A Technical Report for

PROJECT MAHAMPY

Establishing an Ecological Baseline of the *Mahampy* Reedbeds in Sainte Luce

March 2023

Contents

Summary

This report outlines the results of research conducted as part of Project Mahampy by SEED's Conservation Research Programme (SCRP) from August 2020 until February 2023, with the following research aim: *to establish a previously unknown ecological baseline of the* mahampy *reedbeds in Sainte Luce, Madagascar.*

Growth characteristics of *mahampy,* floral biodiversity, and water attributes were monitored over time using longitudinal quadrats. Additionally, comprehensive assessments of bird, floral, and herpetofauna (amphibians and reptiles) biodiversity and water attributes present in *mahampy* wetlands were conducted using belt transects.

Across all *mahampy* reedbed sites a variety of species were present, with variation in the bird, floral, and herpetofauna species observed between wetlands. 29 bird species were recorded, with species richness varying marginally between *mahampy* reedbed sites. Floral species richness did vary between sites. This variation could not be explained by any environmental variables measured. Herpetofauna communities had neither high species richness nor abundance, with the species present largely generalists and not restricted to wetland environments. Water quality assessments were not able to yield detailed insight into wetland characteristics, with water absent for much of the study period, and limited access to calibration materials.

The results of the research have enabled SEED to gain a more holistic understanding of the *mahampy* reedbeds, their composition, potential threats, and the biodiversity they support. The results will inform SEED's continued work during Project Mahampy, with the potential to inform the development of future reedbed conservation and management plans, ensuring that they are context-appropriate, evidence-based, and supported by the existing ecological knowledge from the community of Sainte Luce.

1 Introduction

Project Mahampy aims to improve the profitability and sustainability of *mahampy* weaving as a traditional female livelihood activity in the rural community of Sainte Luce, Anosy region. Livelihood opportunities for women are limited in the southeast of Madagascar. In the Anosy region, women typically work with *mahampy* (*Lepironia mucronata*), a local reed, to weave traditional products to provide a small but vital income for their households.

Despite their economic, environmental, and cultural importance, the *mahampy* reedbeds are severely understudied. Fire, land degradation, and unregulated harvesting threatens both *mahampy* weaving as a livelihood and the existence of a variety of species and ecosystems. To ensure that the wetlands remain healthy, resilient, and productive, research was started by SEED's Conservation Research Programme (SCRP) during Project Mahampy: Phase I (2019-2022), *to establish a previously unknown ecological baseline of the mahampy reedbeds*.

Based on preliminary analysis and expert feedback, the methodology was revised in December 2021, replacing permanent quadrats with belt transects, to enable SCRP to gain a more holistic and detailed understanding of the biodiversity and environmental variables of each wetland. To gather sufficient data, the research was extended into Project Mahampy: Phase II (2022-2025), with final data used for analysis collected from August 2020 to February 2023.

This report details the context, research methods, and project findings that were used to establish an ecological baseline for the *mahampy* reedbeds and wetlands. Research will enable SEED to understand and address the drivers of decline in reedbed productivity, and contribute to global literature on wetland reedbeds of *Lepironia mucronata*, wetland management, and ecology.

1.1 Background

Freshwater ecosystems, such as wetlands, are amongst the world's most vulnerable habitats (Angeler et al., 2014). Despite covering less than 1% of the Earth's surface (Dudgeon et al., 2006; Strayer & Dudgeon, 2010), wetlands support disproportionately high levels of biodiversity (Darwall et al., 2011). However, global wetland extent has reduced by more than one third in the last 50 years (*Threats to Wetlands | WWT, n.d.*), with climate change and human activity such as agricultural clearing, infrastructure development, and fire (Kotze, 2013) primarily responsible (Hu et al., 2017; Reid et al., 2019; Weiskopf et al., 2021; Xu et al., 2019). Concurrently, declines in freshwater mammal, bird, amphibian, and coral populations have been observed (Gardner et al., 2015), with an estimated 83% reduction in all freshwater species population size globally between 1970 and 2018 (Westveer et al., 2022).

Wetlands provide ecosystem services, including supporting biodiversity, water quality improvement, carbon sequestration, and flood abatement (McInnes, 2014; Zedler & Kercher, 2005). In many parts of the world, there is a high reliance on the income that wetland habitats provide (Darwall et al., 2011). Wetland biodiversity is dependent on reliable access to good quality of freshwater (Dudgeon et al., 2006). Wetland ecological communities are influenced by the movement and qualities of the water present (Lammers et al., 2015). This reliance on water quality makes wetlands vulnerable to disturbances, such as water diversion, containment, extraction, and contamination (Dudgeon et al., 2006).

Madagascar is a global freshwater biodiversity hotspot with high levels of endemism (Benstead et al., 2003). Despite this, freshwater ecosystems in Madagascar are disappearing at a rate faster than forest habitats, with a reduction of over 60% since 1960 (Bamford et al., 2017). Primary threats to wetland health in Madagascar are conversion to agricultural land (Lammers et al., 2015), fire (Cochrane & Laurance, 2002; Kotze, 2013; Schwitzer et al., 2013), climate change, and siltation from soil erosion (Weiskopf et al., 2021).

2 Methods

SCRP conducted research across six target wetlands in Sainte Luce (24° 46’ S, 47° 10’ E) (Figure 1), using longitudinal quadrats and belt transects.

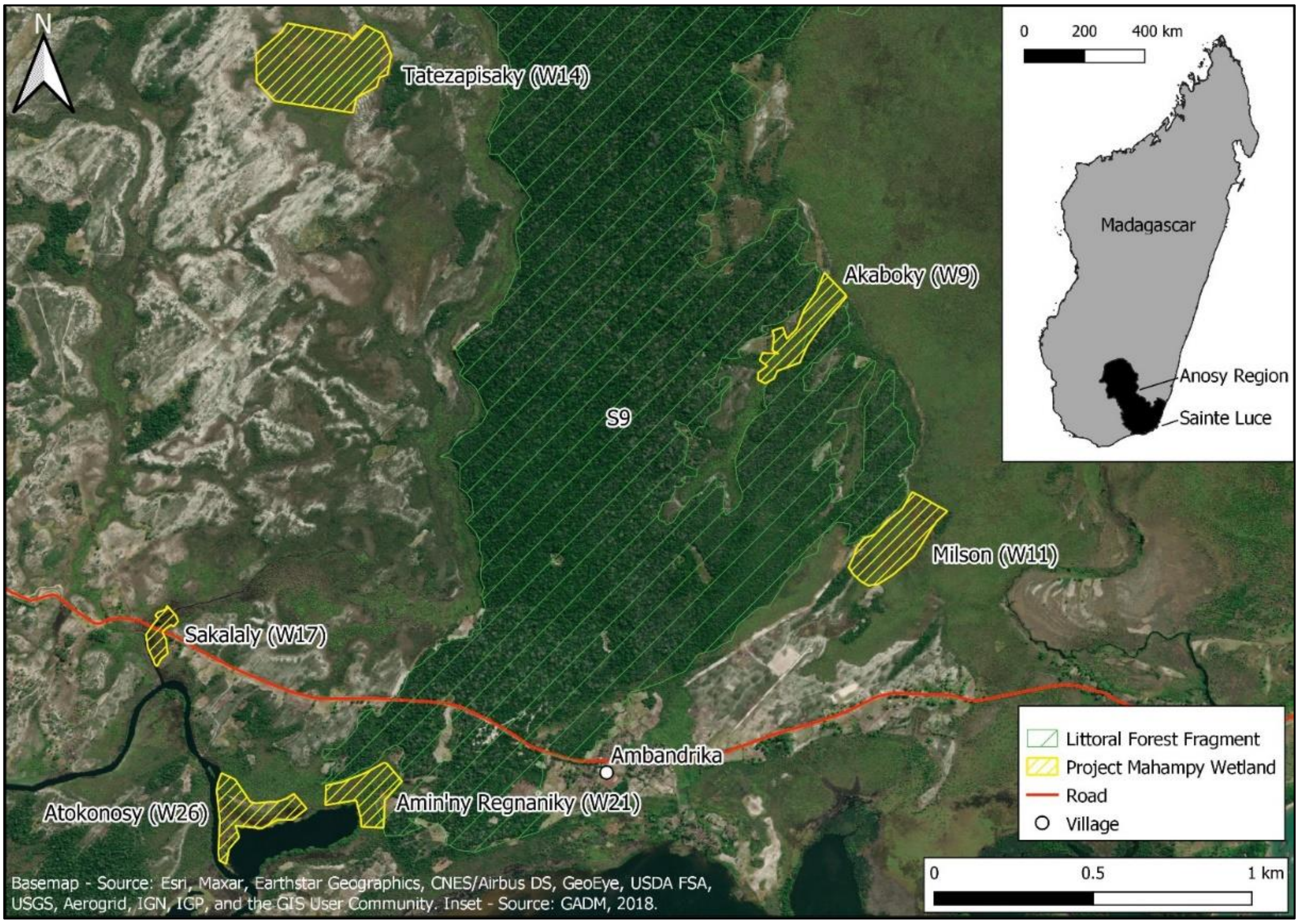

Figure 1 – Sainte Luce study site.

2.1 Longitudinal Quadrats

To gather temporal data and contribute to ecological baseline knowledge within each of the six target *mahampy* reedbeds, data were collected from three permanent quadrats measuring 1m x 1m. Two quadrats were positioned near the wetland edge, and one quadrat was placed in the interior of each target wetland, accounting for differences in habitat structure within each wetland. Assessments of floral diversity were made in each quadrat and, where possible, water quality. Measurements were taken every two months from September 2020 until September 2021. At the start of the study period, GPS coordinates were noted for each quadrat. Before each survey, the number of researchers was noted, as well as the survey start time. Time at survey end was also noted.

2.1.1 Flora

In each quadrat, all floral species present were recorded. Data collectors estimated the floral coverage of each wetland to the nearest 10%. A value of 0% was given to a quadrat with no coverage of a given species, whereas a value of 100% was given to a quadrat with complete coverage of a single species. If perceived to be less than 10%, increments of 1% were used. The condition of each species was scored on a scale of one to four. A score of one meant that the plant was dead, whilst a score of four indicated the plant was of good health, with no signs of damage. Data was collected using local Malagasy names for each species. Scientific names are currently being sought for each species and compiled into an identification guide, requiring external assistance from botanical experts. In its absence, Malagasy names are used in this report. Both percentage coverage and condition of *mahampy* was recorded, improving understanding of how *mahampy* characteristics change over time. The average height of the *mahampy* reeds were estimated based on the measurement of a stem judged to be representative of the quadrat.

2.1.2 Water

To gain a better understanding of the water quality in each of the wetlands, measurements were taken of surface water presence, water depth, algal presence, water state (e.g., fast flowing, slow flowing, stagnant), pH, colour (hue, value, chroma), and sediment level. Colour was measured by filling a jar with water from the quadrat and comparing it to Munsell system standard soil colour charts once the sediment had settled.

2.2 Belt Transects

To gain a more holistic and detailed understanding of the biodiversity found within each of the *mahampy* reedbeds, longitudinal quadrat data collection was replaced by belt transect data collection between December 2021 and February 2023. The belt transect methodology was chosen as it is a stratified sampling technique that collects information from a greater area of the wetland than permanent quadrats (Hill et al., 2005). Data was collected on the birds, herpetofauna, and flora of each wetland, alongside water quality assessments.

Transects were run in a random direction from a random point on the wetland edge. Assessments were conducted within quadrats (4m^2) 10 meters apart in larger wetlands, and five metres apart in smaller wetlands. Transects were run until ten quadrats were completed. This method allowed transects to intercept many heterogeneous micro-habitats within each wetland.

2.2.1 Birds

Bird biodiversity assessments were conducted via point counts at 08:00 prior to the start of each belt transect. Three experienced SCRP staff, equipped with binoculars, carried out the point count. All bird species that were heard or seen over a period of 25 minutes were recorded. A note was made of whether each observation was less or more than 50 metres away. Each observation was given an index number depending on when the individual was observed. A bird seen within the first five minutes of the survey was given an index number of 5, whereas a bird seen in the last five minutes was given an index number of 1. To reduce the chance of duplicated data, efforts were made to track the same individuals throughout the duration of the observation period.

2.2.2 Herpetofauna

Herpetofauna biodiversity surveys took place continuously along the length of each belt transect. This was conducted by searching for reptiles and amphibians two metres each side of the transect line, with the total strip width being four metres. When an individual was sighted, the species name, time of observation, behaviour, location, and life stage (adult, sub-adult, or juvenile) was recorded. Additionally, data was collected on the individual's height above ground (or depth below water surface) and vegetation type where it was found.

2.2.3 Flora

Floral biodiversity was assessed using the same methodology as implemented in the longitudinal quadrats (section 2.1.1) within ten-equally spaced quadrats along each transect. The average height was measured for each floral species, and average crown width was recorded for tree species within the quadrat.

2.2.4 Water

Water assessments were conducted within every other quadrat along the belt transect, for a total of five assessments per transect. When equipment became available in February 2022, salinity measurements were taken. Wetland water characteristics were assessed using the same methodology as implemented in the longitudinal quadrats (Section 2.1.2).

Shannon-Wiener diversity was calculated using the 'vegan' statistical package in R (Oksanen et al., 2013). Environmental variables were summarised, and a linear mixed-effect regression (LMER) model run to examine relationships between environmental and ecological variables.

3 Results

3.1 Longitudinal Quadrats

Each of the six target wetlands were surveyed eight times between September 2020 and November 2021, with the exception of Wetlands 21 and 26 in November 2021 due to an active fire event. With each wetland containing three quadrats, a total of 135 quadrat assessments were completed over the study period.

Due to the small sample size in each wetland, the following results are not representative of the wetlands' characteristics as a whole, but rather help inform how the area within the quadrats changed over time.

3.1.1 Flora

Floral data was collected during each of the 135 quadrat assessments. The initial values of the height and coverage of *mahampy* in each wetland are summarised in Table 1. There was no apparent trend in mean height across the study period (Figure 2), whilst mean percentage cover of *mahampy* appeared to decrease over time (Figure 3).

Table 1 – Mean and median height and coverage of mahampy *stems in the longitudinal quadrats.*

Wetland	Mean height (m)	Median height (m)	Mean coverage (%)	Median coverage (%)
Wetland 9	1.19	1.15	62.6	70.0
Wetland 11	0.89	0.90	61.7	67.5
Wetland 14	0.73	0.80	46.5	50.0
Wetland 17	1.15	1.11	79.2	80.0
Wetland 21	1.07	1.10	62.8	60.0
Wetland 26	0.99	1.00	54.7	50.0

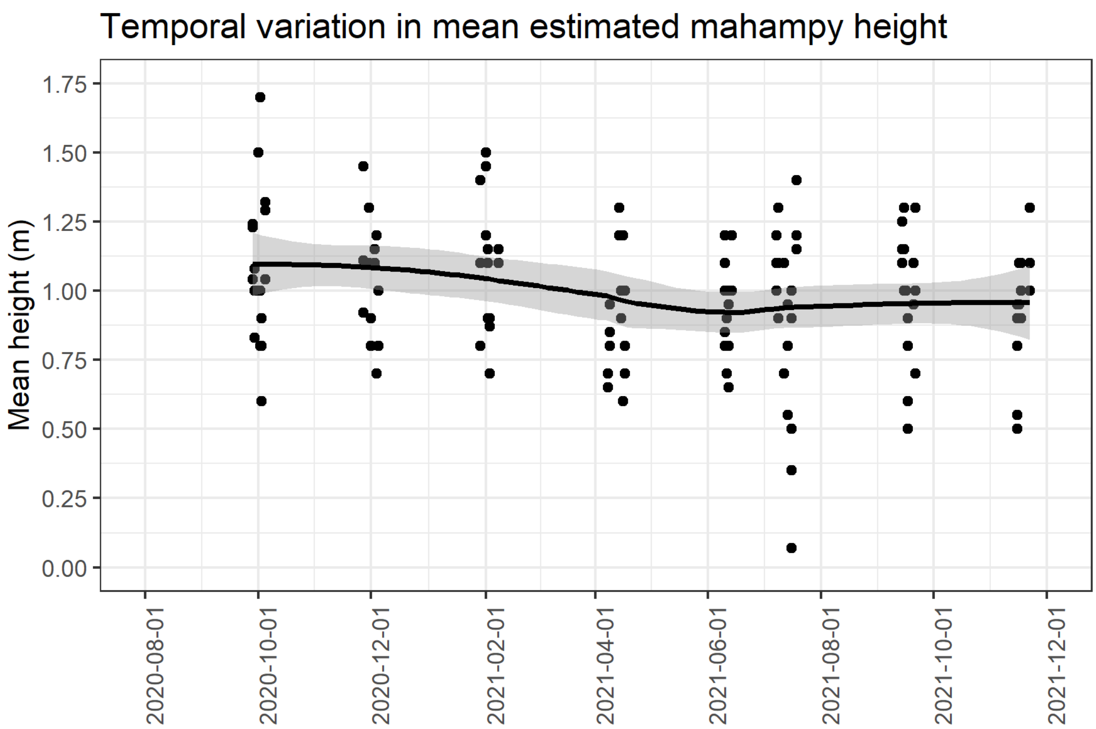

Figure 2 – Temporal variation of mean estimated mahampy *height for all wetlands between September 2020 and November 2021. Line fitted by locally estimated scatterplot smoothing (LOESS).*

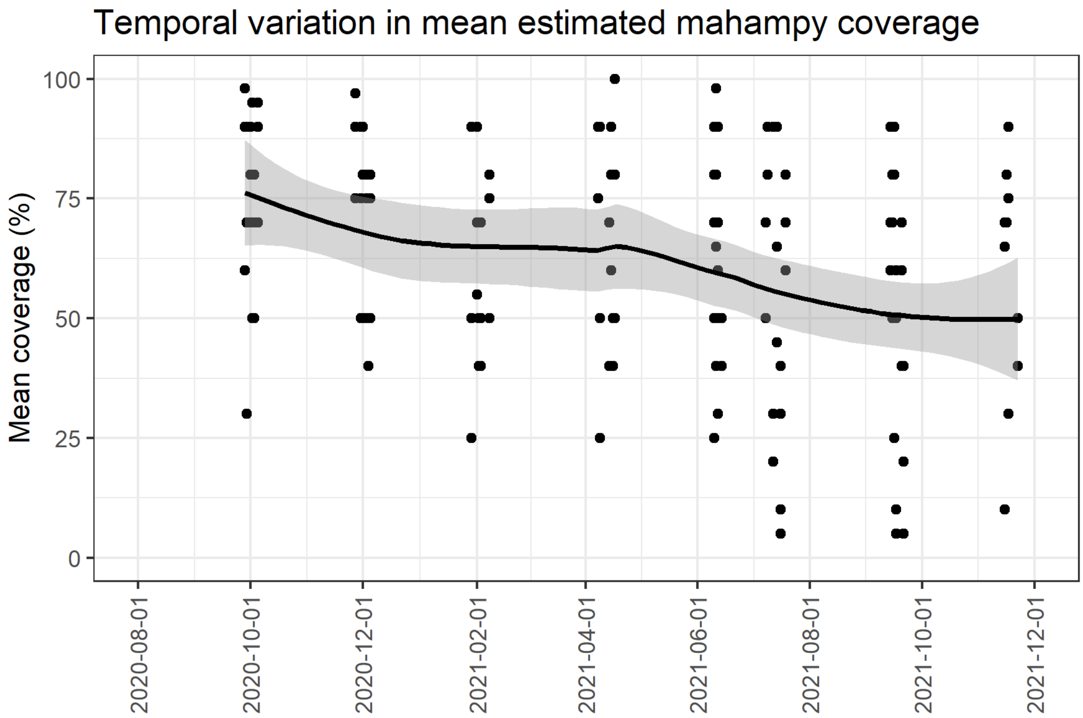

Figure 3 – Temporal variation of mean estimated mahampy coverage for all wetlands between September 2020 and November 2021. Line fitted by locally estimated scatterplot smoothing (LOESS).

Floral condition was generally high across the sample sites, with quadrats in each wetland having a mean condition score between “fair” and “good” (Table 2). Floral condition appeared to peak between July and September 2021 (Figure 4).

Table 2 – Mean and median floral condition scores of quadrats in each wetland, on a scale of one to four. Values are calculated after first calculating the mean condition score in each quadrat.

Wetland	Mean	Median
Wetland 9	3.56	3.67
Wetland 11	3.45	3.50
Wetland 14	3.35	3.18
Wetland 17	3.71	3.78
Wetland 21	3.77	4.00
Wetland 26	3.60	4.00

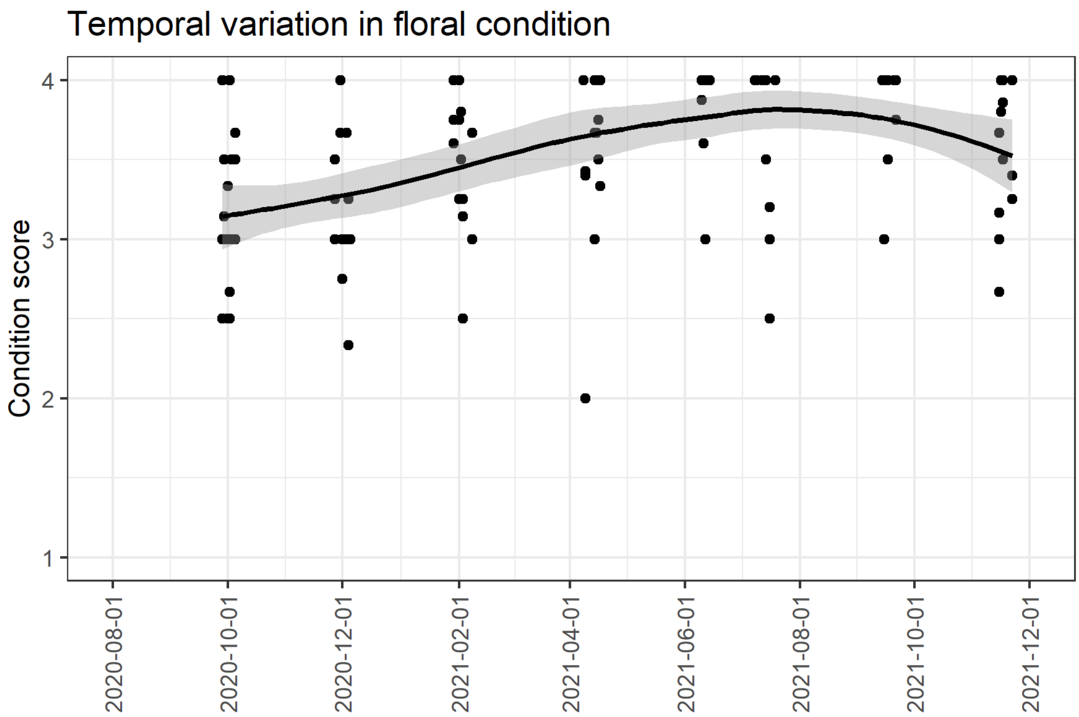

Figure 4 – Temporal variation in the mean condition score per quadrat between September 2020 and November 2021. Data is shown from all six wetlands. Line fitted by locally estimated scatterplot smoothing (LOESS).

3.1.2 Water

Water data collection was attempted during all 135 samples between September 2020 and November 2021. In 120 of these attempts, there was no surface water present to measure. At least one water survey was possible in each wetland. There was no algae cover observed in any of the wetlands. Water properties (sediment level, pH, colour hue/value/chroma) are summarised in Table 3.

*Table 3 – Summary table of water properties in each wetland. *Mean pH should be read with caution, as calibration was not able to be performed to the suggested frequency due to lack of access to appropriate equipment during this study period.*

Wetland	Quadrats with water	Date(s) water present	Mean sediment level (mm)	Mean pH*	Hue	Value	Chroma	Colour name
Wetland 9	6	14/6/2021 15/9/2021	2.83	4.18	10GY 7.5GY 5G 2.5GY	7, 8	0.83	Gray Grayish White Light Gray
Wetland 11	2	10/6/2021	3.50	3.75	7.5Y 10YR	7	5.50	Pale Yellow Yellow Orange
Wetland 14	8	5/12/2020 8/4/2021 12/6/2021	0.00	3.90	0Y 10Y 10YR	8/1, 2/1, 8/3, 1/7	1.40	Light Gray Light Gray Yellow Gray
Wetland 17	3	1/2/2021	0.17	6.07	10YR	1/7	1.00	Black
Wetland 21	3	11/6/2021	1.67	3.87	10BG 5B 2.5Y	7, 8	1.00	Light Bluish Gray Light Gray
Wetland 26	1	11/6/2021	1.00	4.20	5YR	8/2	2.00	Yellow

3.2 Belt Transects

Between December 2021 and May 2022 seven surveys were carried out in each of the six target wetlands, with the exception of Wetland 17 and 26 in December 2021 due to fire. In total, 40 belt transect surveys were conducted, encompassing 400 quadrats. During each survey, a floral biodiversity assessment, water assessment, bird biodiversity survey, and herpetofauna biodiversity survey were conducted. A total of 35 bird, 13 herpetofauna, and 73 floral species were observed across all study sites (Annex 1).

3.2.1 Mahampy

Mahampy height, coverage, and condition varied across the target wetlands (Table 4), with Wetland 9 demonstrating the highest mean height (Figure 5). Wetland 17 demonstrated the highest mean coverage (Figure 6), whilst Wetland 17 and 26 demonstrated the highest mean condition (Figure 7). Wetland 14 exhibited the lowest coverage, in addition to one of the lowest condition scores of all target wetlands.

Table 4 – Mean and median height, coverage, and condition of mahampy *stems in the belt transects.*

Wetland	Mean height (cm)	Mean coverage (%)	Mean condition score
Wetland 9	104.00	37.27	2.48
Wetland 11	83.64	34.14	2.39
Wetland 14	76.59	9.58	2.36
Wetland 17	65.72	45.20	3.16
Wetland 21	93.34	41.54	2.56
Wetland 26	64.03	34.75	3.16
Total	81.22	33.75	2.75

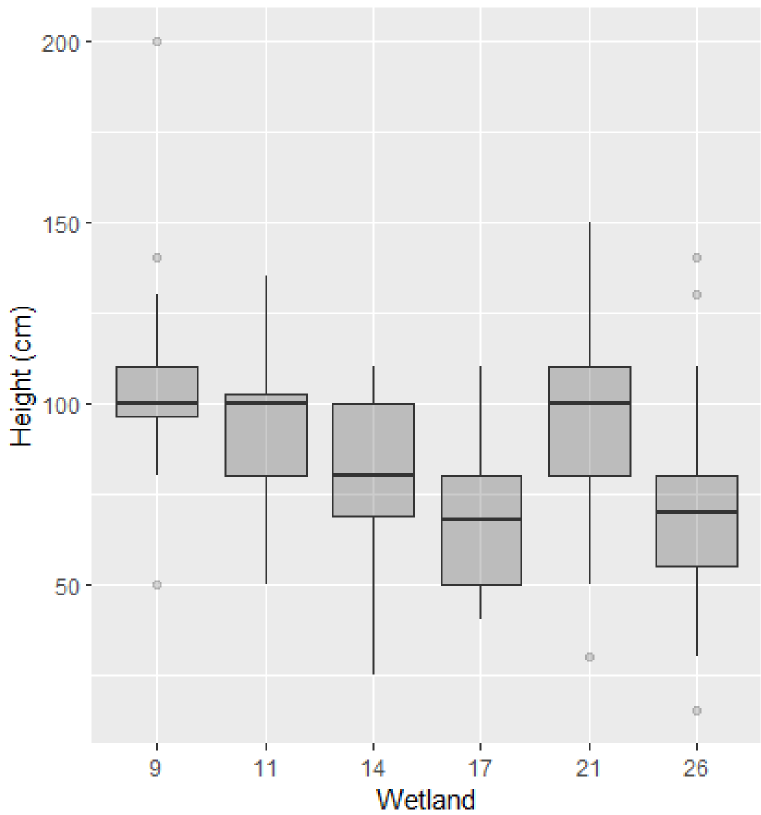

Figure 5 – Boxplot showing height of mahampy *stems in the belt transects.*

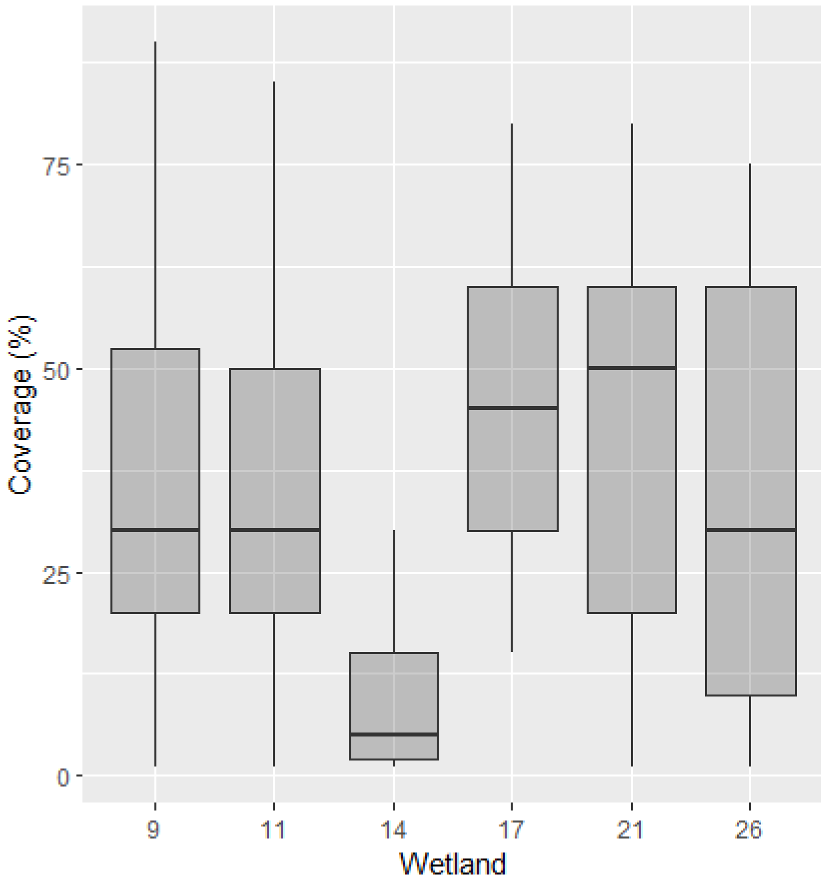

Figure 6 – Boxplot showing estimated coverage of mahampy *stems in the belt transects.*

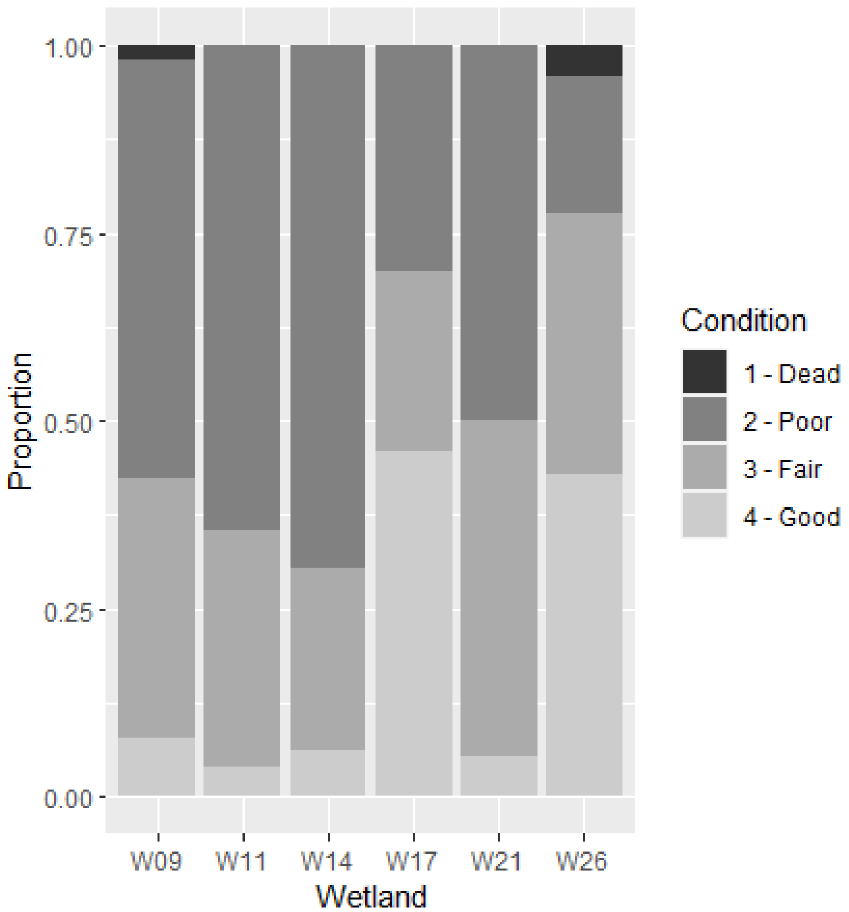

Figure 7 – Proportion of mahampy *stems for each condition score.*

3.2.2 Flora

The floral community composition was similar in each wetland, comprised of primarily grass, shrub, and moss species. Grasses, including *mahampy,* and mosses were the dominant vegetation type, with trees, shrubs, ferns, and vines constituting a much smaller proportion of the ecosystem (Figure 8). Wetland 14 is notable in its high coverage of non-*mahampy* grasses and relatively low *mahampy* coverage, whilst Wetland 11 had a relatively high proportion of tree species. Wetland 17 had barer ground and lower overall vegetation coverage than the other wetlands.

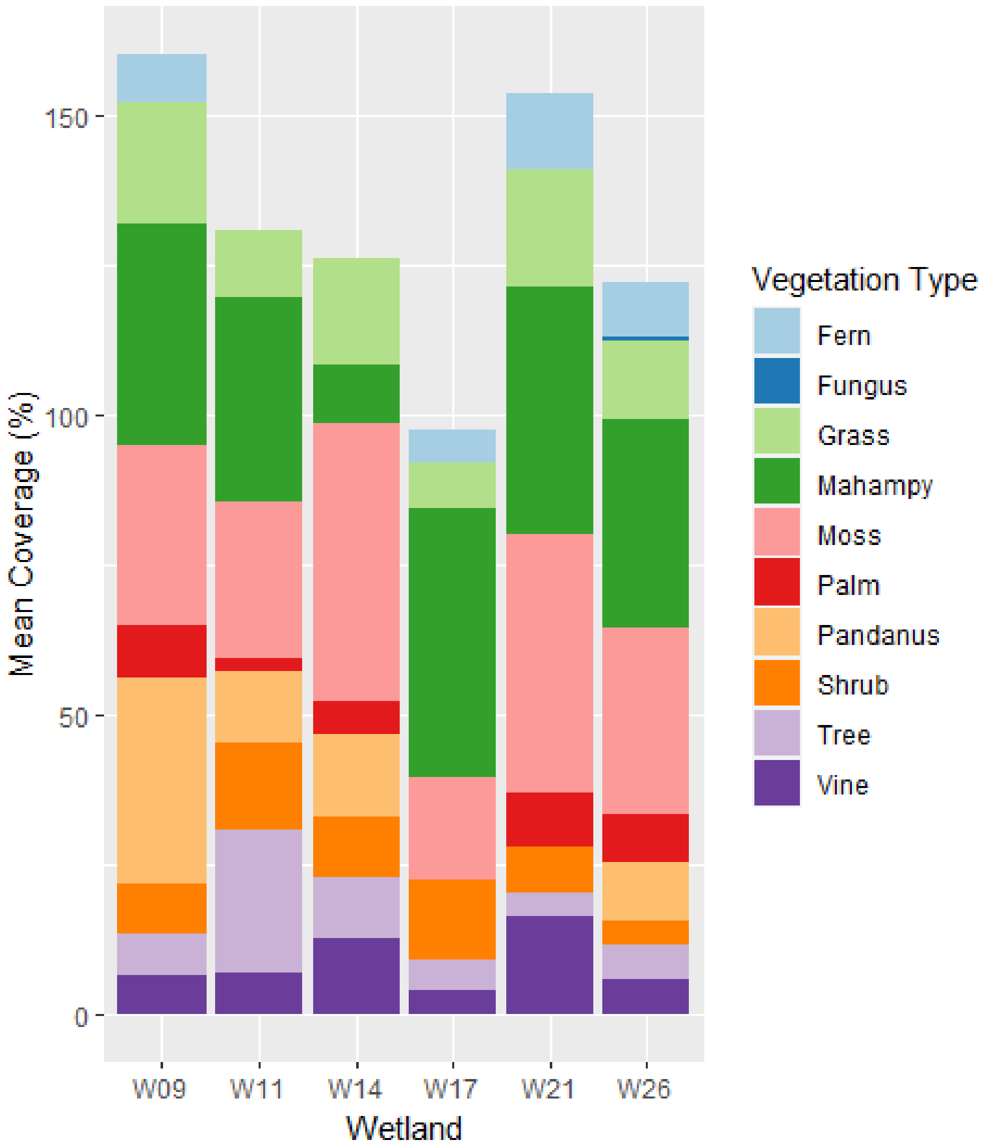

Figure 8 – Mean coverage of each vegetation type in the belt transects. Due to spatial overlap of species within the same quadrat, total coverage can exceed 100%. Bare ground and/or water were considered as having no floral species present.

Floral condition was relatively consistent across the wetlands, with most floral species in all wetlands receiving a score of 2 (Poor) or 3 (Fair) (Figure 9). Wetlands 9, 17, and 26 contained the highest proportions of floral species rated as 4 (Good) with over a quarter of all species receiving this score.

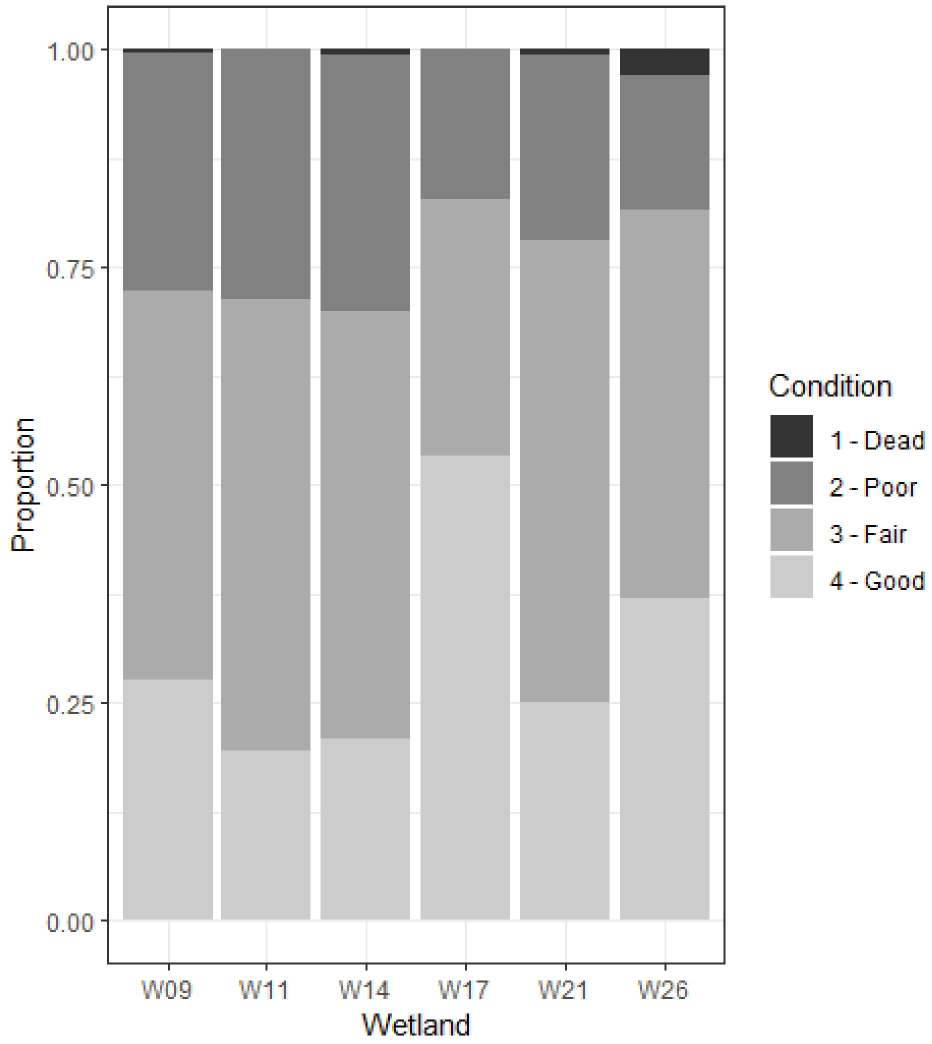

Figure 9 – Proportion of floral species in each wetland shaded according to condition.

Similarity in floral communities was assessed between the six wetlands using Jaccard similarity index. Floral communities between wetlands were largely similar, with between 47-78% similarity observed. Wetland 11 and Wetland 17 (J=0.7802198 (78.02%)), Wetland 14 and Wetland 17 (J=0.7802198 (78.02%)), and Wetland 17 and Wetland 21 (J=0.7802198 (78.02%)) were the most similar (Table 5). High degrees of similarity were due to the presence of grass (e.g., *mahampy*), shrub (e.g., *akatafotsy* and *marefifolahy*) and moss (e.g., *randrandrano*) species common to the four wetlands. The floral community in Wetland 11 and Wetland 14 were the least similar, at 47.42%. This can be attributed to a greater abundance of grass (e.g., *ahipoly*, *forimbato* and *vendra*) and shrub (e.g., *takotry*) species in Wetland 14 that were either less abundant or not present at all in Wetland 11.

Table 5 – Jaccard similarity coefficients for floral communities in each wetland. Jaccard similarity coefficient of 1 indicates identical communities. Jaccard similarity coefficient of 0 indicates non-identical communities.

	Wetland 9	**Wetland 11**	**Wetland 14**	**Wetland 17**	**Wetland 21**	**Wetland 26**
Wetland 9	-	-	-	-	-	-
Wetland 11	0.6745562	-	-	-	-	-
Wetland 14	0.5794574	0.4742857	-	-	-	-
Wetland 17	0.6885965	0.7802198	0.7760943	-	-	-
Wetland 21	0.5142232	0.6491863	0.5849387	0.7253788	-	-
Wetland 26	0.5306554	0.6471631	0.6243740	0.6108871	0.5077519	-

Further inspection of the flora present in each wetland revealed different species with the same vernacular name were present in all wetlands. At least two species of *akatagiso* (grass), two species of *ambora* (tree), two species of *forimbato* (sedge), two species of *rementso* (vine), four species of *vendra* (grass), two species of *votrotroky* (shrub) (Figure 10), and two unknown species were identified, with more species likely needing formal identification. At least 84 species of plant have now been identified, with further species classification ongoing.

Figure 10 – Photographs of leaves and flowers of two different Votrotroky *species (*Votrotroky *1 top left and bottom left;* Votrotroky *2 top right and bottom right).*

3.2.3 Birds

Most of the 35 bird species sighted or heard in the wetlands were recorded multiple times, with the number of individuals varying per wetland. Souimanga sunbird was the most frequently observed species (*n*=251), with Lesser vasa parrot (*n*=79), Common myna (*n*=67), and Malagasy green sunbird (*n*=51) also often sighted (Annex 1). Wetland 14 had the highest number of individual records, and Wetland 26 the least (Figure 11). The bird community composition between the wetlands was similar, though some species were more abundant in certain wetlands. Wetland 17 appeared to have a unique bird community composition, with a greater occurrence of species such as Madagascar bush lark, Madagascar malachite kingfisher, and Madagascar red fody.

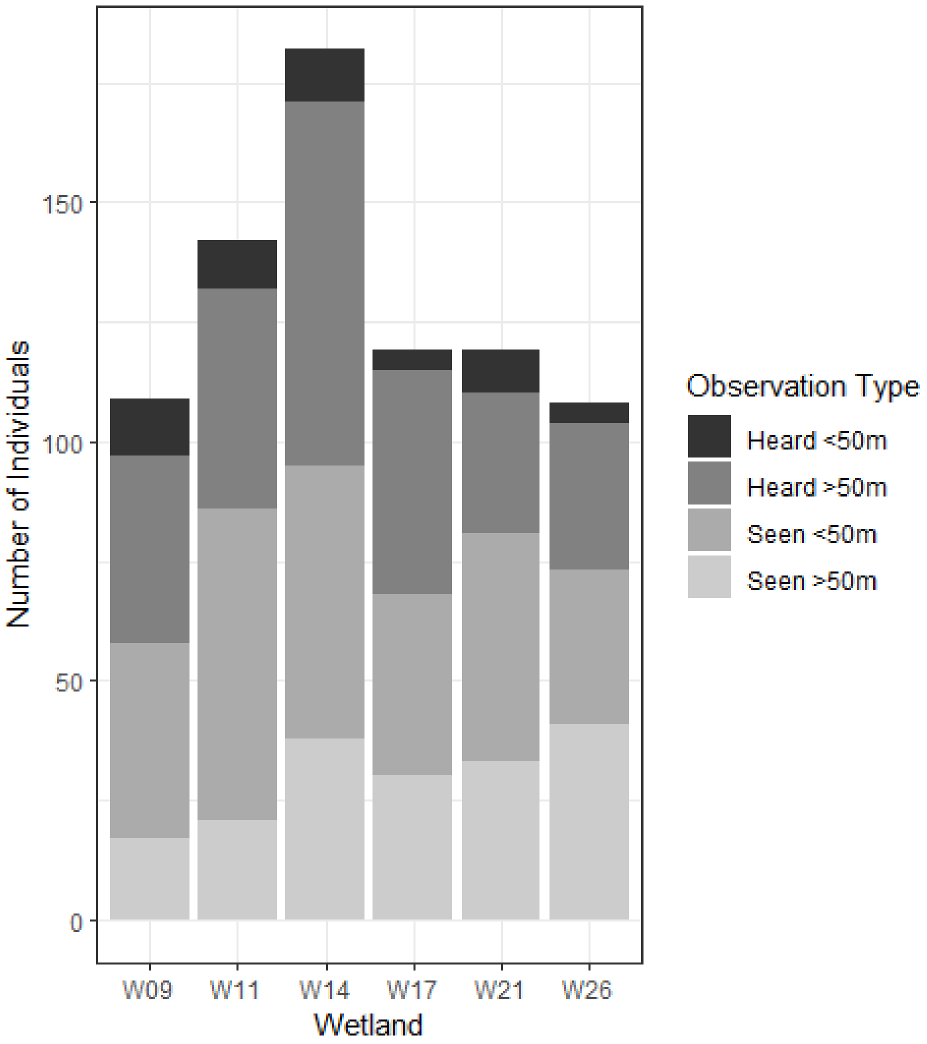

Figure 11 – Number of bird observations per wetland

Bird communities between wetlands were dissimilar, with between 28.39-57.01% similarity observed. The bird communities in Wetland 9 and Wetland 17 (*J*=0. 5701754 (57.01%)) and Wetland 17 and Wetland 21 (*J*=0.5462185 (54.62%)) were the most similar (Table 6). Wetland 11 and Wetland 14 had the least similar bird communities (*J*=0.2839506 (28.39%)).

Table 6 – Jaccard similarity coefficients for bird communities in each wetland. Jaccard similarity coefficient of 1 indicates identical communities. Jaccard similarity coeffiecient of 0 indicates non-identical communities.

	Wetland 9	**Wetland 11**	**Wetland 14**	**Wetland 17**	**Wetland 21**	**Wetland 26**
Wetland 9	-	-	-	-	-	-
Wetland 11	0.3545817	-	-	-	-	-
Wetland 14	0.4364261	0.2839506	-	-	-	-
Wetland 17	0.5701754	0.4176245	0.4750831	-	-	-
Wetland 21	0.3508772	0.3409962	0.4285714	0.5462185	-	-
Wetland 26	0.3425926	0.3092369	0.3287197	0.4690265	0.3362832	-

3.2.5 Herpetofauna

The herpetofauna community of the wetlands is comprised of a relatively small number of generalist species and were not found to be particularly rich or abundant. The greatest herpetofauna species richness (*S*) and abundance was found within Wetland 9 (*S*=10) whilst Wetlands 14 (*S*=6) and 17 (*S*=5) were found to have the least. A total of 13 different species were observed within all of the wetlands (Annex 1), including three species of snake (*Dromicodryas bernieri* , *Ithycyphus oursi,* and *Mimophis mahfalensis*), four species of frog (*Blommersia blommersae, Heterixalus boettgeri*, *Mantidactylus tricinctus,* and *Ptychadena mascareniensis*), three species of day gecko (*Phelsuma lineata, P. modesta,* and *P. parva*), one species of chameleon (*Furcifer lateralis*), and two species of skink (*Trachylepis elegans* and *T. gravenhorstii*).

Similarity between wetland herpetofauna communities varied, with between 47.34-80.15% similarity observed. The herpetofauna communities of Wetland 9 and Wetland 17 (*J*=0. 8015267 (80.15%)), Wetland 17 and Wetland 21 (*J*=0.7692308 (76.92%)), and Wetland 14 and Wetland 17 (*J*=0.7278912 (72.79%)) had the greatest similarities (Table 7). Wetland 9 and Wetland 11 had the least similar herpetofauna communities (*J*=0.4734513 (47.35%)).

Table 7 – Jaccard similarity coefficients for floral communities in each wetland. Jaccard similarity coefficient of 1 indicates identical communities. Jaccard similarity coefficient of 0 indicates non-identical communities.

	Wetland 9	Wetland 11	Wetland 14	Wetland 17	Wetland 21	Wetland 26
Wetland 9	-	-	-	-	-	-
Wetland 11	0.4734513	-	-	-	-	-
Wetland 14	0.6007605	0.4888060	-	-	-	-
Wetland 17	0.8015267	0.6951673	0.7278912	-	-	-
Wetland 21	0.4830918	0.4805195	0.6148148	0.7692308	-	-
Wetland 26	0.6326531	0.6119403	0.5477941	0.6934866	0.6250000	-

3.2.6 Species Richness and Diversity

Wetland 26 had the highest levels of species richness (*S*=63). Wetland 11 was found to be the least species-rich (*S*=38). Wetland 21 had the greatest overall Shannon-Wiener diversity index (*H’*=3.398074) whilst Wetland 9 was found to have the lowest overall diversity index (*H’*=3.037440) (Table 8).

Table 8 – Summary of bird, floral, and herpetofauna species richness (S) and Shannon-Wiener Diversity (H’) calculated from belt transect survey.

Wetland	Bird – *S*	Bird – *H’*	Flora – *S*	Flora – *H’*	Herp. – S	Herp. – *H’*	Overall – S	Overall – *H’*
9	18	2.181474	25	2.559176	10	1.4224159	43	3.037440
11	14	2.151621	24	2.586011	7	1.2272419	38	3.055963
14	19	2.320636	22	2.713221	6	1.2211757	41	3.204878
17	22	2.450710	30	2.757989	5	0.5981326	52	3.269091
21	20	2.344818	40	3.005628	7	1.3323361	60	3.398074
26	18	2.046463	44	3.087143	8	1.6781977	63	3.383646
Total	35	-	73	-	13	-	-	-

3.2.7 Water

Water assessments were completed between December 2021 and February 2023 to account for differences in water presence and quality because of seasonality. Across all six wetlands, 420 assessments were completed. Of these, water was observed in 209 quadrats and absent from 211 quadrats.

Water presence in the wetlands varied spatially and temporally, with little water observed during the height of the dry season in 2022 (July-November). Wetland 17 was observed to be the most saline (0.28ppt). Mean salinity values between the five remaining wetlands were low. Wetland 11 had the most acidic water (pH 4.72), with Wetland 21 comparatively more acidic (pH 4.84) than the other four wetlands. Wetland 17 was the least acidic of the wetlands sampled (pH 6.04). Wetland 9 was the deepest of the six wetlands (10.76cm), while Wetland 21 was the shallowest wetland (5.53cm). Wetland 21 had the greatest sediment load, with 3.01mm of sediment settling in each sample. Wetland 14 had the lowest sediment load (0.87mm). Algae cover was generally low across the six wetlands, however, Wetland 11 had the greatest percent coverage (Table 9).

Table 9 – Summary of environmental variables (water pH, water salinity, water depth, and sediment level) collected during the belt transect data collection. Mean pH should be read with caution. Calibration was not able to be performed to the suggested frequency due to lack of access to appropriate equipment at the beginning of the study period. Outlier values produced by malfunctioning equipment removed from dataset.

Wetland	***n***	**Mean water salinity (ppt)**	**Mean water pH**	**Mean water depth (cm)**	**Mean sediment level (mm)**	**Mean algae cover (%)**
W9	48	0.05	5.29	10.76	2.36	0.00
W11	28	0.04	4.72	5.59	1.57	4.31
W14	33	0.04	5.25	9.50	0.87	1.82
W17	32	3.23	6.04	7.09	1.31	1.56
W21	36	0.04	4.84	5.53	3.01	0.42
W26	32	0.28	5.36	6.42	1.33	1.00
Total	209	0.57	5.27	7.73	1.80	1.49

Each variable was tested for normality prior to further analysis using a Shapiro-Wilk test. All variables were found to be normally distributed ($p<0.05$). An LMER model was used to assess the degree to which the collected environmental variables could explain the variation seen in two response variables; total species richness and overall Shannon-Wiener diversity index. The "lme4" package in R was used to achieve this (Bates et al. 2011, R: The R Project for Statistical Computing, n.d.). The wetland location variable was added to the model as a random effect, while water salinity, water pH, depth, sediment level, and percent algae cover were treated as fixed effects. Water pH (*t[159]=-2.61313, Std. Error=0.02472573, p=0.0019*) and salinity (*t[159]=3.15998, Std. Error=0.02063993, p=0.0064*) were found to influence total species richness, but only minimally so. No other variables significantly related to species richness. No significant relationships between overall Shannon-Wiener diversity and the independent variables were observed.

5 Discussion

The data collected provides a picture of the biodiversity and hydrological characteristics of the *mahampy* reedbeds, enabling SCRP to describe the wetlands in the area and to begin examining their differences. Floral, bird, and (to a lesser extent) herpetofauna communities were described for each wetland, and an understanding of species richness gained. Correlating environmental variables to floral growth characteristics and biodiversity proved challenging, with most variables lacking clear relationships with other data collected. Though the collected data were unable to uncover the drivers behind differences in the wetlands, combined with local knowledge, the descriptions of the *mahampy* reedbeds provide important site-specific context for wetland conservation or management strategies.

5.1 Longitudinal Trends

Both longitudinal quadrats and belt transects were able to track wetland variables over time, with longitudinal quadrats spanning a longer period but covering a smaller wetland area. Mean height of *mahampy* was not found to vary throughout either study period, though mean coverage did decline in the longitudinal-specific quadrats (sections 3.1.1 and 3.1.2). Though this may point to low variation in *mahampy* characteristics, it should be noted that prior to December 2021, a severe drought gripped the Sainte Luce area. From December 2021 through the end of the study period, irregular rainfall had persisted and may have obscured trends that would otherwise be seen in 'regular' seasonal cycles. Extremes in weather patterns are expected to intensify, with climate change leading to more frequent droughts and cyclones (Weiskopf et al., 2021). Continued data collection could reveal long-term trends that may not have been captured within this shorter and finer-scale study.

5.2 Wetland Biodiversity

Belt transects were able to shed light on species richness and diversity in the wetlands, with a focus on bird, herpetofauna, and floral diversity. Supplemental information on the surrounding habitat has also been added for context, collected through researcher observations.

5.2.1 Birds

Bird species observed were largely generalist (e.g. Black swift, Pied crow, and Common myna), forest-dwelling (e.g. Hook-billed vanga and Madagascar coucal) or grassland-dwelling (e.g. Common jerry and Madagascar cisticola). Waterbird species were observed, such as the Madagascar malachite kingfisher, Purple heron, and White-faced whistling duck, however, far less frequently. Many of these species observations, with the exception of the waterbirds, are thought to be largely a result of each wetland's proximity to a large littoral forest fragment, rather than the wetland providing primary habitat for foraging, nesting, or other purposes. To better understand how biodiverse the *mahampy* reedbeds are relative to other ecosystems in Sainte Luce (e.g. littoral forest, degraded littoral forest, grassland, or agricultural land), further research into the spatial distribution of Sainte Luce's avian community is needed.

5.2.2 Herpetofauna

Similar to the bird species recorded, the observed herpetofauna species were largely generalists, and not specific to wetland environments. Some species, such as *Trachylepis sp.*, *D. bernieri*, and *M. mahfalensis*, are particularly well adapted to drier habitats such as grassland and scrubland. However, the *mahampy* reedbeds do provide an important habitat for amphibian species, particularly *B. blommersae*, *H. boettgeri*, and *M. tricinctus*. The limited herpetofauna diversity in the wetlands could be a consequence of limited habitat heterogeneity, high levels of exposure (e.g. few or no large tree canopies present), or relative dryness. It is not possible to say with certainty whether these anecdotal descriptions cause these observations. All surveys were completed during the day, with nocturnal herpetofauna species unable to be assessed.

5.2.3 Floral and Environmental Characteristics

Floral species were generally uniform across the wetlands (section 3.2.2), though characteristics such as condition and coverage did vary. For both *mahampy* and floral species, Wetland 26 had one of the highest and most varied overall condition. Wetland 26 also supported the highest species richness and highest diversity index (section 3.2.5). Within Wetland 26, there exists habitat heterogeneity, likely a result of the nearby river, some lightly forested areas in the eastern part of the wetland, and sections of the wetland that are recovering from fire. These different microhabitats are characterised by different floral communities. Recently burnt areas had a higher abundance of fast-growing species such as grasses (e.g., *mahampy*, *tsiboradrano*, and *tsitokotoko*), whereas the more forested areas contained tree species such as *lalo* and *ravenala*. It is possible that high habitat heterogeneity may have supported more diverse floral communities, though again no significant predictor variables were found.

5.2.4 Additional Observations

Wetlands 14 and 17 were observed to have several unique characteristics. Wetland 14 had low values for multiple *mahampy* characteristics, namely mean coverage and condition (section 3.2.1). Wetland 14 also had a unique floral community including a high proportion of non-*mahampy* grasses (section 3.2.2), the highest number of individual bird records (section 3.2.3), and the lowest sediment load (section 3.2.6). With regards to observed characteristics, Wetland 14 is covered in small pools that collect rainwater, and a collection of small freshwater streams pass through the wetland. During transects, most of the water sampling took place within the small rainwater pools, which are inherently less turbid. While significant correlations between *mahampy* growth characteristics and environmental variables were not observed, it is worth exploring further what factors may influence the relatively low presence and lower quality of *mahampy.*

Wetland 17 was particularly anomalous, with a different floral and bird community composition than other wetlands (sections 3.2.2 and 3.2.3). Whilst Wetland 17 had the barest ground, it contained the highest relative percentage cover of *mahampy* and a high condition of floral species present. When correlations between species richness, diversity, and environmental variables were modelled, no meaningful relationships were observed. Several species were observed within the wetlands that appear better suited to wetter conditions. Species observed in Wetland 17, such as *mahampy*, *sofimbolavo*, and *sonjokoaky*, are frequently found in wet environments. The high abundance of such species in Wetland 17 potentially indicates this, however, as this study did not focus on the local fluvial regime and the specific effects it may have on wetland biodiversity, more targeted research is required to prove this. Furthermore, due to seasonality of rain events, the total number of water samples made in each wetland were unequal and low in number. Consequently, accurate conclusions cannot be made regarding overall water quality in each wetland, nor the relationship between water quality and species richness or abundance.

The examined wetlands contained water with low salinity and turbidity, were acidic, and were fairly shallow. Water salinity, depth, and sediment load are factors that influence wetland floral assemblages. Saline water can be damaging to some plants, particularly those that are adapted to fresh water. Increased salinity can alter biomechanical properties (Zhu et al., 2020) and affect the ability of the wetland to perform ecosystem services (Herbert et al., 2015). Water depth is known to influence the cover and structure of wetland plant communities (Langer et al., 2018; Seabloom et al., 1998). Whether carried in suspension or deposited, sediment can inhibit a plant's access to sunlight and ability to photosynthesize. One possible explanation of the unique characteristics of Wetland 17 is its location compared to the other target wetlands. Wetland 17 is located alongside a freshwater river influenced by the tide, and it is regularly inundated by river water during periods of high tide and/or recent rainfall within the catchment. The other five target wetlands are each fed by water sources including smaller streams, pools of rainwater, and (in the case of Wetlands 21 and 26) rivers themselves. However, these five wetlands are not flooded to the same extent and frequency as Wetland 17. The frequency and duration of water cover over the wetland may influence which floral species are present.

Wetlands 9, 11, and 21 also exhibited unique characteristics that differentiate them from the other wetlands, further contributing to the understanding that *mahampy* reedbeds can be extremely varied. Wetlands 9 and 21 had relatively tall and healthy *mahampy* reeds that are favoured for *mahampy* weaving (section 3.2.1). Wetland 21 had very high floral coverage, with species present having high overlap and very little, if any, bare ground present. Wetland 11 was average with regards to most of the metrics measured, however, it had the highest proportion of tree species present and one of the shallowest water depths; factors which may be related.

5.2.5 Synthesis

It is likely that these factors – water presence and quality, sediment load, bird species, herpetofauna species, and floral community composition and coverage – influence each other and the *mahampy* present, though these ties were not able to be explained statistically with the data available. Natural variation across wetlands supported different ecological communities, as well as variations in *mahampy* characteristics, with wetlands overall supporting generalist faunal species and providing additional habitat for a number of forest-dwelling species. Taken together, there was no clear relationship between wetlands that supported favourable *mahampy* characteristics for weaving (tall reeds, high reed coverage, and healthy reed condition) and their environmental variables, including species richness, diversity, and community composition. As such, the scope of this research and collected data were not able to identify what characteristics denote a healthy wetland, but rather, data showed that there exists a variety of wetland types in the study area which are all influenced by a complex suite of interacting variables.

5.3 Conservation Recommendations

Research conducted during Project Mahampy: Phase I sought to understand the ecological and environmental characteristics of the *mahampy* reedbeds in Sainte Luce. The findings from this research and wider observations point towards several broad recommendations for the conservation of this ecosystem.

Sainte Luce's *mahampy* reedbeds are unique, providing refuge for an array of floral species as well as threatened species, including the Endangered Meller's duck (*Anas melleri*) (BirdLife International, 2021; Goodman et al., 1997). Wetland ecosystems such as the *mahampy* reedbeds also provide multiple ecosystem services which benefit local dependent communities. However, Sainte Luce's *mahampy* reedbeds are threatened by climate change and anthropogenic activities, primarily in the form of proposed local sand mining operations by QIT Madagascar Minerals (QMM).

While the findings of this research do not prove this, observed stress brought by changing environmental conditions (e.g., shorter rainy season duration and drier conditions) will cause the wetlands, and associated plant species such as *mahampy*, to become dry and increasingly susceptible to events such as fire. Water presence within *mahampy* reedbeds is seasonal (Eppley et al., 2015) and *mahampy* is able to exist without persistent inundation from local freshwater sources. However, the degree to which local seasonality has changed and conditions have become drier is a concern for *mahampy* reed survival and growth, as well as the general wetland ecosystem. With future drought events predicted to become more frequent and longer in duration (Weiskopf et al., 2021), these observed patterns may worsen. It is therefore recommended that site-specific wetland management strategies that account for the future effects of drought and fire are considered.

Proposed mining operations by QMM in the Sainte Luce area would significantly affect local water quality, likely increasing radionucleotide (e.g., thorium and uranium) and lead content within local freshwater ecosystems (Emerman, 2019; Emerman 2020; Harbinson, 2007). In combination with the physical impacts associated with this mining technique, increased radioactivity, disruption to local freshwater regimes, destruction of habitat, and other associated impacts would have detrimental impacts for ecosystems and communities alike.

6 Conclusion

During Project Mahampy: Phase I, SCRP began holistic research to generate a baseline understanding of the *mahampy* reedbed environment and the biodiversity it supports, whilst gaining a deeper insight into the hydrological characteristics of the wetlands.

Whilst no causal relationships can be established, the six target wetlands studied varied in their bird, floral, and herpetofauna community composition. *Mahampy* condition, height, and coverage were also examined, and varied across wetlands. No variables were identified to predict where 'high quality' *mahampy* may occur. With little literature existing on *mahampy* reedbeds, the results of research carried out as part of Project Mahampy have provided key descriptive accounts of wetlands in the region. Gaps in knowledge were identified, with areas for further research defined, that will be used to improve the sustainable management and conservation of *mahampy* reedbeds in Sainte Luce.

Project Mahampy: Phase II is employing a participatory monitoring approach, with weavers from Sainte Luce currently assessing the effects of fire and harvesting techniques on *mahampy* regrowth. Participatory monitoring by the weavers will be complemented by aerial surveys to monitor landscape-scale changes in the wetland condition and resource availability. With support from SCRP, research findings will be used by the Mahampy Weavers' Cooperative to inform an integrated reedbed management strategy, protecting both the reedbeds and the sustainability of *mahampy* weaving as a women's livelihood.

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8 Appendix

8.1 Annex 1 – Wetland Species Inventory

Bird Species							
Species	**Wetland 9**	**Wetland 11**	**Wetland 14**	**Wetland 17**	**Wetland 21**	**Wetland 26**	**Total**
Black Swift	5	7	1	7	11	3	34
Blue Coua	0	0	0	0	1	0	1
Blue Pigeon	3	0	0	1	7	1	12
Common Jerry	11	8	8	1	8	0	36
Common Myna	0	17	11	28	1	10	67
Crested Drongo	1	0	0	1	0	0	2
Green Pigeon	0	3	2	1	4	4	14
Grey-headed Lovebird	0	6	2	0	2	1	11
Helmeted Guineafowl	0	0	0	0	0	1	1
Hook-billed Vanga	8	4	9	2	3	4	30
Lesser Vasa Parrot	5	9	25	6	15	19	79
Madagascar Bee-eater	0	1	4	3	2	0	10
Madagascar Bulbul	0	0	1	0	2	0	3
Madagascar Bush Lark	0	0	17	13	0	2	32
Madagascar Buzzard	2	0	1	1	1	0	6
Madagascar Cisticola	1	10	22	8	1	1	43
Madagascar Coucal	7	9	6	3	10	4	39
Madagascar Crested Ibis	1	0	0	0	0	0	1
Madagascar Kestrel	0	0	0	2	0	0	2
Madagascar Malachite Kingfisher	0	0	0	4	0	1	5
Madagascar Mannequin	6	0	0	0	0	0	6
Madagascar Paradise Flycatcher	0	0	0	1	0	0	1
Madagascar Pranticole	0	0	0	0	6	0	6
Madagascar Rail	0	0	0	1	0	0	1
Madagascar Red Fody	0	2	0	6	1	1	10
Madagascar Turtle Dove	2	1	0	0	0	0	3
Malagasy Green Sunbird	5	15	21	3	2	5	51
Malagasy White-eye	0	0	0	1	0	0	1

Pied Crow	0	0	2	0	2	0	4
Purple Heron	0	0	1	0	0	2	3
Souimanga Sunbird	45	50	47	25	39	45	251
Sunbird sp.	3	0	0	0	0	1	4
White-faced Whistling Duck	2	0	1	0	0	1	4
White-throated Rail	2	0	1	1	0	1	4
Yellow-billed Kite	0	0	0	0	1	0	1
Floral Species							
Species	**Wetland 9**	**Wetland 11**	**Wetland 14**	**Wetland 17**	**Wetland 21**	**Wetland 26**	**Total**
Acacia	0	0	0	4	0	0	4
Ahipatra	0	38	21	0	0	0	59
Ahipoly	52	10	35	28	46	45	216
Akatafotsy	1	46	27	0	3	6	83
Akatagiso	0	0	0	5	0	8	13
Ambanivoa	0	0	0	0	4	4	8
Ambora	0	0	0	0	1	3	4
Angama	0	2	0	1	1	5	9
Azavidy	0	0	7	0	0	0	7
Bamby	0	0	0	0	2	0	2
Belataky	0	0	1	0	0	0	1
Beloha	9	0	0	1	6	2	18
Bereko	0	0	0	0	15	3	18
Betratra	4	5	19	14	9	11	62
Falinandro	0	0	0	0	4	1	5
Fandra	22	4	22	0	0	2	50
Fantsikahitry	0	0	0	0	1	0	1
Fataka	0	0	0	2	0	0	2
Fengalala	0	0	0	6	0	3	9
Finha	0	0	0	1	0	0	1
Fitoizoambalala	0	0	0	2	5	0	7
Forimbato	21	7	39	8	6	7	88
Hahabusira	1	0	0	0	0	0	1
Hazombato	0	0	0	0	0	2	2
Hazondroka	0	0	0	0	5	0	5
Hela	0	1	0	0	0	0	1
Holatry	0	0	0	0	0	1	1

Kaboky	0	0	0	0	2	1	3
Kininibonaky	0	0	0	11	0	0	11
Lalo	4	15	2	0	10	14	45
Lavarefy	0	0	0	0	1	7	8
Lendemy	0	1	2	0	0	2	5
Lengo	0	0	2	0	0	0	2
Mahampy	52	51	33	50	39	49	274
Mangarato	0	0	0	0	1	0	1
Marefifolahy	1	40	30	0	30	3	104
Metsilo	6	0	0	2	13	5	26
Ramaria	0	0	0	3	0	15	18
Randrandrano	44	41	50	22	49	40	246
Ravenala	10	1	2	0	9	8	30
Rementso 1	4	14	13	5	5	1	42
Rementso 2	0	2	0	0	0	0	2
Resa	3	1	0	1	1	0	6
Rotry	0	0	0	0	7	1	8
Saratolongo	0	0	0	1	5	2	8
Sarihsy	0	0	0	0	0	1	1
Sofimbolavo	0	0	0	31	0	8	39
Sonjokoaky	0	0	4	44	4	9	61
Takotry	7	32	42	0	2	6	89
Taritariky	1	0	0	1	0	0	2
Tatamo	2	0	0	0	1	0	3
Tavolohazo	0	0	0	0	2	1	3
Teloravy	1	0	0	0	0	0	1
Tengy	0	0	0	3	0	0	3
Tsiboradrano	3	0	0	19	4	31	57
Tsilaka	0	1	0	0	0	0	1
Tsilitolito	18	6	23	5	36	21	109
Tsimenamena	0	0	0	4	1	0	5
Tsimpangapanga	1	0	0	0	0	1	2
Tsindinditry	0	0	0	0	0	2	2
Tsorotsoro	0	0	0	6	0	4	10
Tsotokotoko	0	16	9	1	2	12	40
Unknown grass 1	0	0	0	2	0	0	2

Unknown grass 2	0	0	0	0	0	2	2
Unknown grass 3	0	0	1	0	0	0	1
Unknown tree 1	0	1	0	0	0	0	1
Unknown tree 2	0	1	0	0	0	0	1
Vahifotsy	0	0	0	0	3	0	3
Varikanga	0	0	0	0	3	0	3
Vendra	23	34	47	13	32	41	190
Volovoitry	11	0	0	0	3	1	15
Voraotry	0	0	0	0	0	1	1
Votrotroky	1	0	0	0	4	1	6
Herpetofauna Species							
Species	**Wetland 9**	**Wetland 11**	**Wetland 14**	**Wetland 17**	**Wetland 21**	**Wetland 26**	**Total**
Blommersia blommersae	7	5	15	1	2	28	58
Dromicodryas bernieri	1	0	0	1	0	0	2
Furcifer lateralis	2	0	0	0	0	1	3
Heterixalus boettgeri	1	3	0	3	1	0	8
Ithycyphus oursi	1	0	0	0	0	0	1
Mantidactylus tricinctus	0	0	0	0	0	6	6
Mimophis mahfalensis	0	1	1	0	0	2	4
Phelsuma lineata	27	32	12	0	25	6	102
Phelsuma modesta	1	2	0	0	0	0	3
Phelsuma parva	0	0	0	1	3	0	4
Ptychadena mascareniensis	1	2	1	35	4	19	62
Trachylepis elegans	1	0	1	0	2	4	8
Trachylepis gravenhorstii	3	4	2	0	4	8	21

8.2 Annex 2 – Updated Wetland Floral Species Inventory

Formal identification of the floral species observed within mahampy *reedbeds is ongoing.*

Acacia	**Lavarefy**	**Tsididitry**
Ahipatra	**Legnobe**	**Tsilaka**
Ahipoly	**Lendemo**	**Tsilitolito**
Akatafotsy	**Lona**	**Tsimpangapanga**
Akatagiso	**Magnarato**	**Tsiotsio**
Ambirimbariky	**Mahampy**	**Tsipangapanga**
Ambora	**Maintitsilo**	**Tsotokotoko**
Andrarezo	**Makaragna**	**Tsozokoaky**
Azavidy	**Mangavoa**	**Vahimpiky**
Beloha	**Marefofofahy**	**Varikanga**
Betratra	**Marefolihi**	**Varo**
Bireko	**Marety**	**Veloha**
Drosera	**Mentsilo**	**Vendra**
Fagnalala	**Pandanus**	**Via**
Falinandro	**Pivarefy**	**Vokatra**
Fandra	**Psoreko**	**Volovoitry**
Fantsikahindriaky	**Rababe**	**Vosiho**
Femevoba	**Rementso**	**Votrotroky**
Fengalala	**Ramisia**	**Zoma**
Fiha	**Randrandrano**	
Forimbato	**Resa**	
Fotsy	**Rotry**	
Hagnama	**Saritologna**	
Hagnambalaza	**Sofimbolavo**	
Haipatra	**Sonjokoaky**	
Haipisaky	**Takotsy**	
Hazondroka	**Taritariky**	
Hela	**Tatamo**	
Kaboky	**Tavolohazo**	
Kininibonaky	**Teloravy**	
Lalo	**Tsiboradrano**	