CONSERVATION ACTION PLAN

The Six Threatened Palm Species of Sainte Luce

SEED Madagascar Project Palms

Fondation Franklinia

Contents

1. Introduction

Madagascar is one of the world's highest conservation priorities (Myers et al., 2000). With 98% of palm species endemic to the island, it has one of the most unique and diverse palm collections in the world (Méndez et al., 2022). Despite this, forest ecosystems across Madagascar are in decline with 4.36 million hectares (25%) of forest cover lost to deforestation between 2001 and 2021 (Global Forest Watch, 2022). Specifically, 83% of endemic palm species are threatened with extinction in Madagascar (Rakotoarinivo et al., 2014). As such, it is crucial to understand the local pressures on palms and map viable pathways for their conservation and continued availability.

Littoral forests are one of the rarest and most threatened ecosystems in Madagascar and are considered a national conservation priority (Ganzhorn et al., 2001), with an estimated 90% of original littoral forest cover lost (Krishnan et al., 2012). The southeast region of Anosy contains some of the few remaining viable littoral forests in the country (Bollen & Donati, 2006). The Sainte Luce littoral forest (SLLF), comprising of 17 fragments, is one of three larger littoral forests remaining in Anosy. Although critically important natural resources for the Sainte Luce community, six of the 13 species of palm supported by the SLLF are threatened with extinction (Bennett, 2011; Couvreur & Baker, 2013). Within Sainte Luce there are several uses for these species, including weaving palm leaves to make lobster pots and using palm trunks in the walls of houses (Hogg et al., 2013b). Extant populations in the SLLF are threatened by selective logging, habitat degradation, drought, increased vulnerability to fire, and proposed mining activities by QIT Madagascar Minerals (QMM) (Bollen & Donati, 2006; Vincelette et al., 2007; Krishnan et al., 2012).

This Conservation Action Plan aims to consolidate the current knowledge on the six threatened species of palm: *Beccariophoenix madagascariensis*, *Chrysalidocarpus prestonianus*, *Chrysalidocarpus psammophilus*, *Chrysalidocarpus saintelucei, Dypsis brevicaulis*, and *Dypsis scottiana*. Between 2021 and 2024, under Project Palms, SEED Madagascar (SEED) has carried out targeted research into the ecology of these six species in the SLLF. This Conservation Action Plan summarises current knowledge of the species including their designated conservation status, taxonomic classification, threats, population and distribution, microhabitat preferences, phenology, pollination and frugivory, nursery growth, and socio-economic and cultural importance in the SLLF. Results and methodological learnings from efforts to grow palm seedlings ex-situ and transplant them *in-situ* are reported on. Finally, conservation actions recommended by both communities bordering the SLLF and Malagasy conservation experts are discussed.

This Conservation Action Plan shall serve as a nationally adaptable and scalable resource for the sustainable conservation of threatened species of Malagasy palm to be shared with stakeholders, academics, and policy makers.

2. Context

Palms are a plant family of high ecological, economic, and cultural importance globally (Bellot *et al*., 2022), nationally, and locally. The SLLF supports a large variety of endemic and threatened species, including six threatened palm species. Sainte Luce, with approximately 2,600 inhabitants, is just one of the local communities supported by the forest through the provision of natural resources for firewood, construction materials, and local livelihood generation (Bollen & Donati, 2006; Hyde Roberts et al., 2021; SEED, 2021).

The primary uses of palms in Sainte Luce are to produce lobster pots and construct houses. Considering that lobster fishing is the primary income-generating activity for more than 90% of the 464 households in Sainte Luce (SEED, 2021), the local economic importance of these palms is significant. High community usage threatens target palms populations. Indeed, a previous SEED study found rapidly declining populations of *B. madagascariensis* and *C. saintelucei* in Sainte Luce between 2012-2020, with the majority of losses attributed to anthropogenic factors, such as felling (Roberts *et al*., 2020). *Dypsis brevicaulis* is the only target species with no known community usage (Hogg et al., 2013b).

In addition to high levels of community usage, fire and proposed mining operations pose significant threats to these palm populations. The fragmented nature of the SLLF makes the forest especially vulnerable to fire, due to a frequently practised traditional land management technique called *tavy*, a swidden agricultural practice that involves setting intentional fires to clear land for agriculture. Furthermore, proposed mining operations by QMM to remove 661.8ha of the SLLF significantly exacerbate the risk of local extinctions of these six threatened palm species (Bollen & Donati, 2006). The mining threat is particularly existential for the two species whose main populations exist beyond the protected areas in Sainte Luce: *C. psammophilus* and *C. saintelucei* (SEED, 2023c).

Despite the significant threats facing the palm species in Sainte Luce and their importance for biodiversity and local livelihoods, these palm species remain understudied and poorly understood.

3. SEED Madagascar's Project Palms: An Overview

In response to the threats described in the context section above, SEED launched Project Palms in August 2021. The project aims to improve the conservation status of the six threatened species in the Sainte Luce littoral forest by increasing available knowledge resources and bolstering populations through *in-situ* plantings. Palms is a four-year project, with an end date of July 2025. All project findings informed the creation of this Conservation Action Plan.

The six target palm species are: *B. madagascariensis* (VU), *C. prestonianus* (VU), *C. psammophilus* (EN), *C. saintelucei* (EN), *D. brevicaulis* (CR), and *D. scottiana* (VU).

The activities of Project Palms are concentrated in the five forest fragments of the SLLF seen in Figure 1. Fragments S6 and S7 are designated as community resource zones, from which, natural resource use is permitted; S8 and S9 are part of Madagascar's National Protected Areas network, classified as conservation zones. Much of S17 is protected, with an area of privately owned land and an area designated as a community resource zone.

To-date, SEED has undertaken a significant body of work to achieve the project goal. Between October 2021 and February 2023, a palm population census was conducted in fragments S6, S7, S8, S9, and S17, with 153,616 palms encountered from the six species (SEED, 2023c). During the census, individual palms were identified by demographic (adult, sub-adult, juvenile). The identification of adult palms was vital for seed collection. Significantly, the census data revealed more than 50 adult *D. brevicaulis* (SEED, 2023c), which could lead to the reclassification of the species from Critically Endangered to Endangered (Rakotoarinivo & Dransfield, 2012f). Furthermore, less than 100 adults from three species (*B. madagascariensis*, *C. prestonianus*, and *C. saintelucei*) were encountered during the census (SEED, 2023c), underscoring the importance of Project Palms' work in understanding current distribution and abundance in order to safeguard the future of the six palm species.

To further understand these six palm species, SEED assessed the microhabitat preferences of 20 adult individuals from each species, for example environmental, topographic, and soil characteristics. The microhabitat learnings supported local restoration by informing *in-situ* transplants that contribute to the survival of each species.

SEED conducted phenology surveys between October 2021 and July 2023 that were used to inform seed collection efforts and produce a seasonality calendar for all six species. Additionally, pollinators of the six palm species were surveyed between December 2022 and May 2023. Notably, the pollinator surveys led to the composition and order of pollinators being described for the first time for *C. psammophilus*, *D. brevicaulis*, and *D. scottiana* (SEED, 2023b). Subsequently, Project Palms has significantly increased knowledge resources regarding phenology and pollinators for these six threatened species.

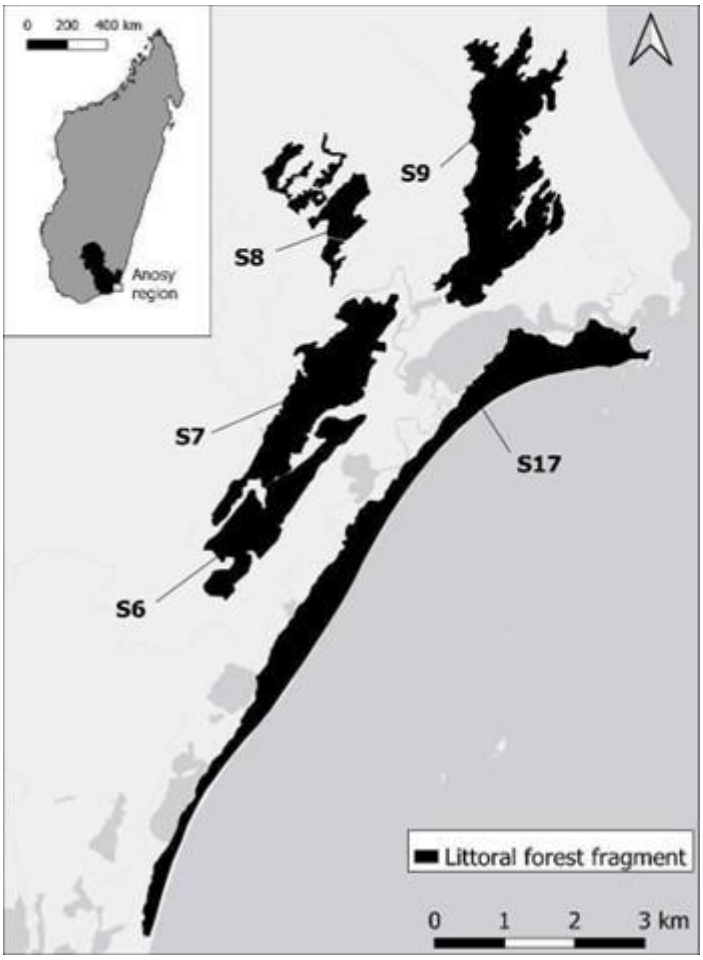

Figure 1 – Map showing the study site of Sainte Luce.

Since Project Palms' inception, 12,906 seeds from the six species have been sown in the SEED nursery, with 3,660 having germinated by July 2024. SEED conducted germination and survival and growth research in the nursery. Germination trials revealed a mean germination rate of 34.23% across all species, with mean germination times fastest for *C. saintelucei* (60 days) and longest for *D. scottiana* (204 days) (SEED, 2023a). Analysis of survival and growth data, completed by July 2023, showed a mean growth rate across all species of 0.53cm/week. *Chrysalidocarpus saintelucei* had the highest mean growth rate at 1.02cm/week out of all six species (SEED, 2023a).

The census, microhabitat, phenology, and nursery data were all utilised to inform the *in-situ* transplantation of seedlings from all six species. Project Palms aims to plant 300 individuals from each species in protected forest fragments in Sainte Luce to bolster populations. To-date, 1,075 palms have been planted.

A trial planting of 66. *C. saintelucei* was conducted in 2023 across four sites in S9. The trial has been highly successful, with an average height increase compared with planting of 104% (19.1cm to 38.9cm), and a survival rate of 97% twelve months after planting.

Following the success of the trial transplantation, a further 1,009 palms from all six species were planted *in-situ* in February and April 2024 across the three protected forest fragments. Up to 360 community members from Sainte Luce led the planting. Notably, the transplantation of 329 *B. madagascariensis* into S8 and S9 has increased the known population of this Vulnerable species in the Sainte Luce littoral forest by 43.5% (756 *B. madagascariensis* were encountered during the population census, (SEED, 2023c)). Monitoring has revealed that the 1,009 palms planted in 2024 have a survival rate of 97% three months after planting. Regular monitoring will continue, to assess the need for aftercare or replants so as to ensure the longevity of these *in-situ* seedlings.

Community engagement has underpinned all Project Palms activities, with community ownership essential for long-term sustainability. At the start of the project, 25 community consultation surveys and five key informant interviews provided information on palm population dynamics and the extent of community use of the six species. These data identified high levels of community usage as the primary reason for palm population change and revealed that species use had changed over time to respond to changes in palm availability, which in turn had affected the price of palm resources (SEED, 2023e).

Twelve focus groups were held during the second year of the project, with a total of 178 participants from three communities bordering the SLLF. The focus groups offered insight into palm conservation strategies recommended by local communities. Strategies for mitigating threats included community involvement (specifically awareness-raising and participation in monitoring activities), provision of alternative resources, elaboration, and reinforcement of the existing *dina* (local law), and livelihood support. Community awareness-raising sessions on the importance of protecting palms were held with the same 178 participants.

Collaboration with local stakeholders has been essential to the success of Project Palms. Members from DREDD (Regional Ministry of Environment and Sustainable Development), COBA (*Communautés de Base* – Forest Management Association), FIMPIA (Forestry Police Association), and *Polisin'ala* (local forest patrol) assisted in the planting and monitoring of the *in-situ* seedlings, strengthening their capacity to manage these threatened species.

Figure 2 – SEED, COBA, and Polisin'ala *planting a* C. saintelucei *together in S9, February 2023*.

In the final year of Project Palms (August 2024 – July 2025), at least 754 palms will be planted *in-situ* during the 2025 rainy season to achieve the project goal of planting 300 of each species to safeguard the survival of these six threatened species. Additionally, SEED will start enacting this Conservation Action Plan by increasing community engagement through dissemination of research findings, community-led monitoring, community awareness raising, and mass mobilisation days.

4. The Six Threatened Species of Palm

4.1 Conservation Status

Table 1: The IUCN Red List of Threatened Species assessment for each species. The 2010 IUCN assessment is the most recent classification of each of the six species.

Species Name	IUCN Red List Classification
Beccariophoenix madagascariensis	**Vulnerable (VU)**
Chrysalidocarpus prestonianus	**Vulnerable (VU)**
Chrysalidocarpus psammophilus	**Endangered (EN)**
Chrysalidocarpus saintelucei	**Endangered (EN)**
Dypsis brevicaulis	**Critically Endangered (CR)**
Dypsis scottiana	**Vulnerable (VU)**

Beccariophoenix madagascariensis belongs to the *Attaleinae* subtribe and is classified as Vulnerable. In 2010, an estimated 900 adult *B. madagascariensis* individuals remained, with subpopulations spread across three locations in eastern Madagascar (Rakotoarinivo & Dransfield, 2012a).

Chrysalidocarpus prestonianus belongs to the *Dypsidinae* subtribe and is classified by IUCN as Vulnerable. In 2010, an estimated 800 adult *C. prestonianus* individuals remained, with subpopulations distributed across four locations in southeastern Madagascar (Rakotoarinivo & Dransfield, 2012b).

Chrysalidocarpus psammophilus is classified by IUCN as Endangered and belongs to the *Dypsidinae* subtribe. In 2010, an estimated 100-199 adult *C. psammophilus* individuals remained, with subpopulations spread across five locations in eastern Madagascar (Rakotoarinivo & Dransfield, 2012c).

Chrysalidocarpus saintelucei is Endangered and belongs to the *Dypsidinae* subtribe. In 2010, an estimated 300 adult *C. saintelucei* individuals remained, with subpopulations distributed across four distinct locations in eastern Madagascar (Rakotoarinivo & Dransfield, 2012d).

Dypsis brevicaulis is a Critically Endangered species of dwarf palm that belongs to the *Dypsidinae* subtribe. In 2010, it was estimated that less than 50 adult *D. brevicaulis* individuals remained, with subpopulations split between two locations in the Taolagnaro district of Anosy, southeast Madagascar (Rakotoarinivo & Dransfield, 2012e).

Dypsis scottiana belongs to the *Dypsidinae* subtribe and is classified as Vulnerable by IUCN. In 2010, an estimated 900 adult *D. scottiana* individuals remained, spread across seven locations in southeast Madagascar (Rakotoarinivo & Dransfield, 2012f).

4.2 Taxonomic Classifications

The six target species all belong to the family *Arecaceae* and the *Arecoideae* subfamily. The six species span three different genera, *Beccariophoenix*, *Chrysalidocarpus*, and *Dypsis*. The *Beccariophoenix* genus falls under the subtribe *Attaleinae* within the tribe *Cocoseae* (Dransfield et al., 2008). *Beccariophoenix* species are solitary palms, endemic to Madagascar that flower with 18-21 stamens (Dransfield *et al*., 2008). The *Chrysalidocarpus* and *Dypsis* genera belong to the *Dypsidinae* subtribe within the tribe *Areceae*, meaning species from these genera have a closer genetic makeup (Eiserhardt et al., 2022).

Attaleinae is a subtribe whose genera are typically found in the Americas, while 174 out of the 178 subtribe *Dypsidinae* species are endemic to Madagascar and constitute 85% of Madagascar's palm diversity (Eiserhardt et al., 2022). *Chrysalidocarpus prestonianus*, *Chrysalidocarpus psammophilus*, and *Chrysalidocarpus saintelucei* were previously classified under the genus *Dypsis* based on morphological observations. They were split from *Dypsis* and reclassified as *Chrysalidocarpus* in 2022 (Table 2) after a phylogenetic study revealed greater species differentiation within the genus *Dypsis* (Eiserhardt et al., 2022). *Chrysalidocarpus* species tend to be larger than *Dypsis* species and always flower with six stamens. *Dypsis* species are generally understory palms and are described as having smaller flowers and either six, three, or one stamen (Eiserhardt et al., 2022).

Table 2: Reclassification of the genus of three study species in 2022.

Previous Name	Current Name
Dypsis prestoniana	*Chrysalidocarpus prestonianus*
Dypsis psammophila	*Chrysalidocarpus psammophilus*
Dypsis saintelucei	*Chrysalidocarpus saintelucei*

5. Species Profiles

5.1 *Beccariophoenix madagascariensis*

Species Summary

Beccariophoenix madagascariensis is one of three species in the *Beccariophoenix* genus in Madagascar (Dransfield & Rakotoarinivo, 2014). It is a large solitary palm, growing to roughly 12m in height and its trunk to 30cm in diameter (Shapcott et al., 2007).

Beccariophoenix madagascariensis was recently distinguished from *Beccariophoenix fenestralis*, which, up until 2014, was treated as the same species (Dransfield & Rakotoarinivo, 2014).

Until 2010, this species was Critically Endangered, however, it was reclassified as Vulnerable with the discovery of two new subpopulations in Vondrozo and Mantadia National Park. *Beccariophoenix madagascariensis* subpopulation densities vary significantly between localities, which are severely fractured as they are several hundred kilometres apart (Rokotoarinivo and Dransfield, 2012a).

Population and Distribution

B. madagascariensis has been observed within multiple localities between Mantadia National Park and Taolagnaro, occurring within the eastern escarpment of the forest between 0-1,200m elevation depending on location. The three localities of Vondrozo, Mantadia National Park, and Sainte Luce were estimated to support around 900 adult palms in 2010 (Rokotoarinivo and Dransfield, 2012a), with the adult palms known in Sainte Luce at the time representing 5% of these (Hogg et al., 2013b).

Between 2011 and 2018, a 25% population decline of *B. madagascariensis* was recorded in the SLLF (Hyde Roberts et al., 2020). More recently, a SEED (2023c) conducted population census recorded a total of 756 *B. madagascariensis* palms in the SLLF. SEED is not aware of a more recent population estimate for the localities of Vondrozo and Mantadia National Park. *Beccariophoenix madagascariensis* was observed in all the SLLF fragments except S17, with the majority of individuals of all age categories found in S8 (Figure 3) (SEED, 2023c). Of the total 756 *B. madagascariensis*, the majority were juveniles (62%) followed by subadults (32%), with 44 adults observed (6%) (SEED, 2023c). The 2023 observation of adult palms in the SLLF represents an increase from 2019, where there were 36 adults located (Hyde Roberts et al., 2020). Today, the adult population size in Sainte Luce is very similar to that found in Sainte Luce by Hogg et al. (2013b), at approximately 50 individuals. Fewer *B.*

madagascariensis were recorded during the 2022-2023 census than any of the other five target species (SEED, 2023c).

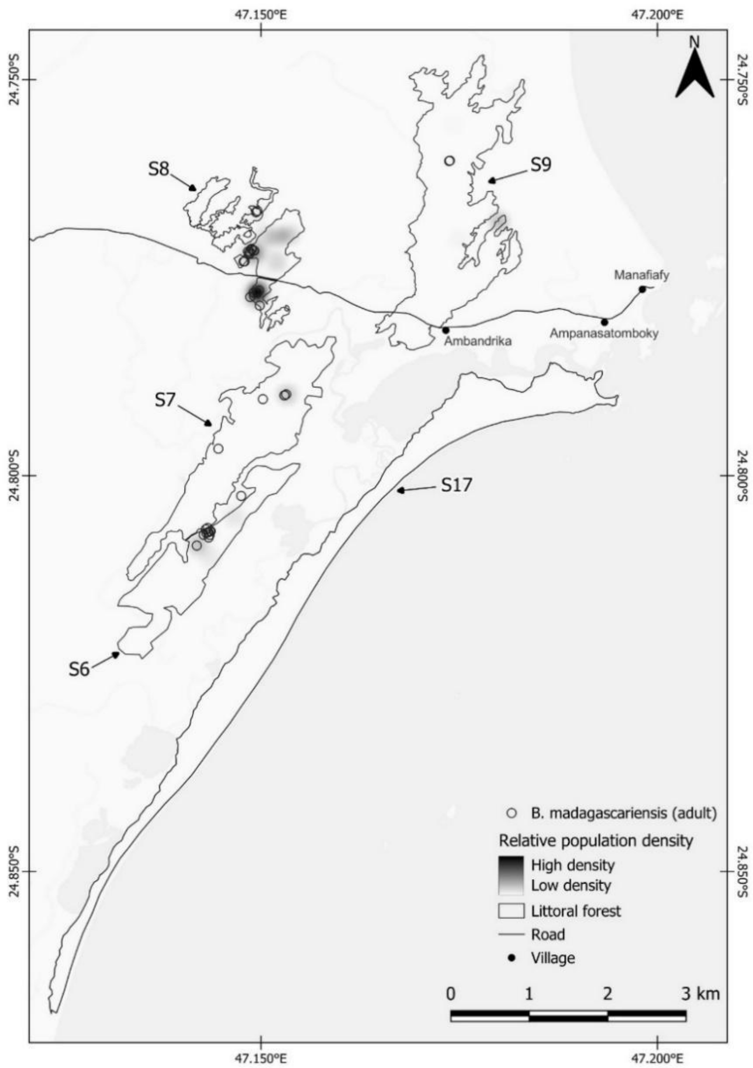

Figure 3: Beccariophoenix madagascariensis distribution map in the SLLF.

Microhabitat

In the SLLF, *B. madagascariensis* have been observed at a mean elevation of 17.7m, within forests of mean canopy height of 9m, and mean canopy cover of 55.4% (SEED, 2023d). *Beccariophoenix madagascariensis* were observed having a mean distance to the nearest tree of 3.61m (tree >12.5cm circumference) and 2.62m (tree 6.5-12.5cm circumference) (SEED, 2023d), which may be associated with less dense habitats. Adults observed in the SLLF were growing on median slope angles of 16^{o} (SEED, 2023d). Palms were observed in acidic soil (mean pH 3.89), which was composed of sand (25%) and organic matter (75%) and had a mean infiltration rate of 4.06ml/sec (SEED, 2023d).

Dransfield & Rakotoarinivo (2012) surveyed the *B. madagascariensis* palms on the mountain of Ivohibe in Tsitongambarika, a forested area north of Taolagnaro. Juvenile palms were observed growing on ridge tops and small crown forest on thin soil, overlooking rock outcrops. Observations by Hogg et al. (2013b) note that *B. madagascariensis* prefer well-drained, nutrient poor soils topped with a thick hummus layer of quartzite or white sands (Dransfield & Rakotoarinivo, 2014).

Phenology

Inflorescence form varies depending on locality. For example, the peduncle is short in Sainte Luce yet is elongated in Tsitongambarika and Mantadia, but it is always interfoliar (Dransfield & Rakotoarinivo, 2014). Inflorescences can reach 50cm long and contain up to 1,000 flowers, which are arranged in triads with one central female flower bordered by two males (Shapcott et al., 2007).

During phenological surveys within the SLLF, flowering *B. madagascariensis* were observed from November to June, with a continuous flowering period observed between November and February (SEED, 2023b). Unripe fruits were green and turned yellow and purple upon ripening (Shapcott et al., 2007) during the period of February to September, peaking from March to May (SEED, 2023b).

Pollination and Frugivory
Literature suggests that potential pollinating insects include bees, beetles, and ants (Shapcott et al., 2007). Frugivores are currently unknown but potentially include lemurs, flying foxes, and pigeons (Shapcott et al., 2007).

Nursery Growth
From experimentation in the SEED nursery in Sainte Luce, *B. madagascariensis* seeds had the highest rate of germination when sown in substrate of equal parts natural soil, manure, and compost (40% germination success) (SEED, 2023a). Across all sowing efforts, mean germination time was 107.5 days (standard deviation 54.9), with 22% (n=211) of seeds successfully germinating (nine months after sowing) (SEED, 2023a). Randriatakifa et al. (2008) commented on the low germination rates observed within the littoral forests of Taolagnaro, and suggested these could be explained by high relative humidity and temperatures in the area. At 98%, post-germination survival within the SEED nursery was very high for *B. madagascariensis* (SEED, 2023a).

Socio-economic and Cultural Importance
In Sainte Luce, the local name for *B. madagascariensis* is *Boakamainty*, which translates as 'black palm'. *B. madagascariensis* has a low level of community usage, with 28% of respondents to a 2022 community survey in Sainte Luce using this species (SEED, 2023e). *Beccariophoenix madagascariensis* is predominantly used for constructing house walls and floors, for which the palm is most commonly harvested by individuals once per year (SEED, 2023e). Despite the poorer durability of *B. madagascariensis* compared with alternative palm species in the SLLF, such as *C. saintelucei*, this species is occasionally used to produce lobster pots (Hogg *et al*., 2013b). *Beccariophoenix madagascariensis* has previously been used in Sainte Luce to produce cultural ornaments and for food (Hogg *et al*., 2013b); however, the decreasing population of this species has likely curtailed these uses.

Elsewhere in Madagascar, *B. madagascariensis* is used to construct beehives, weave hats (Shapcott *et al*., 2007), and is harvested for its edible palm heart (Dransfield and Rakotoarinivo, 2012).

Threats
Threats include habitat loss due to mining activities, along with harvesting for construction materials (Rakotoarinivo & Dransfield 2012a; SEED, 2023e). The use of *B. madagascariensis* within the Sainte Luce has reduced, due to the palms declining population (Hogg *et al*., 2013b; SEED, 2023e).

5.2 *Chrysalidocarpus prestonianus*

Species Summary
Chrysalidocarpus prestonianus is a large solitary palm (Rakotoarinivo & Dransfield, 2012b) reaching up to 12m tall with 8 to 10 leaves. It was first described in 1992 as *Dypsis prestoniana* yet was reclassified in 2022 as *Chrysalidocarpus prestonianus* (Eiserhardt *et al*., 2022). Endemic to the southeast of Madagascar, *C. prestonianus* can be found in lowland rainforest in four locations between Mahanoro and Taolagnaro: Mahanoro, Midongy district, Sainte Luce, and Tsitongambarika. In 2012, an estimated 800 adult individuals remained (Rakotoarinivo & Dransfield, 2012b).

Population and Distribution

The subpopulations of *C. prestonianus* are highly dispersed, with around 600km between Taolagnaro in the south and Mahanoro on the east coast. SEED is unaware of any recent assessments of this species in Mahanoro or Midongy.

In 2023, SEED recorded 9,755 *C. prestonianus* in the SLLF, of which the majority were juveniles (97%), followed by significantly fewer sub-adults (2%, n = 164) and adults (1%, n = 83) (SEED, 2023c). *Chrysalidocarpus prestonianus* was observed in all the SLLF fragments surveyed, with most observations made in S9 followed by S17 (Figure 4) (SEED, 2023c).

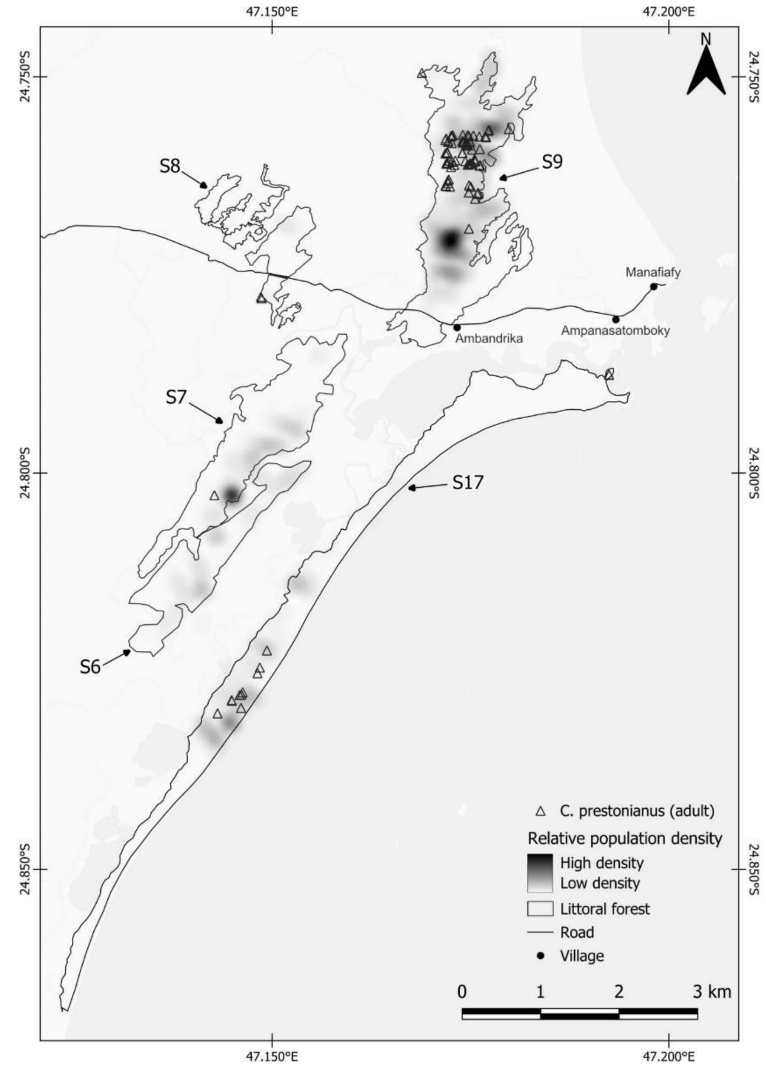

Figure 4: Chrysalidocarpus prestonianus distribution map in the SLLF.

Microhabitat

Chrysalidocarpus prestonianus have been observed within Sainte Luce at a mean elevation of 24.6m, within areas of forest with a mean canopy height of 9.13m and mean canopy cover of 56.8% (SEED, 2023d). *Chrysalidocarpus prestonianus* have been observed in lower mean density forests than other target species; however, these data also show a large range of forest density for *C. prestonianus* ($\bar{x}$ D_1 = 3.40m, $\bar{x}$ D_2 = 3.87m, std D_1 = 5.17, std D_2 = 7.08) (SEED, 2023d). This could suggest a generalist ability of the species to survive in varied forest densities.

Chyrsalidocarpus prestonianus is often found in midslopes or ridgetops from 0-700m elevation (Rakotoarinivo & Dransfield, 2012b). Palms were found in soils that were acidic (pH =4.6), composed of equal proportions sand and organic matter, and with soil infiltration rates of 5.16ml/sec (SEED, 2023d). Hogg et al. (2013b) observed that *C. prestonianus* prefer well-drained soils and 'generous' canopy cover. Microhabitat analysis has not found the occurrence of this species to be associated with soil drainage or canopy cover (Jhaveri *et al*., n.d.).

Phenology
Chrysalidocarpus prestonianus produces a long interfoliar and branched inflorescence, where ellipsoid fruits ripen from green to orange (Dransfield & Beentje, 1995).

Chrysalidocarpus prestonianus has been observed flowering within the SLLF primarily between February and April, with flowering also recorded in June, August, and November (SEED, 2023b). *Chrysalidocarpus prestonianus* could have multiple flowering periods or one long flowering period per year, but data collected so far within the SLLF is inconclusive (SEED, 2023b).

Fruiting has been observed between April and August, with local experts also identifying November as a fruiting month (SEED, 2023b). Bollen & Donati (2006) recorded *C. prestonianus* fruiting in April in the SLLF.

Pollination and Frugivory
There is no literature on pollinators of this species of palm and therefore, more research is needed. *Eulemur collaris* (Red-collared brown lemurs) are known to be frugivores of *C. prestonianus* (Bollen & Donati, 2006).

Nursery Growth
Mean germination time of *C. prestonianus* was 62 days, with 14% of sown seeds germinating (six months after sowing) (SEED, 2023a). The germination rate was highest (50%) in a sowing substrate made of only natural soil, without sand, compost, or manure (SEED, 2023a). Post-germination, *C. prestonianus* had a 100% survival rate until the time of transplanting (SEED, 2023a).

Socio-economic and Cultural Importance
In Sainte Luce, the local name for *C. prestonianus* is *Boakabe*, which translates as 'big palm'. This species has the third highest rate of community use of the six palms studied, with 56% of community survey respondents using *C. prestonianus* for a variety of purposes (SEED, 2023e). Community members of Sainte Luce who do harvest *C. prestonianus*, most commonly harvest the palm once per year (SEED, 2023e). The predominant use in Sainte Luce is for constructing house walls and floors (SEED, 2023e). *Chrysalidocarpus prestonianus* was first used to produce lobster pots around 2007 as an alternative to the declining population of *C. saintelucei* (SEED, 2023e), primarily juvenile stems are used for this purpose (Hogg et al., 2013b). The juvenile leaves have also been used to produce cultural ornaments in Sainte Luce, such as Christmas decorations (SEED, 2023e). *Chrysalidocarpus prestonianus* palm hearts are harvested for food both in Sainte Luce and elsewhere in Madagascar (Dransfield and Beentje, 1995).

Threats
Threats include habitat loss due to mining activities, along with harvesting for construction materials such as flooring (Bollen & Donati, 2006; Rakotoarinivo & Dransfield, 2012b). This palm is a local resource exploited for the long leaf stem of its juveniles, which is used for making lobster pots, and for its crown, which is harvested for the edible palm heart (Rakotoarinivo & Dransfield, 2012b; Hogg et al., 2013b; SEED, 2023e).

5.3 *Chrysalidocarpus psammophilus*

Species Summary
Described in 1986, *C. psammophilus* is a clustering palm reaching up to 6m in height and 3cm in diameter (Dransfield and Beentje, 1995). Inflorescences are branched with flowers occurring in triads.

Chrysalidocarpus psammophilus can be found in subtropical and tropical coastal forests in the east of Madagascar, within seven fragmented locations. *Chrysalidocarpus psammophilus* occurs in lowland forest, upon ridgetops in thin soils overtopping rock, or coastal zone scrub, between 0-100m in elevation (Dransfield & Rakotoarinivo, 2012; Rakotoarinivo & Dransfield, 2012c).

Population and Distribution

Chrysalidocarpus psammophilus can be found in seven isolated localities: Ambila-lemaitso, Mahavelona, Soanierana Ivongo, Sainte Marie, Antalaha Tsitongambarika, and Sainte Luce (Rakotoarinivo & Dransfield, 2012c; Hogg et al., 2013b).

In Sainte Luce in 2023, the majority of *C. psammophilus* palms recorded were juveniles (61%), followed by fewer sub-adults (35%), and adults (3%, n = 1,104) (SEED, 2023c). This number of adults recorded in Sainte Luce was significantly higher than the 100-199 adults estimated to remain in Madagascar in 2010 (Rakotoarinivo & Dransfield, 2012c). *Chrysalidocarpus psammophilus* was observed in all surveyed SLLF fragments during the population census aside from S17 (SEED, 2023c), with the fragment S7 containing the most recorded *C. psammophilus*, as well as the largest number of adults (Figure 5) (SEED, 2023c).

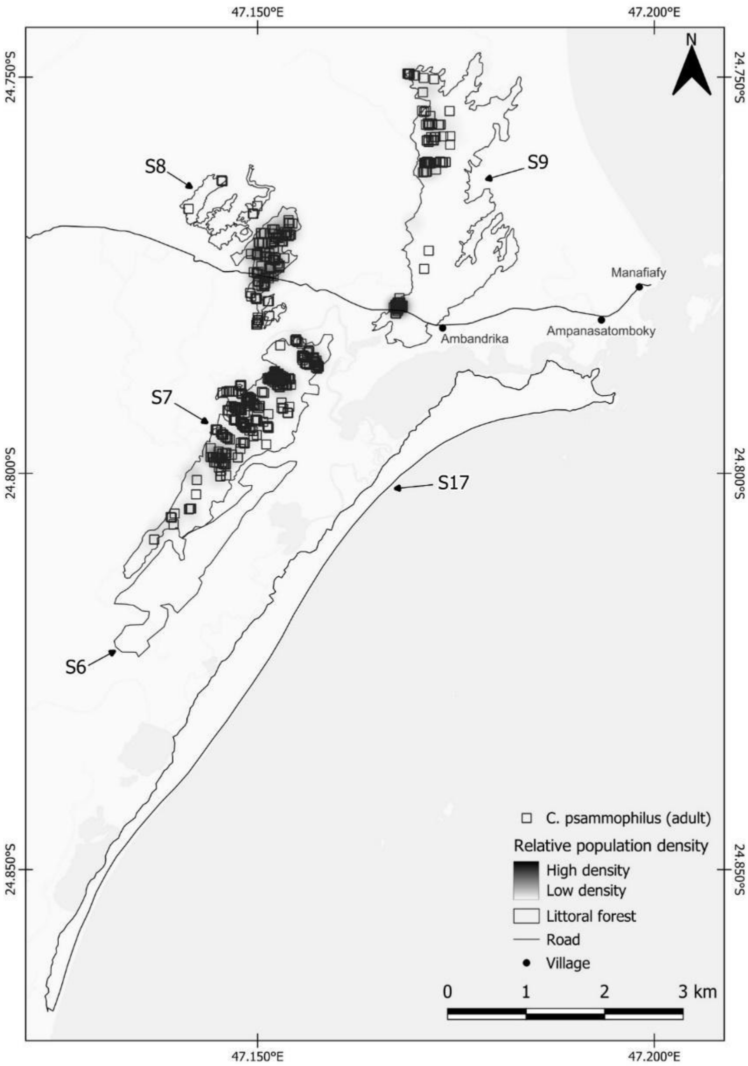

Figure 5: Chrysalidocarpus psammophilus distribution map in the SLLF.

Microhabitat

Chrysalidocarpus psammophilus have been observed within Sainte Luce at a mean elevation of 19.2m, within areas of forest with a mean canopy height of 7.13m, and mean canopy cover of 66.3% (SEED, 2023d). *C. psammophilus* were observed having a mean distance to nearest tree of 1.87m to 1.12m (tree >12.5cm circumference, tree 6.5-12.5cm circumference respectively) (SEED, 2023d).

Adult *C. psammophilus* observed in the SLLF were observed growing at median slope angles of 9.7° (SEED, 2023d). Palms were found in soils that were acidic (pH =3.95), composed of 25% sand and 75% organic matter, and with soil infiltration rates of 4.25ml/sec (SEED, 2023d). A study by Hogg et al. (2013b) conducted in Sainte Luce, observed that *C. psammophilus* prefers well-drained sandy soils and tolerates high sun exposure. Additional literature reports that *C. psammophilus* often grows in flat flooded terrain and open forests (Dransfield & Rakotoarinivo, 2012; Rakotoarinivo & Dransfield, 2012c). Microhabitat assessments revealed that the sand and water content of the soil, and the canopy cover do not statistically influence the probability of occurrence of this species in the SLLF (Jhaveri *et al*., n.d.).

Phenology

In the first study conducted to understand the phenology of *C. psammophilus,* individuals have been observed flowering within the SLLF from July to February (SEED, 2023b). Heavy fruiting has been observed between February and May, with some observed between July and September (SEED, 2023b). As distinct fruiting periods have not been defined, more research is needed.

Pollination and Frugivory

Orders Hymenoptera, Coleoptera, Diptera, and Squamata were observed on flowering *C. psammophilus* inflorescences during pollinator surveys conducted by SEED (2023b). Squamata included the Critically Endangered day gecko, *Phelsuma antanosy*. Observing *P. antanosy* on this palm, Hogg et al (2013b) have interpreted *C. psammophilus* as a foraging microhabitat for this species.

Additionally, communities bordering the SLLF have observed flying foxes (*Pteropus rufus*) feeding on *C. psammophilus* fruits (Hogg et al., 2013b). Fruits produced are green, ripening to orange (Dransfield & Beentje, 1995).

Nursery Growth

In trialling different germination substrates for *C. psammophilus* seeds, germination failed in all substrate types except in an equal composition of natural soil and compost where the germination rate was 70% (SEED, 2023a). In germination trials, 748 seeds were sown and 35% germinated (nine months after sowing) (SEED, 2023a), with a mean germination time of 47 days (standard deviation = 34 days).

Socio-economic and Cultural Importance

In Sainte Luce, the local name for *C. psammophilus* is *Hanjo*. Out of the six study species, *C. psammophilus* is fourth in terms of community usage, with 32% of respondents to a community survey in Sainte Luce utilising this species (SEED, 2023e). *Chrysalidocarpus psammophilus* is typically used to construct house walls and roofs, specifically, to pierce *Ravenala madagascariensis* (Traveller's palm) petioles (leaf stems) to create panels (Hogg et al., 2013b). In Sainte Luce, *C. psammophilus* is also used to produce lobster pots and for the trim around a *pirogue* (Malagasy dugout canoe). Survey respondents most commonly harvested *C. psammophilus* once per year (SEED, 2023e).

Threats

Threats include habitat loss for agriculture, along with harvesting for construction, with petioles are often used for house walls and flooring (Hogg et al., 2013b). Within Sainte Luce, threats extend to habitat loss due to mining activities along with harvesting for building pirogues and making lobster pots (SEED, 2023b).

5.4 *Chrysalidocarpus saintelucei*

Species Summary

Chrysalidocarpus saintelucei is a large solitary palm, which exhibits white nodal scars, growing up to 10m in height, with a mean trunk diameter of 21cm (Dransfield *et al*., 2006; Hogg et al., 2013a). *C. saintelucei* produces branched interfoliar inflorescences and ellipsoid fruits which are yellow when ripe (Hogg et al., 2013a).

As of 2010*, C. saintelucei* has been documented within four distinct locations in the southeast of Madagascar, Amoasimanolotra, Vondrozo, Tsitongambarika, and Sainte Luce (Rakotoarinivo & Dransfield, 2012d). Within these locations, *C. saintelucei* occurred within lowland rainforest or coastal areas, on white sand, and in elevations of 10-700m.

Population and Distribution

The majority of the 10,338 observations of *C. saintelucei* across surveyed SLLF fragments were of juveniles (94%), followed by much fewer sub-adults (5.3%) and adults (0.4%, n = 40) (SEED, 2023c). Most observations for all age categories were made in S7, and no observations of adults or sub-adults were made in S17 (Figure 6) (SEED, 2023c).

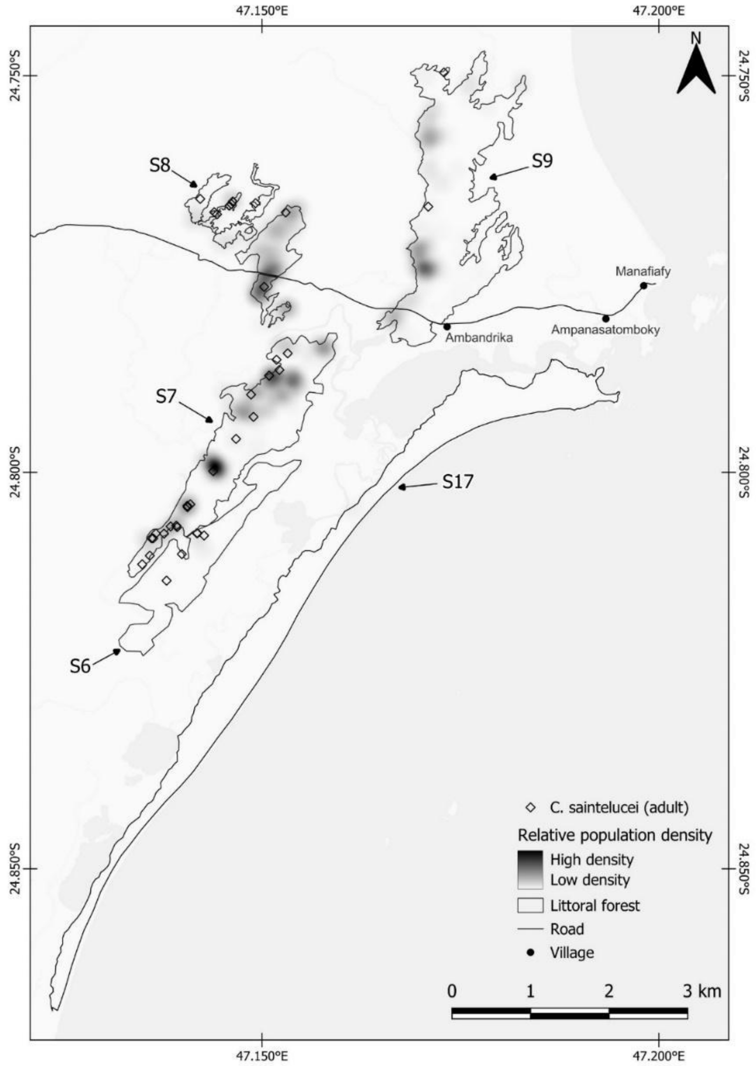

Figure 6: Chrysalidocarpus saintelucei distribution map in the SLLF.

Microhabitat

Chyrsalidocarpus saintelucei have been observed within Sainte Luce at a mean elevation of 14.6m, within areas of forest with a mean canopy height of 7.65m and canopy cover of 55.8% (SEED, 2023d). *Chrysalidocarpus saintelucei* were observed having a mean distance to nearest tree of 2.88m and 1.67m (tree >12.5cm circumference, tree 6.5-12.5cm circumference respectively) (SEED, 2023d).

In the SLLF, adult *C. saintelucei* were observed growing at median slope angles of 18^{o} and were found in soils that were acidic (mean pH=3.84), with a mean soil infiltration rate of 3.11ml/sec (SEED, 2023d). Literature suggests that *C. saintelucei* prefers soils of medium saturation which can tolerate frequent flooding and generous canopy cover (Rakotoarinivo & Dransfield, 2012d; Hogg et al., 2013b). Mean canopy cover observed by Hogg et al. (2013a) was recorded as 63.5% coverage using a densitometer. Despite this, SEED found that canopy cover does not influence the presence of *C. saintelucei* in the SLLF*,* instead, their distribution is positively associated with a low soil sand content (Jhaveri *et al*., n.d.).

Phenology

Chrysalidocarpus saintelucei have been observed flowering within the SLLF between January and October (SEED, 2023b). Hymenoptera and Coleoptera frequently pollinate the flowers on this species, with the gecko species

Phelsuma pava and *Phelsuma lineata* observed on *C. saintelucei* during pollinator surveys in the SLLF (SEED, 2023b). Literature suggests that the Critically Endangered *P. antanosy* requires *C. saintelucei* as a habitat (Ramanamanjato et al. 2002). Squamata are not mentioned as pollinators in a comprehensive review of palm pollination by Barford et al. (2011). Therefore, it is likely that *P. antanosy* has a foraging association with the microhabitat of *C. saintelucei* palms, as opposed to being a pollinator of this species.

Corracopsis vasa (Greater vasa parrot) have been observed foraging on *C. saintelucei* fruits although destroy the seed during this process and are therefore, not considered seed dispersers (Hogg et al., 2013a). There are no other observed frugivores recorded for this species (Hogg et al., 2013b). Seed dispersal mechanisms for *C. saintelucei* are expected to be barochorous, with seedlings germinating at the base of the parent tree (Hogg et al., 2013a).

Nursery Growth

Soil trials revealed no difference in germination time or growth rates in various soil substrates for *C. saintelucei*, the palm germinated in all substrate types (SEED, 2023a). The average germination time for successfully germinated palms (72%) was 8.4 days, with 100% post-germination seedling survival for the length of data collection. This aligns with recordings by Hogg et al. (2013a) of particularly high germination and first-year survival rates of *C. saintelucei* seedlings, of over 90%, within cultivation trials in Sainte Luce.

Socio-economic and Cultural Importance

In Sainte Luce, the local name for *C. saintelucei* is *Telopoloambilany*, which translates to '30 in one pot'. This name shows the high local importance of this species as it references the use of *C. saintelucei* as a foodstuff. Due to a declining adult population however, the practice of eating this palm has reduced (Hogg *et al*., 2013a).

Chyrsalidocarpus saintelucei is the second-most used palm species of the six study species, with 62% of community survey respondents in Sainte Luce using this species predominantly for lobster pots (SEED, 2023e). *Chyrsalidocarpus saintelucei* was most commonly harvested weekly by survey respondents. The palm is also used in house construction, although this is uncommon (Hogg *et al*., 2013a). Due to its declining population, *C. saintelucei* has a significantly reduced community usage compared with the recent past (SEED, 2023e).

Threats

Threats include habitat loss due to agricultural and mining activities, along with harvesting adults and juveniles for construction materials for making lobster pots, and for their edible palm hearts (Hogg et al., 2013b, SEED, 2023e).

5.5 *Dypsis brevicaulis*

Species Summary

Dypsis brevicaulis is a Critically Endangered species of dwarf palm that can grow in solitary or in clusters. The stem can be acaulescent, grow underground or exposed, and reach 2m in height and up to 2cm in diameter (Dransfield & Beentje, 1995; Hogg et al., 2013b). Leaves are long, narrow, and bifid at the apex (Dransfield & Beentje, 1995). Inflorescences can be unbranched or branched and produces red elongated fruits when ripe (Hogg et al., 2013b).

Dypsis brevicaulis is a rare palm restricted to the Taolagnaro region in southeast Madagascar (Rakotoarinivo & Dransfield, 2012e). It is known from three locations; forest fragment S8 of the SLLF, Mount Ivohibe in Tsitonganbarika, and south of Manantenina (Hogg et al., 2013b). Here it occupies littoral forest fragments on white sand or laterite, and lowland humid evergreen forest between 35-700m in elevation (Rakotoarinivo & Dransfield, 2012e).

Population and Distribution

The distribution of *D. brevicaulis* is highly restricted with three known localities much closer together than other species of this study.

In SEED's (2023c) population census*, D. brevicaulis* were only observed in S8 and its associated forest remnants. Of 4,215 observations, most were of juveniles (56.5%) followed by sub-adults (34.5%) with fewer adults observed (9%, n = 382) (SEED, 2023c). In 2011, over 400 adult palms were located within 10ha of SLLF fragment S8, suggesting a possible on-going species decline (Hogg *et al.*, 2013b). There are currently no records of *D. brevicaulis* in S8 Remnant 1 or S8 Remnant 3, and in S8 Remnant 2 there were no sub-adults or juveniles observed, only 5 adults (Figure 7) (SEED, 2023c).

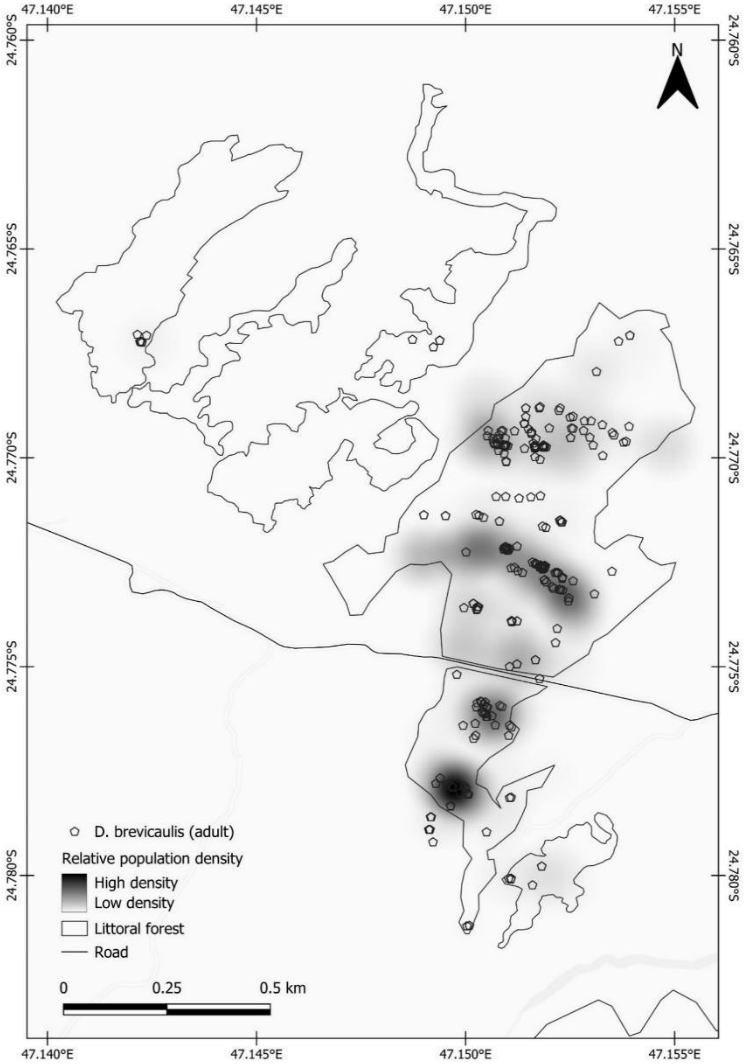

Figure 7: Dypsis brevicaulis distribution map in the SLLF. Only the forest fragment S8 contained D. brevicaulis, so other fragments are omitted from the map.

Microhabitat

Dypsis brevicaulis have been observed within the SLLF at a mean elevation of 25.9m, within areas of forest with a mean canopy height of 7.93m and canopy cover of 68.9% (SEED, 2023d). *D. brevicaulis* have a mean distance to nearest tree of 2.38m to 1.34m (tree >12.5cm circumference, tree 6.5-12.5cm circumference respectively) (SEED, 2023d).

The majority of adults observed in SLLF were observed growing at median slope angles of 15.5^{o} (SEED, 2023d). Palms preferred soils composed of equal proportions sand and organic matter and were found in soils that were acidic (mean pH =4.09), with mean soil infiltration rates of 3.02ml/sec (SEED, 2023d). Hogg et al. (2013b) noted that *D. brevicaulis* prefer well-drained soil. Despite this, a microhabitat study by SEED found that soil drainage did not impact D. brevicaulis occurrence. Instead, the species was positively associated with higher sand content in the soil (Jhaveri *et al*., n.d.). This aligns with Dransfield & Rakotoarinivo (2012) who observed *D. brevicaulis* growing in open forest on sandy soil within Tsitongambarika.

Phenology

Dypsis brevicaulis have primarily been observed flowering within the SLLF from January to June, with additional observations in October and November (SEED, 2023b). Two distinct fruiting periods have been recorded, from April to June and from October to January (SEED, 2023b).

Pollinators

Hymenoptera were observed on flowering *D. brevicaulis* inflorescences within the SLLF during pollinator surveys conducted by SEED (2023b). Observations consisted of ants, bees, and wasps but could not be identified to species level (SEED, 2023b).

Nursery Growth

In soil trials, *D. brevicaulis* had the highest germination rate in a substrate made of natural soil and compost (50%), compared to in natural soil alone (30%), or combinations of natural soil, manure, and compost (10%), and manure and compost (10%) (SEED, 2023a). The mean germination times and mean growth rates were similar in all soil types. Across sowing efforts, 19% of seeds germinated (nine months after sowing) (SEED, 2023a), with a mean germination time of 41 days. Post-germination, the seedlings had a survival rate of 99% in the nursery (SEED, 2023a).

Socio-economic and Cultural Importance

In Sainte Luce, the local name for *D. brevicaulis* is *Tsirombonala*. There are no known community uses for this dwarf palm (SEED, 2023e), and as such, it is the target species with the lowest socio-cultural importance to communities bordering the SLLF.

Threats

Threats include habitat loss for agriculture and mining activities (Hogg et al., 2013b). As there are no known uses for this palm in Sainte Luce (SEED, 2023e), direct harvesting is not a threat to this species.

5.6 *Dypsis scottiana*

Species Summary

Dypsis scottiana is a small clustering palm which grows in clumps of 3-16 individuals (Dransfield & Beentje, 1995). Stems can reach 4m in height and up to 2cm in diameter, producing branched inflorescences which are interfoliar to infrafoliar. Fruits are ellipsoid with a pointed apex, and red upon ripening (Dransfield & Beentje, 1995).

Dypsis scottiana can be found within seven disconnected locations in the southeast of Madagascar between Taolagnaro and Farafanga, including Andohahela and Midongy National Parks, and the SLLF (Rakotoarinivo & Dransfield, 2012f). *D. scottiana* occurs within lowland rainforest but is most abundant in coastal habitats on white sand between elevations of 0-600m (Rakotoarinivo & Dransfield, 2012f).

Population and Distribution

The population of *D. scottiana* is relatively contiguous, reaching from Taolognaro to Farafangana roughly 250km apart. Despite this, subpopulations are likely to exist due to high local forest fragmentation.

Dypsis scottiana was the most frequently occurring palm censused in Sainte Luce (n= 88,129), being found in all SLLF fragments (SEED, 2023c). Most observations were of juveniles (56.5%) followed by sub-adults (40%) with fewer adults (1.5%, n = 1,317) observed across all forest fragments (SEED, 2023c). A new assessment of the other subpopulations would certainly increase the estimated population of *D. scottiana,* which in 2010 was 900 adult individuals (Rakotoarinivo & Dransfield, 2012f). The densest area of the adults observed was in the south of S9, outside of the designated protected area (SEED, 2023c). Most observations of *D. scottiana* were made in S9 and S7 with the fewest in S17 and S6 (Figure 8) (SEED, 2023e).

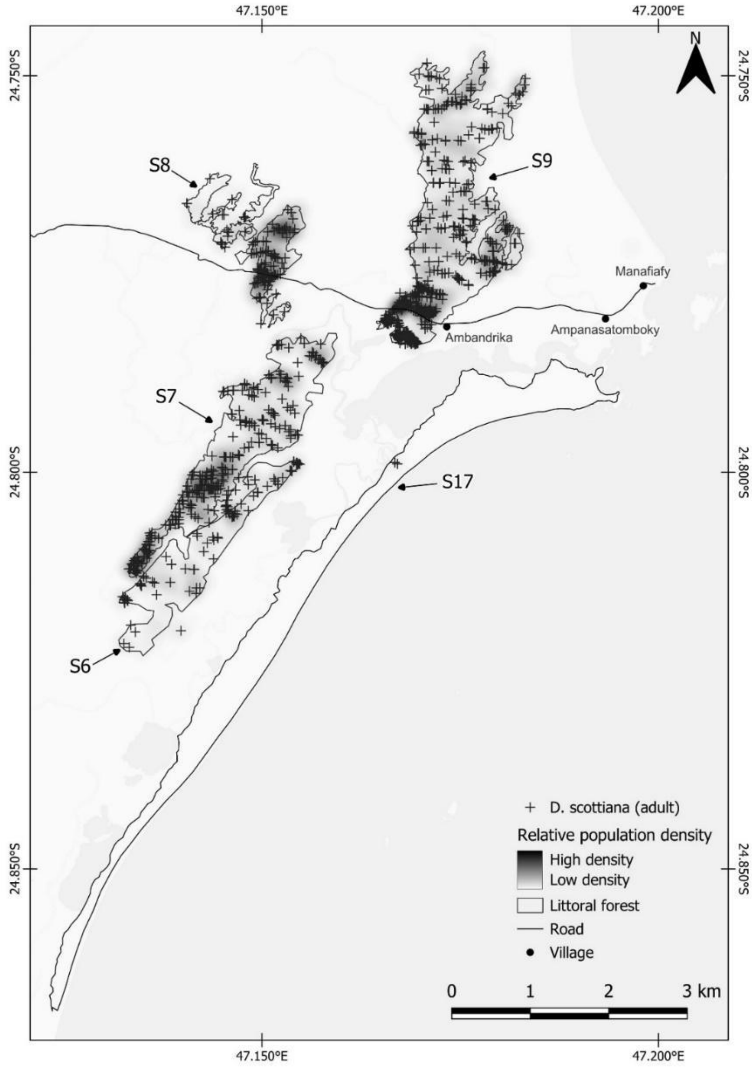

Figure 8: Dypsis scottiana distribution map in the SLLF.

Microhabitat

The *D. scottiana* within the SLLF were found at a mean elevation of 18.3m, within areas of forest with a mean canopy height of 6.69m and canopy cover of 55.7% (SEED, 2023d). *Dypsis scottiana* were observed in areas of forest of mean density 2.31m to 1.19m (tree >12.5cm circumference, tree 6.5-12.5cm circumference respectively) (SEED, 2023d).

The majority of adults observed in SLLF were observed growing at median slope angles of 8° (SEED, 2023d). Palms were found in soils that were acidic (mean pH=4.18), composed of 25% sand and 75% organic matter, and with mean soil infiltration rates of 3.75ml/sec (SEED, 2023d).

Hogg et al. (2013b) observed that *Dypsis scottiana* can grow within dry forest edges, moist forest interiors, and many different microhabitat conditions within their distributional ranges. This is supported by more recent data from SEED which demonstrates the generalist nature of this species, for which occurrence is associated only with high tree density and low canopy height (Jhaveri *et al*., n.d.).

Phenology

Dypsis scottiana has been observed flowering year-round within the SLLF, with most observations concentrated from January to April (SEED, 2023b). This supports the possibility that *D. scottiana* flowers asynchronously, as a result long flowering periods are created (Barford et al., 2011). Fruiting is concentrated between April and July, with observations recorded from February to December (SEED, 2023b). Literature supports these observations, noting that seeds have been collected between April and July, and in September (Randriatafika et al., 2008).

Pollination and Frugivory
Orders Araneae, Diptera, and Hymenoptera were recorded on flowering *D. scottiana* inflorescences within the SLLF during pollinator surveys (SEED, 2023b). Araneae are not traditionally referred to as pollinators and therefore, may have been present without aiding pollination (Barford et al., 2011).

Bollen et al., (2004) lists seven species of frugivores that feed on *D. scottiana*. These include lemurs: *Eulemur collaris* (Red-collared brown lemur) and *Cheirogaleus* spp (Dwarf lemurs), bird species: *Alectroenas madagascriensis*, and *Treron australis*, and rodent species: *Rattus rattus*, and *Eliurus webbi*.

Nursery Growth
For *D. scottiana*, germination success was 45% nine months after sowing (SEED, 2023a). This palm species demonstrated the longest germination period in the SEED's nursery trial, with a mean of 204 days (SEED, 2023a). The lengthy germination period could be explained by some littoral forest species being known to experience seed dormancy until conditions are favourable (Randriatakifa et al., 2008). Seedlings showed a 95% post-germination survival rate (SEED, 2023a).

Socio-economic and Cultural Importance
In Sainte Luce, *D. scottiana* has two local names, *Amboza,* which refers to juveniles of this species, and *Raotry*, which refers to adults. As the only study species with two local names, it can be seen that *D. scottiana* has a high local importance. The high local importance of *D. scottiana* is further evidenced by it having the highest level of community usage of the six study species, with 84% of community survey respondents using this species, predominantly to produce lobster pots (SEED, 2023e). Roughly 30 *D. scottiana* stems are used to produce one lobster pot, with juveniles and sub-adults being selected specifically for their flexibility (SEED, 2023e). A lobster pot can last two to three weeks at sea, as such *D. scottiana* is harvested weekly by community members in Sainte Luce (SEED, 2023e). Anecdotal evidence suggests that *D. scottiana* began to be used for this purpose around 30 years ago (~1990) (SEED, 2023e). Adult *D. scottiana* can be used in construction for house walls, in a similar manner to *C. psammophilus*, where the trunk pierces *R. madagascariensis* to form panels (Hogg *et al*., 2013b). *Dypsis scottiana* has also been used for the trim of a *pirogue* (Malagasy dugout canoe) (Hogg et al., 2013b).

Threats
Threats include habitat loss due to agricultural and mining activities, along with the harvesting of adult stems for construction materials, such as wall panelling (*manohy falafa)*, enforcing *pirogue* walls, and making lobster pots (Hogg et al., 2013b).

6. Transplanting

6.1 Transplanting Methods

Planting Site Selection
After consultation with local experts, 34 candidate planting sites were identified in the SLLF. Microhabitat assessments were conducted at 30 of these sites that were considered to be feasibly accessible for palms planting.

Sites were assessed against several ecological characteristics. The density and tree species of two size categories were recorded to determine habitat density and local arboreal diversity. Canopy cover and canopy height were recorded as proxies for light penetration. The slope angle, aspect, and elevation of each site were assessed. Soil suitability was determined by pH and qualitative measures of leaf litter cover and soil texture (relative sand content).

Microhabitat data of potential planting sites were analysed and compared to data previously collected by Project Palms on the microhabitat preferences of the six target species of palms. Sites were determined by microhabitat compatibility, feasibility of planting, and accessibility. During microhabitat assessments, the size and planting capacity of each site were assessed.

Seedling Preparation

To mitigate seedling mortality post-transplanting, only seedlings above a species-specific height threshold (Table 3), and that were considered to be in good condition were selected for *in-situ* planting. These height thresholds were decided after discussions with local expert staff and considered the following factors: relative growth rates, age, and relative robustness to size ratio.

Table 3: Recommended species-specific thresholds for seedlings to be ready for in-situ planting.

Species	Minimum sapling size (cm)
B. madagascariensis	15
C. prestonianus	10
C. psammophilus	15
C. saintelucei	20
D. brevicaulis	10
D. scottiana	11

Planting Methodology

All palm species were planted in holes with dimensions of 40cm x 40cm x 20cm as recommended by Missouri Botanical Gardens. Precise planting locations were chosen so that each seedling was ≥3m away from any other transplanted seedling, and ≥3m from any naturally occurring individuals of the target palm species or any large tree (DBH ~25cm). This aimed to reduce competition among planted seedlings and existing palms. When large tree roots (>5cm) were found in the holes they were left in place and the hole excavated underneath the palm.

In each prepared hole, one seedling was placed in the centre so that the lowest leaves were level or higher than the surrounding forest floor. Three handfuls of compost were placed underneath the seedling's roots. The topsoil and remaining soil, which was piled next to each hole during digging, was placed back into the hole around the roots and at the base of the seedling. The hole was refilled to 2-3 cm below the surrounding forest floor, leaving a small edge around the sides of the hole helping to retain rainwater. Care was taken to not leave any seedling leaves covered in soil.

Monitoring of Survival and Growth

Of all transplanted palms, at least 15% are monitored for height (cm) and condition (1-4) at intervals of month 0, 1, 3, 6, and 12 after planting, after which monitoring is conducted once annually. For month 0, data of individual palms were recorded immediately after planting to establish a baseline. Height is measured by stretching the longest leaf and measuring the distance from soil level to the leaf apex. Condition ratings are given on a scale of 1 to 4 (Table 4). A condition of 1 means the palm seedling is "Dead", and a condition score of 4 means the seedling is in "Good" health.

Table 4: Descriptions of palm quality to aid in scoring of the Condition.

Condition	Description
1 - Dead	Palm has wilted, lost all its leaves, and turned brown.
2 - Poor	Severe signs of either: damage, pest infestation, discolouration, fungi, or abnormal growth.
3 - Fair	Signs of either: damage, pest infestation, discolouration, fungi, or abnormal growth.

4 - Good	Healthy palm, with green leaves showing no evidence of pests/disease, or human disturbance such as leaf removal or axe marks on trunk.

If 20% of the monitored palms from one species or site score a condition of 1 or 2, an evaluation will be conducted to determine if aftercare is necessary to prevent or reverse declines in palm health.

6.2 Transplantation Evaluation

There are few examples of *in-situ* transplantation of plants taking place within an existing forest ecosystem in southeast Madagascar. Some studies have assessed the success of reforesting areas completely absent of trees or creating corridors between remaining forest fragments through open habitat; however, these studies are not specifically palms focussed.

In 2023, SEED conducted a pilot transplantation of 66 C*. saintelucei* into the SLLF using the method outlined above. Monitoring conducted at 12 months after transplanting (February 2024) revealed seedling survival was 97% and height had increased by 104%.

As of July 2024, a total of 1,075 palm seedlings have been transplanted by SEED Madagascar into the three protected fragments of the SLLF (IUCN Category V), with a survival rate of 96.5% after three months. The high survival rate, particularly in the first month, strongly suggests that the seedling selection process and the transplanting protocol used in this study were well adapted to the palm species.

For all transplanted palms, the mean height increased during the initial three-month period. Individually, there were three species which changed in mean height from month 0 to month 3, *C. prestonianus* (an increase of 13.8%)*, C. saintelucei* (an increase of 13.6%), and *D. brevicaulis* (an increase of 11.6%). The other three species did not have a statistically significant change in mean height during the first three months post-transplanting.

According to Fahselt (2007), transplantation needs to be coupled with ecosystem functions such as productivity, seed dispersal, pollination, allelopathic interactions, and food-chain relationships, in order to fulfil comparisons to natural areas and be considered a success. By transplanting palms into suitable microhabitats and into fragments where they naturally occur, ecological processes and appropriate conditions can be assumed to pre-exist.

Despite consideration of the microhabitat requirements of each target species and comparing these with the microhabitat of potential planting sites, specific local microhabitats may not be optimal for every individual seedling planted within the planting site. This is due to the large number of seedlings planted and the rigid planting of ≥3m from any large tree, target palm species, or planted seedling in the forest. The final planting locations were sprawling and may not all fall within an area of the specific microhabitat characteristics preferred by the individual palm species.

The mean condition of the palms was classified as Good (4) at the time of planting and remained Good (4) as of July 2024 (three months after planting). Only the species *C. psammophilus* showed a statistically significant decrease in condition over time from month 0 to month 3. We expect an initial decline in overall condition score after planting *in-situ*, as seedlings are moved out of the controlled and pest monitored environment of the nursery into the forest. Stochastic events of plant death are inevitable within *in-situ* environments, due to many factors such as environmental stress, herbivory, pests, and diseases (Grossnickle, 2012).

A primary limitation to transplanting efforts was the growth of palm seedlings in the nursery. Two out of the six species have mean germination times that exceed three months. Furthermore, of all 12,906 palm seeds sown from the six species, only 3,660 germinated successfully. Once germinated, growth of all species was slow. SEED found seedlings of all species should be grown in the nursery for approximately one-year post-germination to ensure palms are of a suitable height and condition for planting. Overall, in SEED's experience, long germination times, low germination success, and slow growth rates of palms combined with substantial variation between species to create an unpredictable timeline for nursery growth. As a result, long-term planning for *ex-situ* growth and *in-situ* transplantation are required for successful conservation results.

7. Community-Recommended Conservation Actions

Between April and June 2023, Project Palms held 12 focus groups with three communities bordering the SLLF: Sainte Luce, Ebakika, and Mahatalaky. Focus groups were conducted to understand community motivation for palm conservation, if communities considered protecting palms important, and if there were any specific conservation strategies believed to be particularly effective in the SLLF. Key research questions included:

1) Do communities surrounding the Sainte Luce littoral forest believe the six threatened target species of Project Palms should be protected?
2) If yes, how do communities surrounding the Sainte Luce littoral forest believe the six threatened target species of Project Palms should be protected?
3) What are local priorities in terms of littoral forest conservation?

Community discussions on palm conservation centred around five main themes: livelihood support, community involvement, *dina*, transparent forest management, and alternative resource provision. Numerous and diverse methods of palm protection stemmed from each theme.

7.1 Livelihood Support

The most frequently discussed method of palm protection was the provision of support to specific livelihood groups, primarily fishers but also to loggers. When asked how the threats to palms could be reduced, specific suggestions for support to fishing livelihoods included the provision of lobster pots and fishing materials, the planting of palms for lobster pot construction, the planting of alternative tree resources for lobster pot construction, involving fishers in palm related discussions, and involving fishers in palm monitoring. All Riaky Committee (Fisher Committee) participant groups stated they were willing to help protect the palms, but that they need support to find alternative resources for fishing materials. Lobster pot construction was one of the most frequently referenced palm threats, cited by all participant groups in Sainte Luce and Ebakika. It was noted in several discussions that fishers are willing to break the *dina* to acquire palm resources. Current lobster fishing practices would not be possible without the use of palms, emphasising that to increase palm harvesting sustainability direct support mechanisms will need to be provided to fishers.

Multiple strategies to support loggers in protecting the palms were also suggested. Raising awareness, education sessions, and inclusion of loggers within monitoring activities were all strategies mentioned to reduce the threats to palms caused by logging. It was discussed that if loggers fully understood the impact of their livelihood activities, then fewer palms would be harvested. Most demands for support to loggers were to find completely alternative livelihoods, not to increase the sustainability of their current activities, which represents a stark contrast to conversations around fishing livelihoods.

7.2 Community Involvement

At least five forms of community involvement in conservation were discussed as forms of protection for palms in the SLLF: community awareness-raising, community involvement in palm discussions, community involvement in or community-led palm monitoring, community group education sessions, and community engagement to establish buy-in, such as mass mobilisation events. The most frequently suggested form of community involvement in palm protection was awareness-raising. Awareness raising sessions were suggested on the topics of reviewing and emphasising the existing *dina*, informing people about existing forest management structures, informing people on the existing conservation measures in place, informing people on the importance of palms, and informing forest management bodies on their responsibilities relating to palms. From this diverse set of suggested topics, it is clear that the communities bordering the SLLF would like information and training on how to manage their natural resources.

A similar palm conservation strategy that arose in focus groups was education sessions. Focus group data highlighted that certain livelihood groups (fishers and loggers) would benefit from learning about palm conservation, implying more information on palm conservation would improve the sustainability of their work.

Community involvement in palm monitoring was discussed by every participant group. Demands were made that future monitoring activities are not limited to forest management bodies, and that the community are involved. All focus groups agreed, the more diverse a set of people involved in palm monitoring the more effective conservation efforts would be. It appears that community involvement in monitoring is perceived as an awareness raising tool, as demonstrating how few mature adult palms there are in the SLLF might influence forest users harvesting practises.

7.3 *Dina* (local law)

All participant groups mentioned using *dina* as a protection measure for palms in some form. Discussions of *dina* as a protection measure for palms were on three main topics: the implementation of a new *dina*, expanding the existing *dina*, and awareness-raising on existing *dina*. A suggestion of creating a new *dina* evoked mixed responses. Some voiced concerns that a new *dina* is not required because the forest is already governed by several *dina,* and communities have few places to collect natural resources now. Despite this, others suggested implementing a new *dina* because they see how rapidly palms are declining in both the resource use and protected areas.

The most common palm protection measure involving *dina* was the elaboration or expansion of the existing *dina*. Updating current regulations was a protection measure suggested in all focus groups and in all locations, such widespread demand highlights this need. Similarly, ensuring that the *dina* is followed by everyone in the communities bordering the SLLF was suggested frequently. Participant groups in Mahatalaky specifically mentioned working with groups from different communities to enforce the existing *dina*, and not discriminating when giving punishment for transgressions. *Dina* awareness raising sessions were suggested to remind people about the importance of protecting palms, the consequences of breaking the *dina*, and any updates made to the *dina*. Overall, the community prioritised the conservation actions of updating the existing *dina*, stricter enforcement of the existing *dina*, and *dina* awareness-raising sessions, over the implementation of a new *dina*.

7.4 Alternative Resource Provision

Numerous forms of alternative resource provision were suggested as a method of palm conservation, one of the most common included planting trees in a community resource use zone. Nearly all participant groups, apart from COBA, suggested this action. Several groups encouraged the planting of palms, the main reason given for this was to supply materials for lobster pot and house construction. While other groups proposed planting alternative tree species, specifically fast-growing tree species, to prevent the need to harvest palms. Other recommendations for alternative resource provision, apart from forest resources, included fishing materials to reduce fishers' dependence on palm species, and camera phones to increase the ability of forest management bodies to record information and obtain evidence of transgressions.

7.5 Transparent Forest Management

All locations and nearly all participant groups discussed the need for a more transparent forest management system. Specific ways discussed as to how a more transparent forest management system would help protect palms included avoiding favouritism and nepotism in forest management, impartially applying rules and fines to all community members, and conducting training so that management committees can correctly fulfil their forest roles. If each of these suggestions were achieved, most participants believed forest protection would then benefit everyone, as well as forest biodiversity.

8. Recommended Conservation Actions

It is clear from the findings of this research that the necessary conservation actions required to sustain palm diversity in Sainte Luce fall into two distinct, albeit related categories. Firstly, there is an exigent need to protect and augment the existing populations of threatened palms in Sainte Luce. The results of SEED's population census clearly diagnose the low number of adult palms remaining in the SLLF, and crucially, in the protected areas (SEED, 2023c). Combined with previous appraisals (Hyde Roberts et al., 2020), findings of this research starkly demonstrate a continual and rapid population decline for a number of key species, whose low numbers now make them extremely vulnerable to effective extirpation (i.e., a loss of reproductively active individuals from the population). Protecting remaining adult palms *in-situ* (particularly *B. madagascariensis*, *C. prestonianus*, *C. saintelucei* and *D. brevicaulis*) should form the core of any strategic interventions. Fortunately, this study has identified both the key threats to these palms and has developed a precise understanding of important localities and species distributions. These data will be vital to the development of practical conservation solutions going forward. Secondly, in order for any implemented conservation measures to be effective over a long period of time, the relationship between palm harvesting and community livelihoods needs to be carefully addressed. As well as performing important ecological roles, palms undoubtedly provide critically important natural resources for rural communities such as Sainte Luce (Hogg et al., 2013b), and thus finding a sustainable solution is paramount to conservation efforts.

Whilst the two elements require specific actions, ultimately, both rely on strong local governance, functioning forest protections, and robust local resource management, conditions that are notoriously difficult to establish in Madagascar.

8.1 Practical *In-situ* Conservation Methods

The *in-situ* conservation of the target palm species may initially follow more traditional methods (detailed below); however, the recovery of populations may still take several decades since a number of palm species (particularly *B. madagascariensis*, *C. prestonianus,* and *C. saintelucei*) are slow growing and take many years to mature. Whilst all six target species were observed within the protected forest fragments S8 and S9, providing some hope for the future, it is also apparent that harvesting continues at a pace which is preventing population growth. The discrepancy between the large number of immature palms and the limited number of mature individuals suggests high mortality at some stage in the developmental process, most likely the over-harvesting of mature palms, this trend is seen across all six study species. Thus, the cultivation of wild collected seeds in *ex-situ* nurseries and the subsequent transplantation of immature palms back into protected areas is likely not the panacea it was initially thought to be. Whilst this objective can ultimately only help to bolster palm populations, more impactful protection for existing mature adults and a long period of minimal palm harvesting, providing conditions in which immature palms can develop, appear to be required. Given the predicted impacts of mining in the area however, the future remains uncertain.

Specific Actions Recommended:

- Prohibit the collection of threatened palms at all life stages in the protected forests.
- Mark important mature palms (with signs/cameras) to discourage people from cutting or harvesting.
- Regularly monitor the remaining important mature palms.
- Include palm check-ups in *Polisin'ala* patrol routes.
- Present findings to local protected area managers and discuss viable additional protection measures.
- Communicate potential punitive measures for the illegal felling of palms in protected forest fragments to local community members.
- Work with the local community and stakeholders to strengthen existing forest protections, to prevent further habitat loss through agricultural expansion, deforestation, and fire.
- Expand the local protected area network to encompass additional areas of key palm diversity.

8.2 Livelihoods and Community-based Conservation Methods

Alongside the more practical and conventional conservation efforts required, a strengthening of the pre-existing local forest governance framework is vital. Our results clearly demonstrate that anecdotal declines are very real, with long-term implications for livelihoods and community development. Given that for several utilitarian palm species, the number of mature individuals is now so low that extirpation is a legitimate and likely threat, alternative materials linked to livelihoods (particularly fisheries and construction) are increasingly urgent. From our findings, it is clear that the existing forest protections in the SLLF (IUCN Category V) are inadequate to prevent selective harvesting within the protected area boundaries, and community resources zones are unquestionably unable to sustain community demand for natural resources long-term. Therefore, the careful management of forest localities that host threatened palm populations is now essential for both the long-term, local persistence of these palms and for the continued practice of local livelihood strategies. By sharing research findings and engaging in open communication with local decision makers, SEED's work can potentially help to empower and shape future natural resource management strategies. Supporting transparent and corruption-free decision making is likely to improve the localised management of natural resources, with probable positive effects for local biodiversity. Similarly, the establishment of a specialised working group, comprising of invested stakeholders, could prove productive. Natural resource management decisions, however, must be underpinned by reliable data. As such, continued monitoring, involving local community members and entities such as *Polisin'ala*, should be encouraged and supported. Likewise, initiatives that improve the effectiveness of local environmental policies (e.g., respecting protected areas, harvesting quotas, and firebreak management), and thus will ultimately help to slow the continual loss of palms, should be promoted. As the human population in Sainte Luce, and other communities that border the SLLF, continue to grow as will the demand for natural resources. Consequently, effective livelihood-based and community-supported palm conservation methods will continue to gain importance.

Specific Actions Recommended:

- Identify and encourage the use of alternative resources, particularly those related to the local fishery, to relieve pressure on maturing palm populations.
- Share the research findings of Project Palms with community actors (village chief, local resource management bodies, *Polisin'ala*) and key local stakeholders (invested NGO's and ecotourism bodies).
- Offer support to local community governance bodies who may opt to establish new regulations (e.g. codify palm protection in local law or *dina* or prohibit the further harvesting of mature palms).
- Facilitate communications between the community and key external decision makers (e.g., DREDD and QMM).
- Establish a local working group of invested and affected stakeholders, with a focus of palm conservation.
- Provide appropriate community training on palm monitoring, cultivation, and conservation.

Beyond Sainte Luce, published knowledge regarding the distribution and populations of the six threatened palm species remains patchy and incomplete. As such, the SLLF remains a critically important locality for each of these palm species.

9. Conclusions

In summary, the six threatened species of palm found in the SLLF, southeast Madagascar: *Beccariophoenix madagascariensis*, *Chrysalidocarpus prestonianus*, *Chrysalidocarpus psammophilus*, *Chrysalidocarpus saintelucei, Dypsis brevicaulis*, and *Dypsis scottiana,* all have marked ecological and socio-economic value.

Ecologically, palm populations documented within the SLLF represent significant proportions of the known adult population of each species, making *in-situ* conservation of mature adults in the SLLF key to species' survival long-term. These palms provide important ecosystem services to other endemic and locally endemic forest-dwelling species. For example, *C. saintelucei* acts as a habitat for the Critically Endangered day-gecko, *P. antanosy,* while *C. psammophilus* fruits offer a food source for the Vulnerable Madagascan-flying fox, *P. rufus.* Furthermore, five of six study species, particularly *C. saintelucei* and *D. scottiana* have high local economic importance, as they are a key natural resource used in the Sainte Luce fishery. In Sainte Luce, 93.7% of households rely on lobster fishing as their primary source of income. As a result, both *C. saintelucei* and *D. scottiana* are harvested weekly by community members to produce lobster pots. *C. psammophilus, C. saintelucei,* and *D. scottiana* are also regularly used by the community of Sainte Luce as materials for construction, which further emphasises their high socio-economic importance to communities that border the SLLF.

The six species each experience a large and varying number of threats to their remaining adult populations. These threats include selective harvesting for fishing and construction materials, fires, forest fragmentation and degradation, and proposed mining activities. Measures to mitigate these threats suggested by communities bordering the SLLF include livelihood support to fishers and loggers; community involvement in palm monitoring and planting efforts; *dina* strengthening and awareness raising sessions; provision of alternative resources; and establishing a transparent forest management system. These research findings support community-proposed conservation actions and underscore the need for targeted livelihood interventions, improved and inclusive local forest governance systems, and open channels of communication between rural communities bordering the SLLF and large, institutional decision-makers. An action thought to have significant conservation potential, that has emerged repeatedly throughout this study, is the provision of alternative resources for fishing and construction-based livelihood activities. The primary reason for this being, that community resource zones are unable to sustain community demand for natural resources, as such, community members are driven into illegal harvesting practices. In addition to such livelihood and community-based conservation actions, research findings from this study highlight the need for urgent *in-situ* conservation measures, to prevent the harvesting of mature adult palms in protected areas, and thus prevent the very real threat of extirpation. Such measures include altering current *Polisin'ala* routes to more actively monitor mature adult palms, working closely with local stakeholders to strengthen existing forest protections, and expanding the local protected area network to encompass additional areas of key palm diversity.

The disappearance of these species would have far-reaching, negative implications for forest ecosystems across Madagascar due to the high ecological value and number of regulating and provisioning services that these six species provide, particularly to other endemic and threatened species. Significant socio-cultural and economic impacts would be felt by forest-dependent communities in Anosy and other regions of Madagascar if these palms were no longer available to support income generation and localised livelihoods strategies. Overall, this research highlights that urgent conservation action is required to prevent the expiration of these six species of palm, and the resultant negative biodiversity and socio-economic impacts.

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12. Glossary

Term	Definition
Acaulescent	Without a stem
Bifid	Divided at the tip in two
Inflorescence	The part of the plant that ears the flowers, including bracts, branches, or flowers
Infrafoliar	Where the inflorescence is borne below the leaves
Interfoliar	Where the inflorescence is borne among the leaves
Rachis	The part of the main axis next to the petiole that holds the leaflets
Nodal scar	A scar from where the leaf is attached or used to be attached
Peduncle	The lower unbranched part of a flower stalk

All references are adapted from The Kew Plant Glossary, Henk Beentje, Second Edition.