tree species, vegetation clearing, and possible harvesting of mature cycads by local communities, all of which can disproportionately affect adult individuals. However, such a structure is also commonly observed in many reproductive cycad populations, including relatively stable ones, where high seedling and juvenile abundance is typical but often accompanied by substantial mortality and low long-term recruitment to adult stages. Consequently, the predominance of early life stages in *C. sancti-lasallei* should be interpreted with caution and does not, by itself, provide definitive evidence of disturbance. Nevertheless, other anthropogenic pressures such as habitat degradation, land-use change, and harvesting for ornamental purposes may still pose potential threats to adult individuals, which are particularly important for sustaining the reproductive capacity and long-term viability of the population.

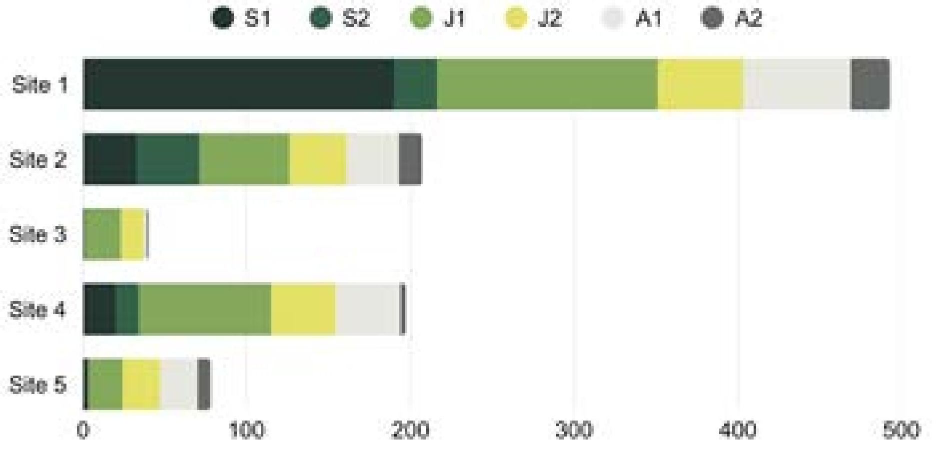

Figure 4. Population Structure of *C. sancti-lasallei* showing the sex ratio distribution. S1 or Seedling 1, S2 or Seedling 2, J1 or Juvenile 1, J2 or Juvenile 2, A1 or Adult 1, A2 or Coned Adult Individuals

Population Density

Among the different stages of life, J1 showed the highest mean density, with 125.6 plants per hectare, followed by S1 with 98.4 plants per hectare, and J2 and A1 both with 65.2 plants per hectare**.** S2 had a lower density of 31.6 plants per hectare. The reproductive adult classes had the lowest densities, with A2 averaging 20 plants per hectare (Figure 5).

The pattern observed in *C. sancti-lasallei* is consistent with the demographic structure of other cycad species under similar ecological pressures. For instance, Marler and Ferreras (2017) reported a seedling-dominated structure for *C. wadei* Merr. in Palawan, Philippines, followed by adult and then juvenile classes. This suggests an ongoing regeneration process but also potentially indicates high seedling mortality and low recruitment to adult stages. Donaldson (2003) also discussed the demographic constraints faced by small or isolated cycad populations, particularly reduced production of viable seeds. However, these limitations have been most frequently documented in species of *Encephalartos*, where low fecundity and the decline of specialized pollinators are common issues. Such conditions appear to be less typical for members of the genus *Cycas.* In contrast, demographic assessments in other cycad genera have revealed different population patterns. For example, the study Castillo-Lara *et al*. (2017) reported that populations of *Ceratozamia zaragozae* MedellínLeal were dominated by adult individuals, a pattern that likely reflects the inherently low reproductive output typical of many species in the genus *Ceratozamia* rather than a directly comparable demographic structure to members of the genus *Cycas*.

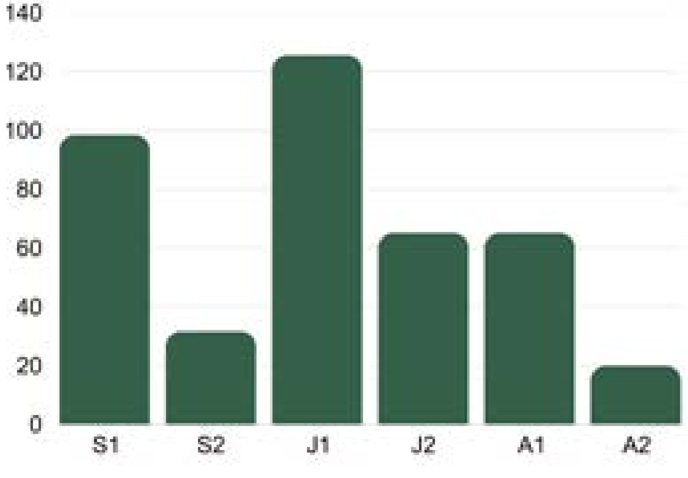

Figure 5. Density of *C. sancti-lasallei* across stage classes from S1 to A2. S1 or Seedling 1, S2 or Seedling 2, J1 or Juvenile 1, J2 or Juvenile 2, A1 or Adult 1, A2 or Coned Adult Individuals.

Furthermore, the clumped distribution of seedlings, often in close proximity to maternal plants, likely results from limited seed dispersal, a common trait among cycad species. When disturbances such as habitat clearing, slope erosion, or vegetation competition occur near parent plants, clustered seedlings may be simultaneously affected, reducing overall recruitment success. Watkinson and Powell (1997) and Alvarez-Yepiz *et al*. (2014) discussed how the extinction of megafaunal dispersers and the limited range of current dispersers have constrained cycad seed movement, promoting spatial aggregation. This clumping can initially benefit seedling survival by maintaining proximity to favorable microhabitats (Hall and Walter, 2013). However, it may also result in density-dependent mortality due to competition for resources and increased vulnerability to pests and pathogens (Octavio-Aguilar *et al*., 2008).

Sex Ratio Distribution

The sex ratio distribution of *C. sancti-lasallei* in the study sites reveals 21 male and 29 female individuals identified through the presence of reproductive structures. This corresponds to a male-to-female sex ratio of approximately 0.72:1, suggesting a greater prevalence of female reproductive adults across the population. However, this difference is based on a limited sample from a single survey year and requires further study to demonstrate a significant deviation from the expected 1:1 sex ratio. As noted by Marler and Ferreras (2017), sex ratio estimates derived from single visits to cycad populations can be misleading because the detectability of reproductive structures differs between sexes. In many species of the genus *Cycas*, male reproductive structures are quickly consumed by pollinating insects, causing evidence of male reproduction to disappear rapidly, whereas female structures remain visible for longer periods. As a result, surveys conducted within a limited time may record disproportionately more female individuals (Marler, 2010).

Among the five sites surveyed, only Site 5 exhibited a male-biased ratio (five males to three females), while Sites 3 and 4 had either no males or a significantly higher number of females during the survey (Figure 6). These site-level differences may partly reflect temporal variation in coning events rather than actual demographic imbalances. Sex ratio is an important demographic parameter that can influence reproductive dynamics, particularly in dioecious

Figure 6. Sex Ratio Distribution of *C. sancti-lasallei* among five sites in Cagayan de Oro City.

plant species such as cycads, where pollination relies on the co-occurrence and synchrony of both male and female individuals (Grobbelaar, 1999). However, given the limited number of reproductive individuals recorded during a single survey year, the present data requires further evaluation to confirm whether the population of *C. sancti-lasallei* deviates from the expected 1:1 sex ratio.

Several studies have reported similar deviations from the expected 1:1 sex ratio in cycad populations. For instance, Donaldson (2003) observed male-dominated ratios (up to 4:1) in small, threatened populations. Interestingly, in contrast to these findings, Keppel *et al.* (2008) reported a nearly neutral sex ratio in *C. seemannii* A. Br., based on a sample of 69 mature individuals, highlighting that sex ratio patterns can vary significantly across species and populations. Similarly, Watkinson and Powell (1997) also documented a close-to-equal sex ratio among four populations of *C. armstrongii* Miq., contradicting the male-biased trends noted by Ornduff (1985) in other Zamiaceae species. More recent data from Swart *et al*. (2019) demonstrated variable sex ratios within different cycad populations: one with a strong male bias (2.6:1) and another showing a female-dominated structure (2:1), underscoring the influence of site-specific environmental factors and historical disturbances.

The study by Castillo-Lara *et al*. (2017) also emphasizes the impact of habitat type and environmental stimuli on sex expression. In grasslands, they found a male-to-female ratio of 1:1.5, while in forest fragments, only female individuals were observed. This variation was attributed to the role of environmental triggers such as fire, which is known to stimulate coning in genera like *Encephalartos* Lehm. and *Macrozamia* Miq. Since *C. sancti-lasallei* inhabits shaded to partly shaded areas where fire is not a common disturbance, other

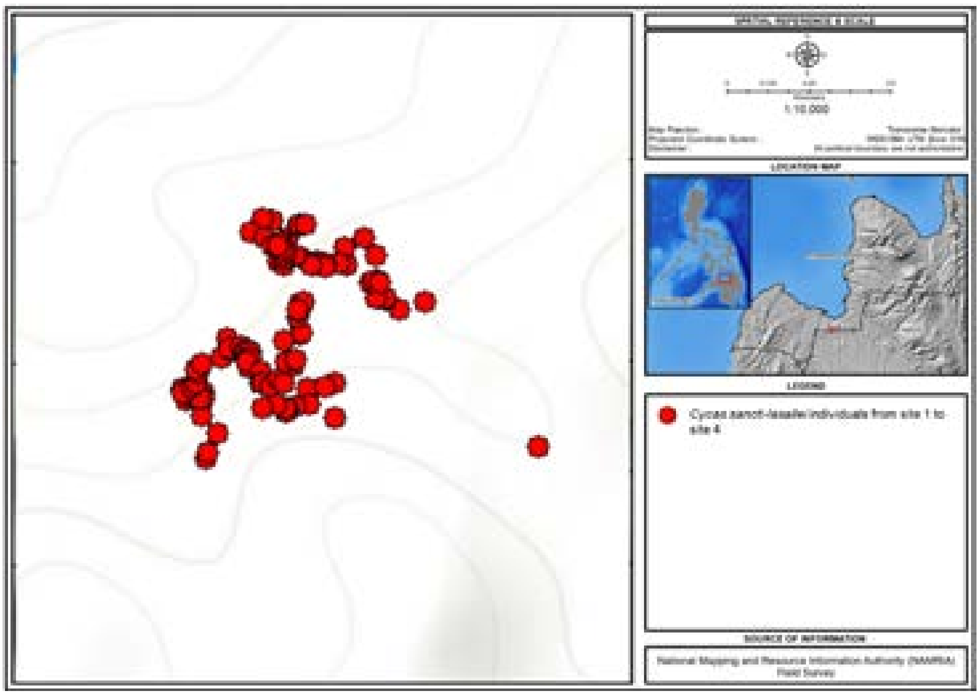

Figure 7. Distribution map of *C. sancti-lasallei* at Mapawa Nature Park (sites 1 to 4).

ecological or physiological mechanisms may be influencing its coning patterns. Additionally, ethnobotanical accounts suggest that male cycads, especially those producing cones, are sometimes intentionally removed due to their unpleasant scent attributed to the toxic compound Cycasin (Schneider *et al*., 2002), which may contribute to their underrepresentation in natural populations. If such practices occur in the habitats of *C. sancti-lasallei*, they could partially explain the observed sex ratio imbalance.

Distribution of C. sancti-lasallei in the area

The distribution mapping of *C. sancti-lasallei* revealed a significant expansion in known population size from the previously reported fewer than 100 individuals (Agoo and Madulid, 2012) to a recorded total of 213 adult individuals, 50 of which were coning. The mapping effort included all life stages namely seedlings, juveniles, and adults across natural habitats.

The reproductive adult class was the least represented, comprising only 4.93% of the population (21 males and 29 females). Furthermore, site-based distribution showed that Site 1, characterized as a secondary forest, harbored nearly half (48%) of all reproductive adults, suggesting it is the reproductive core for the species (Figure 8). In contrast, Site 5, the coastal hill reforestation area, accounted for only 8% of the total population (Figure 9). Despite being historically reported by locals as formerly cycad-dominated prior plantation efforts, current population numbers in Site 5 are very small. Its steep, rocky slopes where rocks can easily dislodge likely restrict both seedling establishment and safe adult anchorage, contributing to its low population density. These physical limitations, combined with possible displacement from plantation development leading to nutrient and sunlight competition, may explain the site's diminished representation.

Soil type may be associated with the observed population distribution of *C. sancti-lasallei*. Population abundance varied among sites with different soil conditions, with Site one, characterized by loamy soil, supporting the highest number of individuals. In contrast, Sites 2–4, which consisted of loamy to sandy soils, exhibited moderate but variable population sizes, while Site 5, associated with low-nutrient ultramafic soil on steep slopes, contained comparatively fewer individuals.

The spatial distribution maps represent GPS-recorded locations of *C. sancti-lasallei* observed during the field survey (Figures 7, 8). In some instances, multiple individuals occurring in close proximity were represented by a single coordinate point due to the aggregated growth pattern of the species and practical limitations in recording separate coordinates for each plant. Dense clustering of seedlings around maternal individuals, as well as accessibility and safety constraints associated with steep and unstable slopes, occasionally limited the collection of individual GPS coordinates. Consequently, mapped points represent occurrence locations and may correspond to more than one individual observed within the same immediate area.

C. sancti-lasallei exhibited an aggregated distribution pattern (Figures 8, 9), a phenomenon frequently observed in cycads (Yang *et al*., 2024). Aggregation results from a combination of environmental heterogeneity, biological interactions, and limited seed dispersal mechanisms. Consistent with Hall and Walter (2013) findings in *Macrozamia miquelii* (F.Muell.) A.D.C., where 70–100% of seeds were found within a meter of the parent plant, *C. sancti-lasallei* also displays limited dispersal which is primarily driven by gravity and secondarily by vertebrate fauna observed in the field. The species' steep-slope habitats reinforce gravity-based dispersal, leading to seedling clustering near parent plants, a pattern that may reduce interspecific competition initially but ultimately hinders broader colonization.

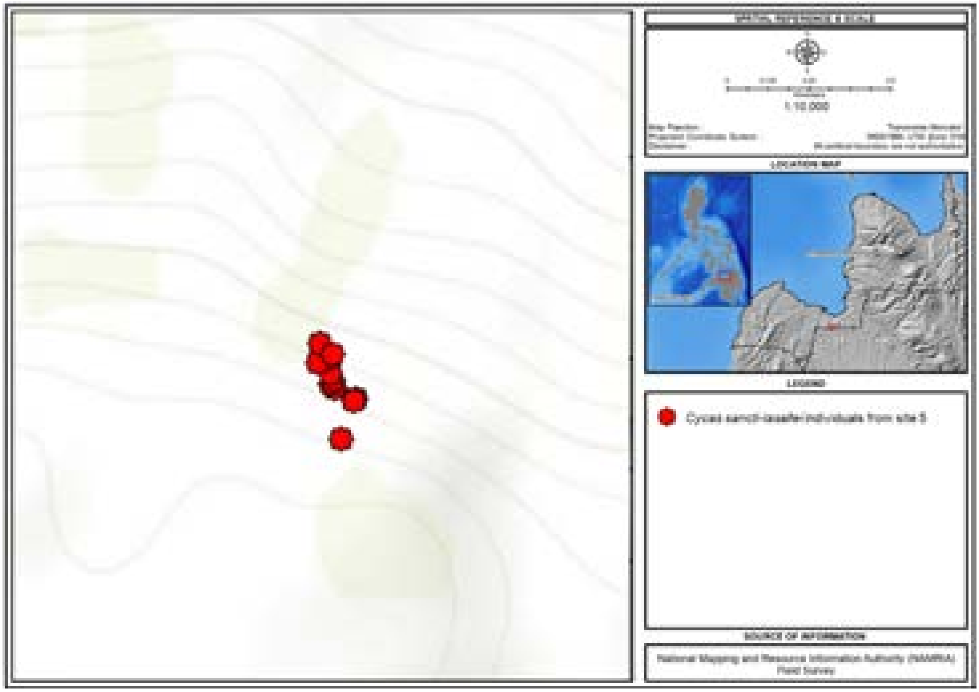

Figure 8. Distribution map of *C. sancti-lasallei* at Barangay F.S. Catanico (Site 5).

Moreover, reproductive success in dioecious species like *C. sancti-lasallei* is often tied to mate proximity and population size (Cabral and Schurr, 2010). The observed density of coning individuals and sex-specific clustering could therefore impose reproductive constraints, especially in more isolated or fragmented sites.

The presence of invasive or competitive vegetation further shapes cycad distribution. Site 3, a reforestation area dominated by the exotic *Acacia mangium*, exhibits the lowest population count and absence of coning adults, likely due to excessive canopy closure, reduced light availability, and strong competition for nutrients, conditions known to suppress cycad growth and reproduction (Wu *et al*., 2021), with potential additional stress from allelopathic effects of *A. mangium* (Ismail and Metali, 2014) and other canopy species such as *Ardisia* sp., *Buchanania* sp., and *Cratoxylum sumatranum* Jack. Interestingly, in Site 1, where the forest canopy is more developed, some individuals were observed to be evenly or randomly distributed, a deviation from the overall aggregation trend. This supports the hypothesis by Yang *et al*. (2024) that canopy shading from trees can lead to more dispersed and sparse cycad distributions for *C. panzhihuaensis* L.Zhou & S.Y.Yang due to limited light availability. In such conditions, cycads may survive under suboptimal light but fail to reach densities or reproductive maturity needed for sustainable population growth. Some flora species in site 1 include *Glochidion* sp., *Heptapleurum* sp., *Leucosyke capitellata* (Poir.) Wedd., *Nauclea* sp., and *Wendlandia* sp. Site 4, a grassland dominated by *Imperata cylindrica* (L.) Raeusch., maintains a moderate population, suggesting some tolerance to open and disturbed habitats, while Site 2, characterized by *Bambusa* sp., shows similar competitive pressures but benefits from a relatively stable microclimate and proximity to a creek. Site 5, located at the highest elevation (408–465 m) on a steep coastal hill (Table 1), exhibits low population density due

Table 1. Site-specific environmental characteristics of C. sancti-lasallei populations in Northern Mindanao, Philippines.

	Site 1	Site 2	Site 3	Site 4	Site 5
Site Description	Secondary Forest Site	Bamboo Associated Site	Reforestation Site dominated by Acacia	Grassland Site dominated by Cogon	Coastal Hill Reforested Site
Location	Mapawa Nature Park	Mapawa Nature Park	Mapawa Nature Park	Mapawa Nature Park	F.S. Catanico
Altitude	270–294masl	266–296masl	299–313masl	259–280masl	408–465masl
Relative Humidity	69%–73%	71%–75%	73%–77%	66%–70%	68%–72%
Temperature	29°C–33°C	27°C–31°C	27°C–31°C	*30*°C–34°C	29°C–31°C
March Rainfall (Appendix H)	101–200 mm	101–200 mm	101–200 mm	101–200 mm	101–200 mm
Proximity to Creek/Stream	3 m away	3 m away	10 m+ away	5 m away	10 m+ away

to shallow, rocky substrates and severe erosion, which limit soil stability, water retention, and root anchorage, thereby constraining recruitment and long-term persistence.

Overall, the population characteristics observed in *C. sancti-lasallei*, including the low proportion of reproductive adults, aggregated seedling distribution, and site-specific declines in abundance, suggest that the species is influenced by multiple ecological and anthropogenic pressures. These include habitat modification from plantation development, dominance of exotic or competitive vegetation such as *Acacia mangium*, limited seed dispersal capacity, steep and erosion-prone terrain, and the potential harvesting of adult plants. Together, these factors may constrain recruitment, reduce reproductive success, and threaten the long-term persistence of the species in the study area.

Conservation Implications and Management Recommendations

The population characteristics observed for *C. sancti-lasallei* provide several considerations for conservation planning. Although the present study documented a larger number of individuals than previously reported, the population structure is characterized by a high proportion of seedlings and juveniles relative to reproductive adults. While such patterns are commonly observed in cycad populations and do not necessarily indicate demographic instability, the relatively small number of coning individuals recorded during the survey suggests that reproductive activity may be limited spatially or temporally. Reproductive adults were unevenly distributed across sites, with nearly half recorded in the secondary forest site (Site 1), indicating that certain habitat conditions may be more favorable for reproduction. The aggregated distribution pattern, combined with limited seed dispersal and site-specific environmental constraints such as steep terrain, vegetation competition, and the presence of exotic species like *Acacia mangium* and *Imperata cylindrica*, may also influence local recruitment and spatial expansion.

Given these observations, conservation measures should prioritize the maintenance of suitable habitats across the sites where the species occurs. Protection of location sites that support reproductive individuals may help sustain natural regeneration, while habitat management actions such as limiting land conversion, managing competitive vegetation, and reducing soil erosion in steep coastal habitats may improve conditions for recruitment. Complementary ex situ strategies, including seed collection, propagation, and the establishment of living collections, may help safeguard genetic diversity. Continued monitoring of population dynamics, reproductive activity, and recruitment patterns is also recommended to better understand long-term trends, particularly since coming events in cycads may vary across years. Community-based awareness initiatives may further contribute to reducing anthropogenic pressures and supporting the conservation of the species within its natural habitats.

CONCLUSION

This study provides an updated assessment of the population structure and distribution of *C. sancti-lasallei* in Northern Mindanao, documenting a total of 1,015 individuals across all life stages. The population was dominated of early life stages, with Juvenile 1 and Seedling 1 comprising the largest proportions, while reproductive adults represented only 4.93% of the total population. Although such stage structures are commonly observed in cycad populations and do not necessarily indicate demographic instability, the limited number of coning individuals observed during the survey suggests that reproductive activity may vary across sites and years. A total of 50 coning individuals were recorded, consisting of 21 males and 29 females (0.72:1). The distribution of reproductive adults was uneven among sites, with the secondary forest area supporting the largest number of coning individuals, indicating that certain habitat conditions may be more favorable for reproductive expression.

Spatially, *C. sancti-lasallei* exhibited an aggregated distribution pattern, with seedlings frequently clustered near maternal plants, reflecting limited seed dispersal and the influence of localized environmental conditions. Differences in abundance among sites appear to be associated with habitat characteristics, including canopy cover, vegetation competition, steep terrain, and soil stability. Areas dominated by dense vegetation or exotic species such as *Acacia mangium*, as well as steep and erosion-prone habitats, may influence plant distribution and recruitment. Although the number of individuals recorded in this study expands the previously known population size, the relatively small proportion of reproductive adults and the influence of site-specific environmental pressures highlight the importance of continued monitoring and habitat protection to support the long-term persistence of the species.

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