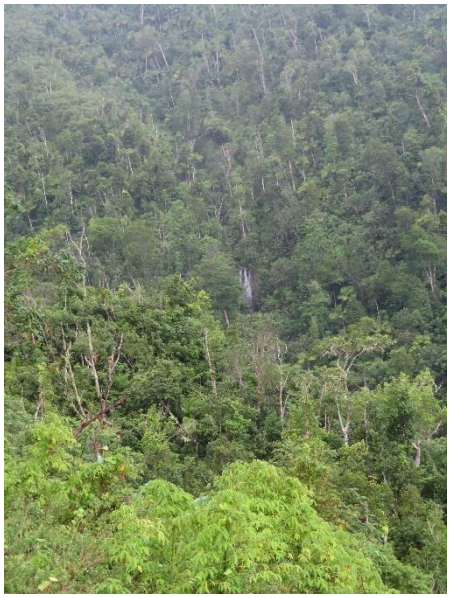



2023

Klima II Environmental Audit

Grand Bois National Park, Haiti



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Prepared for Haiti National Trust

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ACRONYMS & ABBREVIATIONS

ASB	Arbeiter-Samariter-Bund Deutschland eV
C	Celsius
cm, m, µm	centimeter, meter, micron
CIAT	Comité Interministériel d'Aménagement du Territoire
dbh	Diameter at breast height
E. coli	*Escherichia coli* bacteria
FEODTI	Fédération des Organisations de Développement de Tiburon
GRS	Geographic Resource Solutions
ha	Hectare
HNT	Haiti National Trust
SAH	Société Audubon Haïti

EXECUTIVE SUMMARY

An environmental audit was conducted in Grand Bois National Park during 3 – 12 August, 2023 as a component of the Klima II project, financed by Arbeiter-Samariter-Bund. The 3-year duration of the project (2023-2026) is being implemented by Haiti National Trust and FEODTI.

The primary objective of the study was to establish a baseline environmental study of the park, specifically on land acquired by Société Audubon Haïti and currently managed by Haiti National Trust. This included measuring the physical and chemical properties of the spring and stream water; assessing the quality of the riparian habitats; identifying and assessing major threats to the natural ecosystems; acquiring high resolution aerial photos to analyze future change in vegetation cover of the restoration areas; assessing the management of tree nurseries and tree planting activities; identifying trail segments that require remedial work to ensure safety and reduce erosion; and studying in greater detail the threatened species that play a role in ecosystem restoration activities.

The water quality of the springs and streams flowing through the park is very good to excellent. The exception was the Kay Geran Spring that was contaminated with high risk levels of *E. coli.* A major source of contamination is likely the tree nursery that is situated upstream and uses animal manure to fertilize the potting medium. Recommendations are provided to mitigate the problem, including the installation of potable water kits to treat the water for local residents.

The riparian forest habitat along the streams ranged from old-growth forest to vegetation dominated by grasses and herbs or secondary forests recovering from floods or abandoned gardens. The water quality was highest for streams through old-growth forest, as measured by the coliform count, dissolved oxygen and water temperature. The most common biota were tadpoles, macroinvertebrates, shrimp and the threatened endemic freshwater crab – *Epilobocera haytensis.* The most important threats to the riparian forest ecology are the harvesting of crabs, palm thatch for roofing material and numerous trails that use the stream channel.

Forest cover trends in the park indicate a decline in deforestation over a 22-year period. An annual average of 0.4 hectares of forest is deforested as detected by Global Forest Watch. Most of the deforestation occurs in the southwestern and northern regions of the park where land pressure is highest. A forest parcel near Pic Piton that was deforested in 2014 was documented to reference the recovery process.

The tree nurseries and tree planting activities are well managed and an important source of employment for the local community. Improvements in nursery management and restoration activities are recommended to improve seedling quality, to reduce the environmental impact of the nursery and to improve restoration methods. Aerial photos were acquired at fixed points to study the change in vegetation of the restoration areas over time.

The major threats to the natural habitats of the park were assessed. It is recommended that policies be developed to reduce and to manage these threats and training be provided to the park guards. This phase of park management should be done upon completion of the land cadaster by CIAT and preferably after all legal land documents have been processed.

Selected threatened species were studied and recommendations on their management provided.

INTRODUCTION

Grand Bois National Park was officially declared by the government of Haiti on October 8, 2015, demarcating 370 hectares with a perimeter of 14 kilometers and occurring along the 900-m elevation contour enclosing Morne Grand Bois and Pic Piton (Le Moniteur, 2015). The final park boundary and official land cadaster is due to be completed in late 2023. An initial survey by Société Audubon Haïti (SAH) in September 2016, assisted in part by government personnel, established a block of land covering 496 hectares that was then partially sold to SAH. Approximately 205 hectares of this land occurs within the national park boundary and is the area of this study.

The Klima II project, entitled " *Strengthening the resilience of ecosystems and communities at risk from climate change in the Macaya Biosphere Reserve, Haiti*, " includes an environmental audit to be conducted at the beginning of the 3-year project period (2023 – 2026). Klima II is funded by the Arbeiter-Samariter-Bund (ASB) and is being implemented jointly by Haiti National Trust and the Fédération des Organisations de Développement de Tiburon (FEODTI). Project activities also receive additional support from the Yves St. Laurent company through re:Wild's project entitled "Saving and restoring the forests of the Tiburon Peninsula".

The purpose of the study is to establish the state-of-the-environment and associated metrics that reflect the current ecological quality of the native ecosystems found within the park. These range from high quality rain forests to highly disturbed areas impacted by years of human activity. A major focus of the study is to assess the multiple threats and drivers of past and current disturbances to the ecosystems. These include the measurable impacts summarized in the Impact Matrix (Section 4) of the Klima II project description - indicators of ecosystem health (e.g., forest quality index, spring and stream flow, abundance of threatened species) and indicators of threats (e.g., population and distribution of livestock, distribution of active/inactive gardens, human traffic using the park trail network, distribution and abundance of non-native plants and animals). The data to be acquired will be important for park management purposes and the envisioned park management plan. Several of the parameters will be recommended for monitoring throughout the project period due to their significance in evaluating progress toward the effective protection of the natural ecosystems.

METHODOLOGY

Study Area

The study area of Grand Bois National Park is the area acquired by SAH, as shown as the hatched area in **Figure 1**.

Figure 1. Map showing the study areas of Grand Bois National Park.

Methods and Materials

The methods and materials were designed to provide a robust set of parameters that describe the quality of the natural and modified ecosystems within the park. They are not considered to be exhaustive but reflect budgetary and time constraints, logistical difficulties and limited availability of qualified personnel to conduct the assessment. The methodology was limited to a 10-day period of field study, led by a professional resource ecologist and the park's field manager, Wilson Jean. Rainy weather accounted for 2 lost days of field activities and increased the time required to travel within the park.

Springs and Riparian Ecosystems

The springs, streams and rivers that flow through the park have a unique riparian forest ecosystem that provide habitat for many of the threatened flora and fauna, including the threatened Tiburon Stream Frog (*Eleutherodactylus semipalmatus*). The hydrological parameters that are most important are the quality and quantity of stream flow, as well as the quality of habitat and degree of disturbance within a 20-m buffer area of the stream bed. Details of the methodology are summarized in **Annex 1**.

Most of the springs are in the eastern portion of the park and outside the study area (**Figure 2**). The spring study by Lacour (2015) identified 3 springs within the study area. These are 1) Piton à gauche, 2) Piton à droite and 3) Kay Geran. Only the spring at Kay Geran was studied, since the 2 higher elevation springs were too distant from the camp site to complete the methodology without staying overnight, especially considering the rainy weather. At the time of the 2015 study, all 3 springs were reported to be dry.

The Kay Ediron spring, although outside the study area, was visited in order to confirm the presence of the Tiburon Spring Frog since it was the first site that the species was re-discovered in 2011. Prior to that time, expert herpetologists had thought the species had gone extinct since it had not been reported for several decades.

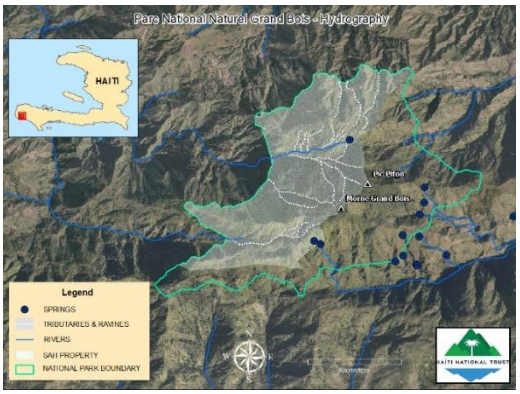

Figure 2. Hydrography of the study area in Grand Bois National Park.

Springs. The ambient meteorological conditions at the time of sampling were taken with a Kestrel 3500 for temperature, relative humidity, barometric pressure, pressure trend, wet bulb temperature (an indication of heat index) and altitude. The volume of water discharge (liter or m^2 per second) was estimated downstream of the spring using the float method. This is an important variable that reflects seasonal precipitation, filtration rates impacted by vegetation cover and geological features of the hydrological basin. In terms of water quality, a test for the presence of coliform bacteria, specifically *E. coli*, was conducted, using 3M petrifilm and the method outlined by Metcalf & Stordal (2010). This indicates the presence of animal fecal matter and is an important health indicator as well as the prevalence of grazing livestock and feral animals in the vicinity of the spring. Basic water chemistry (pH, alkalinity, dissolved oxygen, nitrate/nitrite, phosphate) and presence of heavy metals was taken using LaMotte, Waterworks and Sensafe test strips. Water temperature was taken with a Pentair tube thermometer.

A 100 m^2 area around the spring was assessed for habitat quality in terms of vegetation cover, degree of disturbance, types of disturbance and a brief description of the floral and faunal community. Canopy density was measured at 10 points within the sampling area if tree canopy was a factor. Canopy density was measured using a GRS densitometer and averaged for the site. The presence/absence of the threatened Tiburon Stream Frog (*Eleutherodactylus semipalmatus*) was noted.

Streams. Time constraints and weather allowed for only 3 sites to be studied. Each sample plot was comprised of a 10-m segment of stream bed with a 10-m buffer on each side for a total area of 200 m^2. Water velocity and discharge volume was estimated using the float method. Ambient meteorological conditions, coliform bacteria and water chemistry was recorded as described above. Disturbance to the habitat was determined by degree and type. Any threatened species detected during the survey was noted. An attempt to examine the invertebrate and vertebrate species in the stream was conducted using a 500 µm dip net during a 2-minute period to compare relative diversity among sampling sites. Specimens were preserved in 95% ethanol for later identification and labeled according to date and location. The invertebrate and vertebrate diversity was sorted, photographed and classified to order and if possible, genus, using identification keys. Tree canopy cover was measured at 10 points along each side of the stream within the buffer area and averaged.

Forest Cover

Global Forest Watch was accessed and analyzed for forest loss during the 22-year period from 2001 – 2022. It was originally intended to visit the most recently deforested areas of the park in order to study the cause of the deforestation as well as their current ecological status. However, time did not allow due to the remote locations. One area of the park that was deforested in 2014 was revisited and photos were taken to compare the difference in vegetation cover between the 2 time periods.

Restoration Areas and Tree Nurseries

HNT has been restoring deforested portions of the park since 2019 by removing invasive species and planting native shrub and tree species harvested from within the park. These areas are referred to as Nan Panm, So Blanch and Nan Koulèv (**Figure 3**). Nurseries have been established in order to provide seedlings for reforestation. These were evaluated in terms of current management practices. The Nan Panm restoration area was evaluated in terms of survival rates, growth rates and methods to improve success. The vegetation community was described in terms of the abundance of non-native species and density of planted species.

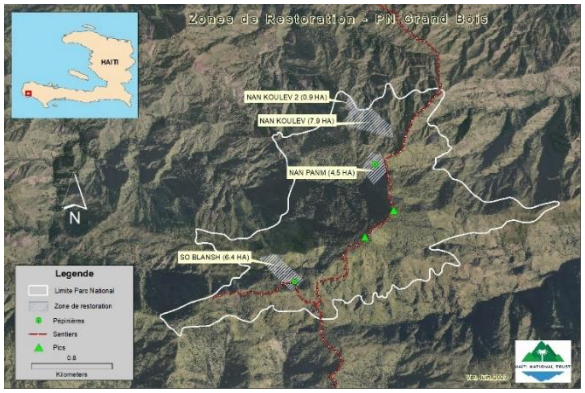

Figure 3. Restoration area and nurseries in Grand Bois National Park.

Fixed points were selected along the perimeter of Nan Panm and Nan Koulèv areas to acquire aerial photos for future comparisons of vegetation cover. The Nan Panm photos were taken at 30 m and 100 m above

ground with a DJI Model FC7303 camera fitted with a 35 mm lens and a focal length of 24 mm. The images are 4.8 MB (4000 x 2250 pixels), 72 dpi, 24-bit depth and ISO 100. A wooden stake was established at each point to mark the position of the photo with GPS location, elevation and a code name. These photos will be used to analyze changes in the vegetation when photos are taken from the same position in 2026.

Threats to Natural Habitats

The major threats to habitat loss in Grand Bois National Park is associated with human activities, both past and present. The drivers of these threats are the clearing of forests for gardens, forest extraction activities (e.g., palm thatch, crabs), livestock grazing, active and abandoned gardens and the daily traffic through the park that introduces non-native species and increases the risk of wildfire, solid waste and noise/light pollution.

Trails and Traffic patterns. The trail that borders the eastern boundary of SAH lands is a major trail used by the area communities to travel from outside the park to Sevré and Tiburon. It passes through the 2 highest peaks of the park – Pic Piton and Morne Grand Bois. An estimate of the daily traffic was conducted on 5 consecutive days to measure the traffic load (**Figure 4**). It was intended to study other trails within the park, which total about 16.4 km, but time and weather did not permit.

Six (6) critical points along the main trail from Sevré to the park were identified and determined for their GPS coordinates, elevation and average percent slope. These critical points will be targeted for improvements during the Klima II project in order to ensure safety and decrease the erosion that is taking place.

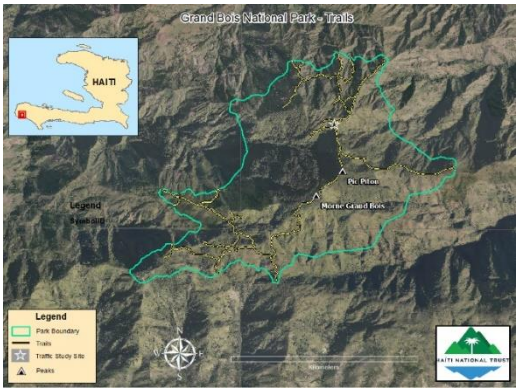

Figure 4. Trails of Grand Bois National Park showing traffic study site.

Livestock and feral animals. It was originally intended to take a census of the livestock and estimate the number of domesticated and feral animals (e.g., dogs, cats, rats) currently inside the study area. However, time did not allow for this and it was decided to address this issue at a later date. The problem was briefly discussed with the HNT personnel on site and a brief summary of this threat to the ecological integrity of the park was provided.

Abandoned/active gardens. As in the case of livestock, the location of abandoned and active gardens inside the study area was to be described. Several gardens were visited and their ownership identified, but an exhaustive inventory was not possible. These examples, as a threat to the integrity of the park ecosystems, were provided.

Forest Resource Extraction. The major types of forest extraction were identified, focusing on the old-growth forests of the park. An assessment of these threats to the park was provided with recommendations for improved park management.

Habitations. It was originally intended to conduct a census of all permanent residents currently living in the study area. However, HNT decided for this task to be the responsibility of CIAT as part of its duties in

completing the land cadaster scheduled for later in 2023. Interviews with park residents allowed for a draft list of the heads of households and their locations within the study area and a portion of the land acquired by SAH outside the park boundaries.

Threatened Species

Grand Bois has dozens of globally threatened plant and animal species. Sub-population locations and estimates were determined for the Critically Endangered *Meriania parvifolia.* A 200-m by 10-m transect along the ridge trail near Pic Piton was sampled for the Critically Endangered *Magnolia ekmanii.* All individuals greater than 2-cm diameter-at-breast-height (DBH) were measured for stem diameter and total height. Trunk diameter was measured with a diameter tape, in cm, and total tree height was estimated with a clinometer, in m. In the case of multi-stemmed individuals, the quadratic mean diameter was calculated along with the stump diameter at 10-cm height. An estimate of the natural density of the species was calculated based on the number of trees measured divided by the area sampled. It is assumed that both the diameter distribution and the number of individuals are close to what would be expected in a natural population for this part of Grand Bois. Phenological data (flowering, fruiting) was observed and recorded.

During the time of the field study, the ecologist spent time with Wilson Jean and others identifying the native, endemic and threatened species of the park. A copy of the guide to the amphibians of southern Hispaniola (Martinez Rivera & Rodriguez Plaza, 2015) was provided to Wilson Jean, as well as the current list of the flora and fauna of the park. Several Creole common names of the plants were added to the list as a result of this study.

RESULTS

Springs and Riparian Ecosystems

One spring and 3 streams were selected to sample water quality and to assess the habitat quality of the aquatic ecosystems within the park. The location of the four sample sites is provided in **Figure 5**.

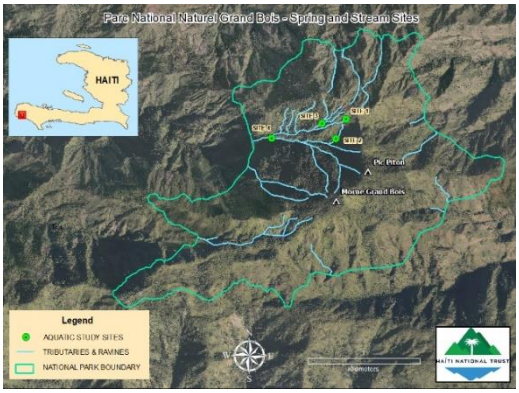

Figure 5. Location of the aquatic study sites in Grand Bois National Park.

The spring near the residence of Clairzida Dasny at Nan Panm was the only spring tested. The other 3 sites were stream tributaries that serve as the headwaters of the Banc de Roche River, ultimately flowing into the Grand-Anse River.

E. coli and coliform bacteria. A 1-ml sample from each site was tested on 3M Petrifilm™ *E. coli* and coliform count plates. The results of the four sites are provided in **Table 1**.

Table 1. Bacterial counts of aquatic study sites.

Site No.	*E. coli* w/ gas	Non-*E. coli* coliform w/gas	Total coliform	Non-coliform gram-negative bacteria
1	28	15	43	70
2	2	6	8	90
3	0	7	7	36
4	2	4	6	60
Disease risk thresholds (counts/ml): 0 = safe; 0.1 – 1.0 = low risk; 2 – 10 = medium risk; > 10 = high risk. Source: Odonkor & Mahami, 2020.				

The results show that the spring site at Kay Geran has a high risk of disease as measured by the *E. coli* counts - an indicator of recent fecal contamination of humans and other mammals. Sources of contamination include the animal manure used to fertilize the potting soil in the nursery that lies upstream of the spring, as well as the daily washing, bathing, and use of the spring for drinking water by humans. The continual discharge of relatively clean water from the aquifer likely keeps the coliform bacterial count from being any higher.

The 3 stream samples all show low or no counts of *E. coli.* The cleanest water sample flows out of a natural forest where there is no presence of grazing animals and very little human activity. The other 2 sites are downstream from patches of abandoned gardens and former grazing areas that may serve as possible sources of contamination. These samples are on the low end of "medium risk for disease".

Spring and Stream Water Chemistry. The 4 sites were tested for the water temperature, dissolved oxygen, pH, alkalinity, phosphate, nitrite/nitrate, and heavy metals. These tests are important to detect levels of pollution that contribute to eutrophication and other anthropogenic causes of low water quality that may result in the loss of biodiversity, especially an organism's intolerance of low dissolved oxygen. **Table 2** summarizes the results of the tests.

Table 2. Summary of water chemistry data from 4 aquatic sites in Grand Bois National Park.

Site No.	Air Temp. (◦C)	Water Temp. (◦C)	Dissolved Oxygen (mg/l)	pH	Alkalinity (ppm)	PO_4X^3 (ppb)	NO_3/NO_2 (ppm)	Heavy Metals (ppb)	Water Clarity
1	23.8	22.0	6	7.2	80	0	0/0	< 10	Clear
2	27.7	20.5	7	7.2	80	0	0/0	< 10	Clear
3	28.0	24.2	4	7.8	80	0	0/0	< 10	Clear
4	28.5	24.0	9	7.2	80	0	0/0	< 10	Clear

The results from the 4 sites are indicative of a high quality of water, lacking in pollution that might disturb sensitive plant and animal biota.

Stream Discharge Volumes. Stream flow was measured at 3 locations in Grand Bois. Two of the locations (Site 1, Site 3) were representative of headwater tributaries and Site 4 was a downstream location toward the western boundary of the park. We were not able to reach the exit of the river out of the park where the volume discharge would have been the greatest.

Site 1. This is an estimate of the discharge volume of the Kay Geran spring. It was not possible to estimate the volume at the spring using the float method. A site about 50 m downstream was selected to estimate

the discharge volume. The estimated discharge volume was 1.14 liter/second. This spring ceases to flow during drought periods.

Site 2. It was not possible to estimate discharge at this site with the float method. The stream was too rocky and there wasn't a main channel to allow for an estimate.

Site 3. The estimated discharge volume was 5.3 liter/second. This stream flowed out of a natural forest and it occurred after a rainfall event 2 days prior to when Site 1 was estimated. It is uncertain to what degree the rainfall event may have impacted discharge volume.

Site 4. This is the furthest downstream site and discharge volume is significantly higher. Several more tributaries flow into the main channel between this site and sites 1 & 3. The estimated discharge volume is 164 liter/second.

Spring and Stream Habitat Quality. A brief description of the spring and stream habitats refers to the 100 m^2 area adjacent to the spring or the 200 m^2 adjacent to the stream.

Site 1. The habitat of the spring at Kay Geran is highly disturbed (**Figure 6a**), being in the vicinity of the nursery and the living compound of Clairzida Dasny. The vegetation around the spring is almost entirely herbaceous, including several non-native invasive species that have yet been eliminated such as Jacob Tears (*Coix lacryma-jobi*) and the West African tulip tree (*Spathodea campanulata*). Most of the species are common to disturbed areas and include the native grass, *Andropogon bicornis*; the bush mint, *Ocimum campechianum*; an endemic gesneriad, known locally as kasinèt (*Rhytidophyllum bicolor*); the colorful native heliconia, *Heliconia bahai;* a common rainforest bush, *Besleria lutea* and kouzen (*Urena lobata).* Despite the open sun conditions, the water temperature of the spring maintains a near constant temperature of 22 ◦C. Tadpoles of the Hispaniola Green Treefrog (*Boana heilprini*) were the most common amphibian species found in the spring (**Figure 6b**) in addition to water striders in the *Limnogonus* and *Rhagovelia* genera (**Figure 6c**).

Figure 6. (a) Site 1 spring habitat at Kay Geran. (b) Froglet of *Boana heilprini.* (c) Water strider (*Limnogonus* sp.).

Site 2. The habitat quality of the stream was partially disturbed on the northern side of the stream as a result of previous gardening activity by the former owner. About 30% of the 20-m transect on the northern buffer area was cleared for gardens in the 1980s and is now slowly recovering as secondary forest. The remainder of the stream buffer area is typical of natural forest. Canopy cover, as measured by a densitometer, measured 90 %, and comprised of a combination of herbaceous, shrubs and trees. The most common herbaceous species were *Heliconia bahai* and the non-native invasive ornamental, *Coleus scutellarioides* (**Figure 7a, b**). Both sides of the stream are lined with boulders covered with epiphytes

(bromeliads, orchids, ferns) and a diversity of shrub and tree species including palm (*Prestoea acuminata* var. *montana*), mahaut piment (*Trema lamarckiana*), laurier (*Ocotoea* spp.), bois rouge (*Gaurea guidonia*), cafe marron (*Psychotria* spp.), bois cabrit (*Palicourea berteroana*), figuier (*Ficus* spp.) and bois patate (*Stenostomum* spp.). The near closed canopy cover of the stream buffer area, coupled with continuous discharge of seepages along the stream edges, keeps the stream water and microclimate cool even during the highest daily air temperatures. The stream bed is rocky, comprised of the blackish basalt rock that is common to the area, with occasional pools of clear water ideal for the tadpoles, macroinvertebrates, shrimp and the endemic freshwater crab – *Epilobocera haytensis* (**Figure 7c**). The rocky stream channel was covered in the water by aquatic mosses and spleenwort and aquatic herbs along the stream edges like the endemic *Dorstenia ekmanii*. The stream was littered with woody debris and fallen rocks creating high quality habitat for the aquatic biota. The water was shallow and likely near base flow discharge. No attempt was made to estimate the discharge volume since the water was too shallow and stream flow was interrupted by boulders that did not allow an estimate by the float method.

Figure 7. (a, b) Site 2 stream habitat showing native *Heliconia* and non-native *Coleus*. (c) Endemic freshwater crab – *Epilobocera haytensis.*

Site 3. This stream site empties a ravine whose cover is dominated by natural forest (**Figure 8a**). *Prestoea acuminata* is the dominant palm in the area and is periodically harvested for its dead fronds as a source of roofing thatch. Holes dug along the sides of the stream can be found where locals dig for the freshwater crab (**Figure 8b**), endemic to Hispaniola and considered Vulnerable according to the IUCN Red List. This crab is a favored delicacy among locals and is vulnerable to being overharvested in the park. A high diversity of understory shrubs and trees occur along the stream, whose water is shallow running over the basalt rock with occasional pools of water where tadpoles, an additional species of water strider (**Figure 8c**) and freshwater shrimp are found. The water temperature was slightly warmer than the spring at 24.2 ◦C. However, the sheltered and shady stream banks offer high quality habitat to the aquatic animals present in the area. No *E. coli* colonies were detected in the stream water, indicating little to no contamination from human-based sources.

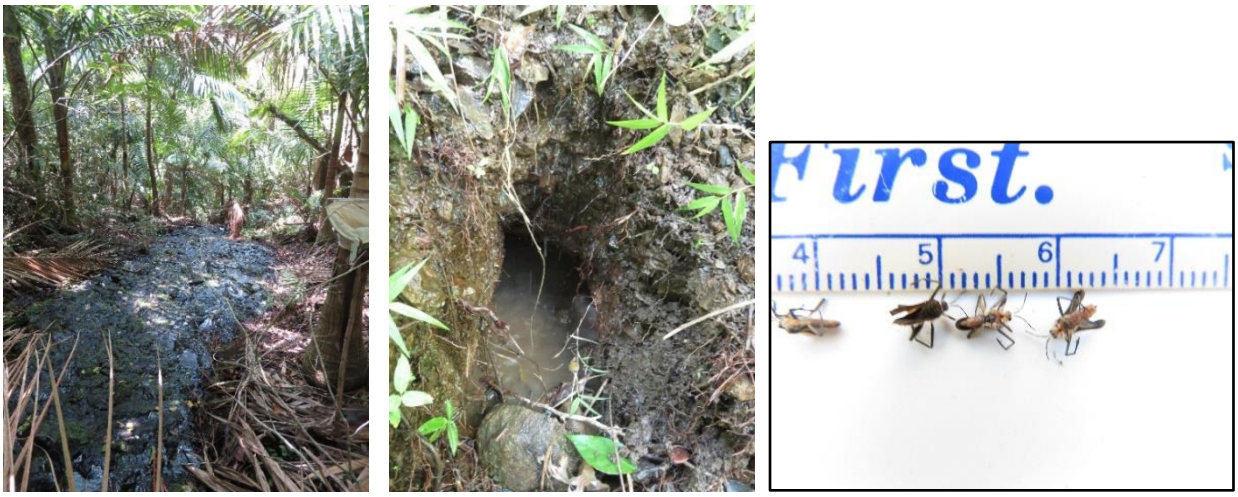

Figure 8. . (a) Site 3 stream habitat. (b) Hole dug to harvest crab. (c) Dwarf water striders (*Rhagovelia* sp.).

Site 4. This site was furthest downstream of any of the sites and the flow and volume of water discharge was considerably higher than the upstream sites (**Figure 9a**). Perhaps as a result of past flood conditions, the banks of the stream are quite open and comprised of secondary vegetation that included mostly native species of *Prestoea, Ficus, Heliconia, Miconia, Ocotea, Rhytidophyllum, Gesneria* and *Lobelia* genera. The stream channel is abundant with riffles and flows over the basalt rock that forms the stream bed. Dead logs and boulders are strewn across the stream providing pools that harbor the aquatic biota. It was at this site that the greatest number of freshwater shrimp, locally known as *krebich* (**Figure 9b**), were caught as well as the immature forms of dragonflies (**Figure 9c**), damselflies and other invertebrates that inhabit these waters. According to the locals, the current was too fast in order to capture the larger crayfish, locally known as *mordant.* Other types of crustaceans that inhabit this portion of the stream include the freshwater crab, *Epilobocera haytensis* and other shrimp species, distinguished by their Creole names as *patte* and *patte cheval.*

Figure 9. (a) Site 4 stream habitat. (b) Freshwater shrimp (*Potomirin* sp.) caught at Site 4. (c) Dragonfly (Odonata) nymph found in the stream bottom.

Forest Cover

A brief analysis of deforestation within the Grand Bois National Park area was conducted with the data from Global Forest Watch (https://www.globalforestwatch.org/). The results show that over the course of a 22-year period (2001 – 2022), a total of 8.46 hectares of land was estimated to have been deforested. The annual rate averaged about 0.4 hectares, with several years showing no deforestation (**Figure 10a**).

While most of the deforestation may be attributed to clearing the land for gardens or wildfires, a certain amount might be the result of natural disasters such as Hurricane Matthew in 2018 or minor landslides in steep areas due to recent earthquake tremblors. The overall trend line from 2021 is in decline. Most of the deforested parcels are occurring in the southern and northern portion of the park where land pressure is highest (**Figure 10b**). The annual deforestation rate is equivalent to about 0.1% of the park area and does not consider forest gain that is occurring as a result of garden abandonment or ecosystem restoration by SAH/HNT. The rate of deforestation should continue to decline as park guards are hired and the land conflicts and acquisition of the park lands are resolved.

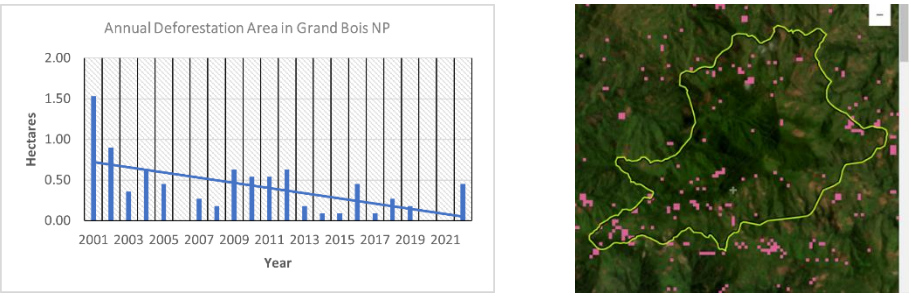

Figure 10. (a) Annual deforestation rate in Grand Bois (ha/year). (b) Deforested areas (pink) of the park over 22 years. (Source: Global Forest Watch, 2023).

Time did not allow us to investigate the most recent areas of the park that were shown to be deforested. However, one site near Pic Piton that was deforested in 2014 was revisited, showing a remarkable recovery in terms of habitat quality after 9 years (**Figure 11**).

Figure 11. Recovery of forest ecosystem in Grand Bois National Park. Left. Deforested parcel in 2014. Right. Same parcel in 2023.

Restoration Areas and Tree Nurseries

The first tree nursery was established in Grand Bois in November 2018 at Nan Panm, near the residence of Geran Morace and Clairzida Dasny. The main purpose of this nursery was to begin the propagation of *Magnolia ekmanii* whose population at Grand Bois is perhaps the largest natural population of the species at any single location in this part of Haiti where the species is endemic. The Nan Panm nursery has been in near continuous production of tree seedlings since 2018, though the data of seedling production and

out planting totals for the period of 2019 – 2021 are not complete due to inadequate past record keeping and reporting. The reports during this period indicate that at least 110 seedlings of the West Indian laurel cherry (*Prunus occidentalis*) and 2000 seedling of Ekman's magnolia (*Magnolia ekmanii*) were planted in September 2019 and May 2020, respectively. These seedlings were planted in the field gardens of Geran and Clairzida in what is now part of the Nan Panm restoration area.

A sample of these seedlings were randomly selected and measured for height growth (**Table 3**). Growth rates are moderate considering the soils are a mix of laterite and serpentine – both soils being relatively infertile once the original forest cover is removed and the process of erosion takes its toll. Survival rates ranged from 90-95% for the *Magnolia ekmanii* and *Prunus occidentalis* to a much lower rate for the *Prestoea acuminata* palm – 60-70%. The palm is also growing much slower on these soils.

Table 3. Height growth of tree species planted in 2019/2020 and 2022 in the Nan Panm restoration area.

Species	Height (m) - 2019/2020	Height (m) – 2022
Magnolia ekmanii	1.5	0.8
Prunus occidentalis	1.2	0.7
Prestoea acuminata	0.3	0.3
Prunus myrtifolia	-	0.6

From the Spring of 2022 to the present, the record keeping much improved, nursery production increased and more areas of the park were selected for restoration. A key factor in selecting these areas was whether the former landowners were paid for their land by SAH and agreed to support the replanting of their former land with native tree and shrub species. In addition to Nan Panm, two other areas of the park were selected – So Blanch in 2022 and Nan Koulèv in 2023. The So Blanch site required its own nursery due to the remoteness of the area from Nan Panm. The seedlings produced for Nan Koulèv originate from the central nursery at Nan Panm. During the course of this study, another nursery was established at Bwa Grenn.

In total, approximately 20 ha of land has been the target of restoration efforts (**Figure 3** above). In addition to the plantings in 2019/2020, the planting totals for 2022 were 61,632 seedlings representing 24 species, surpassing the 60,000-seedling target set for the year. In 2023, the planting totals up to August were 31,261 seedlings representing 11 species and mostly planted during rains of Jan/Feb and May. The below-normal rainfall during the 2023 Spring rainy season limited the number of seedlings that could be planted. Planting in the Nan Koulèv area resumed once sufficient rainfall began in early August, 2023.

Assessment of nursery production. Overall, the main nursery at Nan Panm is well managed and is a significant source of employment for the local community. The significance of these jobs was readily apparent this last spring when poor rains resulted in a disastrous cropping season and people relied on the income to make up the shortfall in subsistence and income from their agricultural activities. Generally speaking, the late Spring is the most difficult time of year for local farmers since food stores have been depleted from the previous cropping season and gardens have yet to produce sufficient food to meet current needs.

A rainfall gauge and a thermometer were installed at the nursery to begin measurements in Grand Bois. To date, rainfall and temperature have never been recorded in the park, so this is the first time that we

will be able to track these parameters. A local employee was trained in record keeping and this will need to be supervised on a regular basis so that the data is reliable and accurate.

Certain features of the nursery are recommended to increase seedling quality and to decrease the negative impact of the nursery on the local ecology of the park. These are further elaborated below under "Findings and Recommendations".

Assessment of ecosystem restoration efforts. The main objective of investing in ecosystem restoration is to accelerate natural succession and the development of tree canopy cover on areas that have been deforested in the past. The rate of natural succession in Grand Bois is constrained by several factors. First, the soil is influenced by the magnesium-rich serpentine rock that is infertile and highly erodible. The clayey lateritic soil at the surface retains moisture that is favorable to high survival rates, but modest height growth, also due to its relative infertility. Nitrogen appears to be the primary limiting element, supported by the fact that tree growth is highest where past piles of bean debris were left to decompose into the soil. Several *Prunus occidentalis* have achieved growth rates of greater than 1 m/yr in such areas and are now close to 4 m tall. Secondly, the dominant herbaceous cover of native and non-native grasses and forbs out competes the planted seedlings for light, nutrients and soil moisture. Given these conditions, the recommended activities are provided below in "Findings and Recommendations".

Assessment of Invasive Species. Since 2021, an effort has been made to decrease the presence of invasive plant species in the park. The initial efforts targeted the largest individuals of West African tulip tree (*Spathodea campanulata*) and a selection of ornamentals (e.g., *Coix lacryma-jobi, Coleus scutellarioides, Iresine herbstii*). Additionally, during the time that native species were planted in the restoration sites, an effort was made to uproot invasive species, especially the grasses (*Panicum maximum, Cenchrus purpureus*) and replant the same spot with a native tree or shrub species.

While progress has been made on the management of invasive species, there is still much to be done if the goal is to eventually eradicate the populations of the most problematic species. Two of the stream sites confirmed the persistent populations of *Coleus* and *Iresine.* The Philippine Ground Orchid (*Spathoglottis plicata*) was flowering at the time of this study and clusters of the species were noticeable in the Nan Panm restoration area (**Figure 12a**). These were immediately removed during the time of this study and recommendations were made to be on the lookout elsewhere in the park while it is still flowering. Other non-native species found in the restoration areas should also be removed as time permits, including the cultivars of the most common fruit trees such as guava (*Psidium guajava*) and banana/plantain (*Musa* spp.).

Another species of concern is actually a native species – *Imperata brasiliensis* – that exhibits similar behavior to its close relative, *I. cylindrica,* an extremely invasive non-native species found elsewhere in the Caribbean. The latter has been introduced throughout the tropical world and is very difficult to eradicate. It's presence in Haiti has not been confirmed. The native *I. brasiliensis* that occurs in Grand Bois is typically found on deforested land and in association with the bracket fern, *Pteridium aquilinum.* Both are extremely flammable, favoring wildfires during droughty and windy periods, as was the case of the recent burn event in Bwa Grenn (**Figure 12 b, c**). As part of an effort to decrease the fire danger, fire breaks around areas of *I. brasiliensis* should be established by eliminating the fuel load and replacing it with fire-resistant vegetation (e.g., *Heliconia bahai*).

Figure 12. (a) Invasive *S. plicata* ground orchid. Credit: Martin Reith. (b) July 2023 burn event at Bwa Grenn. (c) One-month old regrowth of highly flammable *I. brasiliensis* grass at burn site.

Fixed Point Aerial Photos. Six points were established on the perimeter of 2 restoration areas. Each location was cleared of brush and a square-meter landing strip was created for the DJI Mini 2 drone (**Figure 13a**). A stake was established at each location to mark the site which will be maintained periodically to keep it clear of weeds (**Figure 13b**).

Figure 13. (a) DJI Mini 2 drone. (b) Drone landing area and reference stake marking the fixed points. (c) Example of an aerial photo taken at 30 m altitude.

High resolution aerial photos were taken at each point in order to establish a reference to analyze the change in vegetation cover over time (**Figure 13c**). These photos were taken at 30 m altitude above ground level for the 2 Nan Koulèv points. It was not possible to take photos at 100 m due to foggy conditions at the time and date of the flight. Aerial photos were taken at 30 m and 100 m altitude for each of the 4 points of Nan Panm. The approximate land area captured in the photo is 0.1 ha at 30 m altitude and 1.0 ha at 100 m altitude. The correlation is based on *flat land*. Since the locations were at the highest points of the surrounding terrain, the land areas represented by the photos will be slightly greater. The series of aerial photos representing the restoration areas are provided in Annex 2.

In addition to the weather, the other major limiting factor was battery charge. Without any means to recharge the lithium batteries, flight time was limited. For this reason, it was decided to take off vertically from each point rather than fly a flight plan with a risk of crashing the drone. The three batteries provided about an hour of flight time, less than the specifications provided by the manufacturer.

Threats to Natural Habitats

Trails. There are a large number of trails within the park. The principal North/South trail running along the ridge is one of the major trails that traverses the park and is used by local residents on a daily basis. Traffic along this trail was monitored for 5 successive days at the intersection of this trail and the spur to the Nan Panm nursery (**Table 4**).

Table 4. Traffic during peak daytime hours along the North/South trail of Grand Bois National Park. Latitude: 18.37767; Longitude: -74.30002; Elev. (m): 1136 m.

Date	Time	People	Livestock	Notes
Aug. 3	06h45 – 14h30	49	2	Market day in Sevré.
Aug. 4	07h00 – 15h45	86	3	
Aug. 5	06h45 – 13h45	75	8	Market day in Pòtonye
Aug. 6	08h30 – 13h00	41	0	
Aug. 7	07h00 – 10h00	65	0	
	Total	319	13	Daily average: 64 persons, 3 livestock.

The traffic pattern at this location is not unusual, since a good portion of the users were destined for the Nan Panm nursery or its immediate environs. This portion of the traffic was more important than the through traffic en route to other locations inside and outside the park. The recommended alternate trail around the eastern boundary of the park would likely lessen the traffic, though the trail would still be heavily used as long as central activities continue at the Nan Panm locale.

While it is difficult to eliminate and to monitor the numerous smaller trails in the park, it is obvious that the risk of disturbance to the ecological integrity of the forests is not negligible. These risks include an increased likelihood of wildfire incidents, continued resource extraction, habitat disturbance and ongoing introduction and establishment of invasive species. All these issues must be dealt with as part of the park management plan. This plan should be delayed until the official park survey and final land acquisition process is completed.

Livestock. It was originally intended to enumerate the livestock population that are currently found inside the park boundaries. Their presence inside the park is a problem for the various roles they play in disturbing the ecology: 1) Vectors for the introduction of invasive species; 2) Source of fecal coliform, especially *E. coli*, and other pollutants, especially nitrates/nitrites that contaminate the surface waters and cause eutrophication; and 3) Soil erosion and disturbance that favors invasive plants, especially grasses, that alter soil nutrient budgets, the frequency and intensity of wildfires and delay the process of ecosystem restoration.

According to the HNT personnel, the incident of livestock infractions inside the park has declined during the rainy season when forage is available in the lower elevations of the buffer zone. Several former landowners have moved their livestock to either outside the park or on lands inside the park that have not yet been paid for. However, during periods of drought, the illegal pasturing of livestock in the park remains an important threat. The upcoming CIAT mission to officially establish the land cadaster will be accompanied with a census that may enumerate the livestock as a household asset. This should provide a clearer picture of the ongoing risk associated with livestock inside the park.

Gardens. There are many gardens inside the current park boundaries that are mostly located on lands not yet acquired by SAH/HNT (**Figure 14a**). Most of the areas where these gardens occur, either active or in fallow, had been deforested previous to 2015 when the park was established. An active bean garden was found on land acquired by SAH (**Figure 14b**). The garden is owned by a relative of the former landowner that received payment and established the garden through an "association" - a local sharecropping arrangement. Another garden within the park is on land claimed by the Ediron family who recently planted a bean garden on slopes below the upper palm brakes of the original forest (**Figure 14 c, d**). The tall old stems of *Prestoea* palm attest to the fact that this area has been cultivated for a lengthy period of time.

Figure 14. Gardens in Grand Bois National Park. (a) Typical yam garden on park land not yet purchased by SAH/HNT. (b) Bean garden on park land acquired by SAH/HNT. (c) Tall palms on fallow land previously cultivated for gardens. (d) Garden on park land showing burned fringe of rainforest parcel.

Regardless of the legal status of the land, all these gardens pose a risk to the adjacent forests since they are burned to clear the vegetation and this in turn heightens the risk of wildfire, especially if drought and wind conditions exist. Each time that the land is cleared with fire, it is a chance that the adjacent forest is also harmed, either damaged or subsequently cut for charcoal or fuelwood. The organic carbon cycle of the soil – fundamental for fertility – is also damaged despite the short-term gains in productivity from the fertilizing effects of the ash.

Forest Extraction. The natural forests of Grand Bois are a major source of palm thatch material used locally for roofing material – almost entirely from *Prestoea acuminata* var. *montana* (**Figure 15a, b**). This practice was established long before the park was created. However, the pressure has increased as habitations have increased in number in and around the park, but also because of an increased frequency of extreme weather events, including the recent high wind event in May – June 2023. This latter event caused many roofs to blow off and resulted in a spike in the demand for palm thatch. This in turn resulted in a marked increase in the number of trails into the forests and destruction of natural habitat. In addition to the thatch, collectors also harvest the palm cabbage that requires killing the palm entirely (**Figure 15c**). Guidelines should be established for the harvest of palm thatch since currently there is no control and the harvests run the risk of damaging the ecological integrity of the forests.



Figure 15. Palm thatch harvests. (a) Typical thatched dwelling found in Grand Bois. (b) Harvested area of *Prestoea.* (c) Palm stem harvested for the cabbage also known as the "heart of palm".

Another major target for harvest is the threatened freshwater crab – *Epilobocera haytensis* as mentioned previously. It is one of two freshwater crabs endemic to Hispaniola and is assessed on the IUCN Red List as Vulnerable. due to the threats of being overharvested where it is consumed in local cuisines. The crab is indiscrimnately harvested with no regard to reproductive season, size or sex. Ideally, only males of a certain carapace length are harvested in order to protect the egg-laying females and ensure the reproductive capacity of the local population. However, such measures are difficult to enforce, so a total ban should be considered and enforced for the park, at least the portion that SAH has acquired. It was apparent that this is already in practice, at least among the HNT employees, since permission was requested to eat an adult crab that had been severely injured during its capture.

It appears that for the most part, lumbering has ceased in the upper elevations of the park. Most of the lumbering were the past efforts of the late Geran Morace and Ti Mechan. Logs of timber species such as *Octoea*, felled or left standing as dead snags from Hurricane Matthew in 2018, are distributed throughout the forest. This is a welcome sign as fallen logs and standing dead are important habitats for the native flora and fauna, in addition to storing carbon and ensuring a healthy soil ecosystem.

Medicinal plants are also regularly harvested in the park. Typically, these harvests are sustainable and have a negligible impact on the forest ecology since only portions of the plant are harvested.

Habitations. The number of residences occurring in the park and on land acquired by SAH was estimated through interviews with the local residents. At least 28 residences were found in 5 areas of the park known as 1) Nan Panm, 2) Nan Koulèv, 3) Bwa Grenn, 4) Chenn Kan and 5) Sou Tann. Several of these residences occur outside the park boundaries and on land that is no longer being considered by SAH/HNT. It was intended to conduct a census in order to assess the impact these residences may have on the park ecology. However, HNT decided that this census is the responsibility of CIAT, since the issue of residency and land ownership is related to the land cadaster that is to be completed.

The rural household in Grand Bois typically has a perennial tree-dominated garden near and around the home. Trees provide shelter, shade, food, fiber and wood for construction. Understory plants include coffee, plantain, citrus and vines such as yams, grenadier and mirliton. A nearby field garden producing vegetables, grains and tubercles is also common. Some land is reserved for grazing.

The proximity of the residences to the natural ecosystems is a threat insofar as the flora becomes modified with non-native species that occasionally become invasive. The residences harbor domesticated and feral animals (e.g., cats, dogs, rats) that are major predators of the native fauna.

At such a time that a park management plan is prepared, special attention should be directed to the remaining residences inside the park boundary so that measures can be taken to mitigate and decrease the negative impact on the native ecosystems of the park.

Critical Points of the Sevré trail to Grand Bois. The Klima II project requires the identification of 6 critical points along the trail in order to improve the trail for safety and runoff issues that are caused by the erosion of the soft basalt bedrock. These points were identified as shown in **Figure 16a**. Examples of trail segments at such critical points are shown highlighting the drainage and erosion problems associated with the soft geological substrate (**Figure 16b,c**).

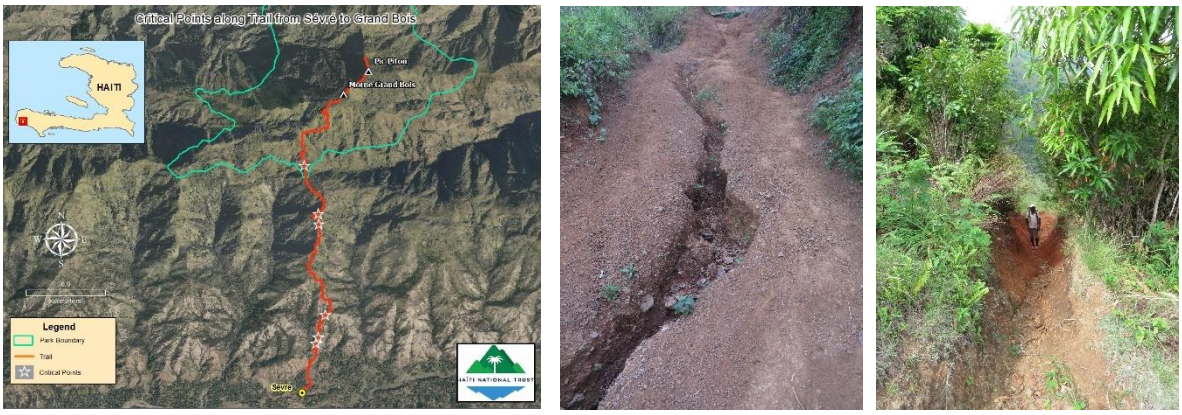

Figure 16. (a) Critical points along the trail from Sevré to Grand Bois. (b) Eroded portion of the trail. (c) Deep gully formed as a result of untreated trail segment.

Features of the critical points are summarized in **Table 5**. The average slope of a 5-m trail segment ranged from 48 – 140% - all beyond the slope thresholds recommended for safe trails. Most of the critical points are where the trail has eroded to such an extent that a ravine has formed, sometimes several meters deep.

Table 5. Features of the critical points along the Sevré – Grand Bois trail.

No.	Latitude N	Longitude W	Elevation (m)	Average Slope (%)
1	18.3455	-74.3047	238	91
2	18.3461	-74.3043	268	70
3	18.3485	-74.3037	380	140
4	18.3577	-74.3044	755	91
5	18.3588	-74.3045	826	77
6	18.3636	-74.3057	909	48

Several trail construction guides are available and should be consulted for proper design, construction and maintenance (National Park Service, 1996; Portland Parks & Recreation, 2009; USFS, nd). The major challenge along this route is the highly fractured and erodible soft basalt rock. The hard limestone rock that is available in the area will be needed to create the rock dams and to reinforce the runoff channels. Timbers of selected hardwoods may also be used as an alternative to rock to create steps along steep slopes. The establishment of vetiver hedges along the contour are a low-cost alternative to stabilize the slopes adjacent to the trail and to retain soil in drainage channels that are exposed to high runoff volumes and susceptible to erosion.

Threatened Species

Several threatened plant and amphibian species in the park were observed and studied during the course of this audit.

Meriania parvifolia. This species was described by Judd & Skean (1987) from its type locality in Macaya National Park. At the time of discovery, it was thought that the species only occurred in that location on the northern slopes of Morne Formon at elevations 1450 – 1800 m. Several small sub populations of the species were discovered in Grand Bois during the course of collecting botanical specimens in 2018. Ajohnson et al. (2018) assessed the species as Endangered due to its restricted range and small population in only 2 known locations in Haiti – Macaya National Park and Grand Bois National Park. The flower of the species is unique and attractive as an ornamental (**Figure 17a**).

To date, 5 sub populations are known within the park (**Figure 17b**). Each sub population is comprised of 2-12 individuals with the largest specimens reaching between 2-3 meters height. Since the species is susceptible to stem wilt when germinated from seed, it is being propagated as stem cuttings. The species sprouts leaves from the cuttings (**Figure 17c**) but fail to root properly in the pots. As such, they do not survive in the field when out planted. The application of the IBA root hormone, purchased and brought to the nursery during this time, will be used to ensure successful rooting.

The species was in flower during this study with several in bud. In addition to a late July - early September flowering period, the species has also been observed to flower in January – February. It may flower in other months as well.

Figure 17. (a) Flower of *M. parvifolia.* (b) Locations of populations in Grand Bois National Park. (c) Stem cuttings sprouting leaves without root development in nursery at Nan Panm.

Magnolia ekmanii. A total of 18 trees were found and measured within a 200-m transect along the ridge trail near Pic Piton (elev. 1250 m). The diameter-at-breast height (DBH) and total height of the trees are summarized in **Table 6** with the size class distribution shown in **Figure 18**.

Table 6. Size class distribution of *Magnolia ekmanii* in the natural forest of Grand Bois park.

DBH Class (cm)	N	Individual DBH (cm)	Individual Heights (m)
0.0 – 9.9	7	3.1, 4.7*, 8.3, 8.5, 9.5, 9.7, 9.9	3.5, 4.5, 4.5, 6.0, 5.0, 5.0, 6.0
10.0 – 19.9	7	10.0, 10.4*, 11.1, 12.3, 15.7, 18.5, 19.6	8.0, 6.0, 5.0, 10.0, 10.0, 7.0, 8.0
20.0 – 29.9	2	22.4, 25.0	6.0, 14.0
30.0 – 39.9	1	36.9	20.0
40.0 – 49.9	1	43.0	8.0
Average		**15.5**	**7.6**
***** Multi-stemmed individuals.			

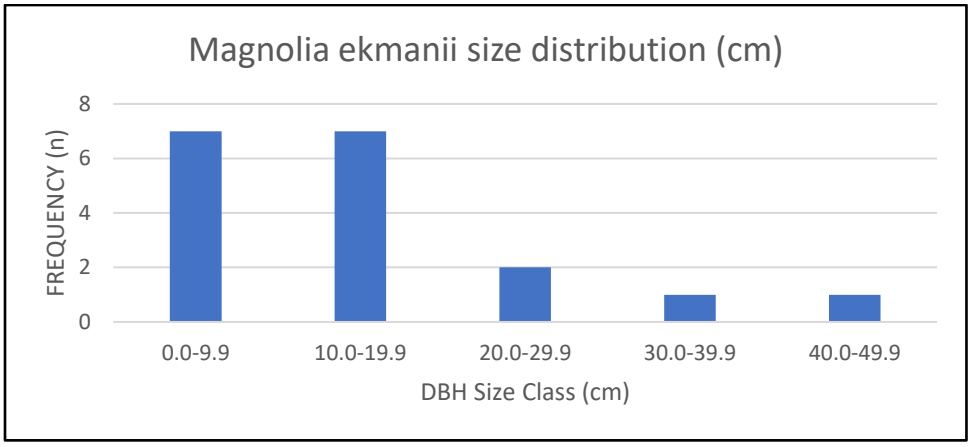

Figure 18. *M. ekmanii* size class distribution in a natural forest of Grand Bois.

The size classes are skewed toward the 2 lowest classes indicating a relatively young age of the population. In other areas of the park where land had been cleared for gardens, the remaining individuals were found to be significantly larger (and likely older) than the average found in a natural forest. Five individuals found near the former residence of Geran Morace, where the owner had cleared land for gardens, ranged from 15.0 – 43.6 cm and averaged 28 cm dbh. Two other individuals found near Bwa Grenn, in another patch of natural forest within the park, measured 10.7 and 32.8 cm dbh.

The poor relationship between trunk diameter and tree height can be explained by damage to the tree crown as a result of wind (e.g., hurricanes, tropical storms), lightning and drought. It does not appear that disease is a factor. The result of a damaged crown results in much side branching and multiple stems. Many large trunked trees are thus relatively short compared with trees that were free from damage. The nonlinear function of tree height as a function of stem diameter is provided by the equation: Y (Height, in m) = 5.17128*ln(DBH, in cm) – 5.18544. The correlation coefficient = 0.76 indicates a strong correlation between stem diameter and total tree height. The largest diameter tree was considered an outlier (due to the broken crown resulting in its short height) and eliminated from the data used to calculate the logarithmic regression (**Figure 19**). Available time limited the sample number. The regression equation would be vastly improved with a greater sample number and only recording non-damaged trees whose height is not impacted by physical damage to the tree.

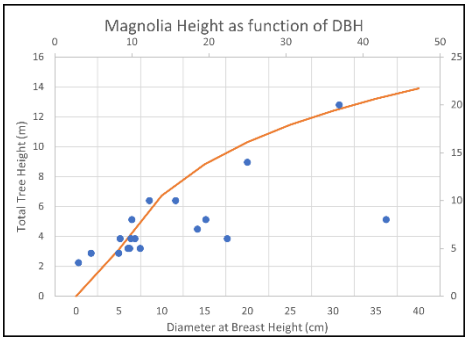

Figure 19. *M. ekmanii* stem diameter and tree height relationship. The equation is Y (Height) = 5.171228 x ln (DBH) – 5.18544. Left scale is the predicted height and right scale is the actual height.

The density of magnolia stems greater than 2-cm DBH in the transect is approximately 90 trees/ha. A previous estimate of the natural population of *Magnolia ekmanii* within the park ranged 200-300 trees (E. Veltjen, pers. comm.). However, the researchers were not able to tally all the natural forests in the park or adjacent areas. It is likely that this count is an underestimate of the species in the Grand Bois area.

A couple of flowers of magnolia were collected and photographed from a large specimen occurring in secondary forest near the old residence of Geran Morace (**Figure 20a**). These represent the latest date of flowers for the species. Peak flowering occurs from late May to early July.

Pinus occidentalis. A small population of this species, endemic to Hispaniola, occurs in Grand Bois National Park. This is the western-most extension of the pine on Hispaniola and likely an important genotype of the species. The current IUCN designation of the species is Endangered, but the species is being reassessed and will likely be considered Vulnerable.

The interest in this species is due to a report by Teodoro Clase (National Botanical Garden, Santo Domingo) in 2018 that the non-native *Pinus caribaea* occurred in the park. As a result, specimens of the local pine were examined during this study from locations in the Nan Panm area (**Figure 20 b, c**). These specimens confirmed that the native *P. occidentalis* rather than *P. caribaea* occurs is present. Incidentally, the species was included in the Nan Panm nursery in May 2019. Several dozen bags were transplanted with wildings dug up nearby. However, none were observed in the restoration area of Nan Panm during this study and it is uncertain whether any individuals were actually planted in the field. It is a rare species in this region of Haiti and should be included in restoration efforts.

Figure 20. (a) Late flower of *M. ekmanii.* (b) Mature *P. occidentalis.* (c) Young *P. occidentalis* regenerating naturally in the Nan Panm restoration area.

Other threatened plant species. Several other threatened plant species were studied during this study. A cluster of mature individuals of the wild star anise (*Illicium hottense,* EN) was observed in dense primary forest near Bwa Grenn, along the trail to the recent burn site. Immature fruit was found on the trees which will be collected later in September for propagation. It was not possible to visit two rare palm species due to time constraints and the remoteness of the populations. The seed of *Geonoma pinnatifrons* subsp. *oxycarpa,* locally known as panache, was collected in March 2023, and sown in the nursery. However, it failed to germinate (as of August 2023) and the nursery person in charge of sowing the seed explained that the seed likely rotted in the soil. Also, attempts to harvest the ripe seed of *Calyptronoma rivalis* (chapelèt) have not been successful to date. According to seed collectors, the fruit is relished by birds and rats leaving none to be harvested if the fruits are not protected. Protection with mesh netting has not been tried yet but is something to consider for future harvests. The old polyethylene shade cloth currently being used in the nursery could be used for this purpose, since it is being replaced by old palm fronds of *Prestoea* as a more appropriate and economic shade material.

Amphibians. The park has a high diversity of amphibians. Eleven species were observed either visually or by their vocalizations, as summarized in **Table 7**. An excursion was conducted to the Kay Ediron spring, where the Critically Endangered Tiburon Stream Frog (*Eleutherodactylus semipalmatus*) was first re-discovered in June 2011. At that time, the land above the spring had been cleared for a yam and sweet potato garden and it was feared that the drastic change in habitat would harm the frog population in the spring. This area is now re-vegetated with a vigorous cover of secondary forest. The resulting shade cover and more humid conditions of the stream habitat has vastly improved and the discharge rate of the spring is substantial. While we failed to find the stream frog, it is recommended to continue monitoring the population, especially in the evenings after sundown. The frog is relatively common in the streams flowing west of the central ridge trail.

Table 7. List of amphibian species recorded in Grand Bois National Park during this study.

Species	Common Name	IUCN Status	Notes
Boana heilprini	Hispaniolan Green Treefrog	VU	Seen and heard in the springs and streams; one of the more common tadpoles seen in stream pools.
Eleutherodactylus abbottii	Common Chirping Frog	LC	Heard
Eleutherodactylus bakeri	La Hotte Bush Frog	CR	Heard
Eleutherodactylus conouspeus	Yellow Cave Frog	EN	Heard
Eleutherodactylus eunaster	La Hotte Whistling Frog	CR	Heard
Eleutherodactylus inoptatus	La Hotte Giant Frog	CR	Seen and heard in secondary forests; commonly seen crawling on ground.
Eleutherodactylus lamprotes	Hispaniolan Orange-legged Frog	CR	Heard
Eleutherodactylus nortoni	Spiny Giant Frog	CR	Heard
Eleutherodactylus wetmorei	Tiburon Whistling Frog	VU	Heard
Eleutherodactylus sp. 'bay'		CR	New species, similar to *E. apostates.* Seen near Pic Piton.
Osteopilus vastus	Hispaniolan Giant Treefrog	VU	Seen resting on trunks of *Prestoea acuminata* var. *montana* & *Magnolia ekmanii.*

FINDINGS AND RECOMMENDATIONS

The environmental audit of Grand Bois National Park was conducted during August 3 – 12, 2023. This was the first time that the park had been assessed for a wide range of parameters to measure the current status and impact of conservation and restoration activities. The findings and recommendations have broad implications in the ongoing efforts by HNT to manage Grand Bois as a "national natural park".

Spring and Riparian Ecosystems

The springs and streams that flow throughout the park are an extensive and important ecological feature of the park. It was apparent during field activities that the Lacour (2015) study vastly undercounted the network of springs in the park. It would be challenging to determine the actual number since many of the springs are seasonal and others are difficult to differentiate from seepage areas due to the rocky and precipitous terrain. It is estimated that over 10 km of streams occur in the park and many of these streams are fed by numerous springs.

The streams and springs range from highly disturbed to lightly disturbed and approaching pristine. The spring at Kay Geran is likely the most disturbed and contaminated spring in the park. The high *E. coli* and coliform count in the water support the following recommendations:

- Water must be boiled or treated chemically prior to drinking.
- The practice of using fertilizers in the tree nursery upstream of the spring should be modified in order to decrease and possibly eliminate this source of contamination to the spring water.
- Potable water kits should be installed, beginning with the compound at Clairzida Dasny and extending to other households within the park. An additional benefit to HNT is to build goodwill by providing safe drinking water for the Grand Bois community.

The volume of freshwater generated within Grand Bois National Park is among the most important ecosystem services provided to downstream communities. The furthest downstream site (Site 4) measured a discharge volume of about 164 liters/second, equivalent to more than 14 million gallons per day. While it was not possible to estimate the total discharge volume of freshwater from Grand Bois, this parameter would be an important one to estimate in the future.

In terms of habitat quality, the springs and streams range from disturbed to relatively pristine. The main sources of disturbance include the harvest of *Prestoea* for palm thatch, the harvest of freshwater crabs, the past use of the stream banks for agriculture and the presence of non-native invasive plant species. The recommended actions are to

- Remove and burn the invasive plants along the stream buffer areas.
- Create standards and controls for the harvest of wildlife and plants in the park.
- Continue to restore the riparian ecosystems by establishing a diversity of native trees, shrubs and herbs.

Forest Cover

The natural forest cover in the park appears to be stable in terms of deforestation. The trend in deforestation rates are on the decline for the park as a whole. However, where deforestation occurs, it is mostly in the northern and southwestern portions of the park where land pressure is greatest to clear the forest for gardens. Wildfires and natural disasters such as hurricanes, earthquakes and landslides have played an insignificant role in the loss of forest cover, especially compared to other parks such as Macaya National Park. The areas cleared are relatively small and the forests have recovered rapidly if cultivation of the parcels is halted immediately after disturbance. Recommended actions include:

- Continual monitoring of the park with Global Forest Watch and Planet platforms.
- Follow up with those responsible for forest clearing with warnings and a set of remedial activities to restore the forest.
- Training of park guards in proper procedures in alerts and response to land use violations, including wildfires, tree cutting, gardening and livestock grazing activities.

Restoration Areas and Tree Nurseries

Restoration on lands formerly cleared and used for agriculture began in 2019, but significantly increased with new park management in 2022. Restoration activities have increased in terms of the area treated, the diversity of native species used and the modes of establishing the woody plants in the field. Nursery procedures and overall management have greatly improved over time. However, there is still room for improvement in terms of both the production of seedlings and their out planting in the field. The following areas of managing the tree nurseries in Grand Bois should be considered:

- Shade cloth. Dead palm fronds are being used as a substitute for polyvinyl shade cloth, thus reducing plastic waste and expensive costs of importing the material from the Dominican Republic. Once the palm fronds are no longer useful, they should be shredded and composted, to be mixed as part of the potting medium.
- Nursery bags. Biodegradable bags are being experimented with as a substitute for plastic bags to reduce plastic waste and improve survival and growth rates in the field. These bags are intended to keep the root ball intact when out planting so that the root system is not disturbed during handling. It remains to be seen if it eliminates 2 other major problems of plastic bags - the development of circular roots and the tendency of tap roots to penetrate the nursery soil. Both problems can be remedied with proper nursery and out planting procedures.
- Tree seed. Seed of a greater diversity of species and a greater number of mother trees per species is recommended in order to increase the genetic diversity of seedlings in the restoration areas. Mother trees are selected based on their health and form, indicating resistance to damage related to disease, drought and high winds. It is the tendency of seed collectors to collect as much seed as possible from a single tree. However, it is much better to collect fewer seeds from a greater number of trees, despite the higher costs in doing so. These seeds are then mixed together and sown in the nursery.
- Potting Medium. The soil being used in the nurseries is too heavy and clayey as well as limited in terms of its fertility. Heavy soils decrease root development and limit the number of seedlings that can be carried to the restoration sites, sometimes over long distances. The potting medium

should be no more than 20% soil with the remainder as organic material from decomposed vegetation. The organic material is much lighter, increases aeration for better root development and is significantly more fertile for faster growth in the nursery.

- Compost. Animal manure is currently being incorporated directly into the soil as the sole source of additional organic material and nutrients. However, it would be much better to use the nitrogen in the manure to "cook" and speed up the decomposition of compost piles that are a mixture of kitchen waste, garden waste and forest litter containing native fungi and bacteria. Temperatures inside compost piles should reach 40-50 ◦C if moisture and nitrogen are not limited. An added benefit is that if the animal manure is properly handled and moved to the southern slope of the Nan Panm nursery, a major source of *E. coli* contamination in the Kay Geran spring water would be eliminated.
- Propagation of Stem Cuttings. Improving the techniques of propagating stem cuttings will require using root hormone for difficult-to-root species. This is important for species that are difficult to harvest for seed or species for which there are insufficient number of wildings. Candidate species for this approach are *Meriania parvifolia, Brunellia comocladiifolia, Turpinia picardae* and *Cecropia schreberiana.*
- Propagation of Branch Cuttings. Many species are propagated directly in the field using branch cuttings. Such species include *Comocladia, Spondias*, *Ficus* and others. Success is correlated directly with the diameter of the branch cutting for most species. It was observed that many branch cuttings that failed to survive in the field were too small and could only survive if planted in moist soil or with frequent rains. A 3-cm minimum caliper should be adhered to in order to guarantee that sufficient reserves are available in the cutting to survive up to 1 week of drought.
- Seedling mix for out planting. When hauling the seedlings to the restoration site, try to mix as many species as possible being carried per person so that there is less likelihood that the same species are planted together.

The survival of the trees that were measured in the Nan Panm restoration area was excellent – generally above 90% for the hardwood species and somewhat lower for the palms. The growth of the trees were found to be moderate, typically under a meter/year height growth, due to the relative infertility of the lateritic and serpentine soils combined with the intense competition of herbaceous species, primarily grasses that are both native and non-native. Restoration can be improved with the following recommendations.

- Maximize the diversity of species of neighboring trees and avoid monocultures of planted trees composed of a single species.
- Increase the spacing between the longer-lived hardwood species (e.g., *Magnolia ekmanii, Prunus* spp.) since a large number of these seedlings will have to be thinned within the next 3-5 years in order to balance the diversity of species and allow succession of species that are better adapted to the shady and mesic conditions of a developing forest. Spacing, assuming 90-95% survival, should be a minimum of 5-6 m x 5-6 m for large trees. Fill in the space with branch cuttings or seedlings of native shrub species and slower growing palms.
- Mulch the base of the seedlings with a heavy layer of grasses to conserve soil moisture and reduce weed competition. If non-native grasses are used, carefully remove the seed heads to avoid contaminating the soil and burning the seed heads.

- Remove invasive species during their flowering period when they are more noticeable and prior to fruiting to avoid contaminating the soil with seed.
- When thinning is necessary, remove trees of the same species in favor of maximizing species diversity, including the naturally regenerated species such as *Piper, Miconia Ocotea, Myrica* and *Myrsine.* In the case of *Magnolia ekmanii*, the final density of mature individuals should approach 100 – 150 trees ha per ha.
- Analyze the fixed-point aerial photos in 3-5 years in order to measure change in vegetation cover both in terms of tree canopy cover as well as species diversity.

Threats to Natural Habitats

The major threats to the natural habitats are the trails and traffic patterns in the park, livestock grazing, gardens, forest extraction activities, human residences and non-native invasive species. Livestock grazing varies as a threat, increasing during the dry season and tapering off during the rainy season. Other threats, such as the harvest of palm thatch and crabs and the use of trails throughout the park appear to be more constant throughout the year. Many of these threats will change in magnitude once CIAT completes the land cadaster and HNT/SAH finalizes the land titles. Recommendations for immediate consideration by HNT/SAH include the following.

- Explore the creation of an alternate route around the eastern boundary of the park to reduce traffic through the main North/South trail that passes through Pic Piton and Morne Grand Bois. This trail should be built under contract with the current landowners who would then have a stake in the trail and be responsible for its upkeep in collaboration with the park.
- Explore the feasibility of eliminating trails that traverse the intact forests. Replant these trails with native vegetation to reduce the risk of erosion.
- Establish a policy regarding the harvest of forest products such as palm thatch and wildlife. Train the park guards in the best approach to implement this policy.
- Establish a line of communication with all active garden owners and livestock grazers inside the park boundary and on lands acquired by SAH in order to halt all future activity, to reduce the risk of wildfire and to plan future activities such as ecosystem restoration. A policy for future infractions should be established and park guards should be trained in the best approach to implement this policy.
- Develop a plan with each of the households remaining on SAH/HNT land to control domestic and feral animals, including the black rat (*Rattus rattus*), eliminate sources of invasive species and increase the use of native trees and shrubs, such as melliferous species used in honey production.
- Begin study on trail improvement plans for the 6 critical points along the trail from Sevré using locally sourced labor and material. Some material (e.g., vetiver grass) may have to be sourced outside the project area.

Threatened Species

Grand Bois National Park has dozens of threatened plant and animal species that have been assessed for the IUCN Red List. In some cases, it is the only known location of the species. This study revealed a new

threatened species – the endemic freshwater crab, *Epilobocera haytensis.* It is assessed as Vulnerable and is being harvested in the park for food.

The 2 threatened tree species that were studied – *Meriania parvifolia* and *Magnolia ekmanii* – have healthy populations. Five sub populations of *M. parvifolia* were located in the park, though it is likely that the species occurs throughout the park. It is not a common species and is typically found in the forest understory as a large shrub. *Magnolia ekmanii* was studied for its size distribution and density in a parcel of old-growth forest. The density of the species in a natural forest is about 90 trees per hectare and far less than the density being planted in the restoration areas. This suggests that several thinnings in the restoration areas will be required in the future as the species develops in tandem with the other native tree species. The mature height of magnolia in the natural forest was quite variable in terms of its relationship with stem diameter. Many old trees were damaged by wind, drought and lightning thus stem diameter, rather than height, is a better indicator of tree age.

The vertebrate and invertebrate species of Grand Bois were not studied in detail. The majority of the threatened amphibians were observed and this study was the first in Grand Bois to collect and to begin identifying invertebrates. Recommendations regarding the threatened species include the following.

- Improve the propagation technique for *M. parvifolia* by utilizing root hormone to ensure the successful rooting of stem cuttings.
- Increase the spacing of *M. ekmanii* in the restoration areas in order to reduce the amount of thinning required in the future to achieve the natural density of the species (100 – 200 trees per ha).
- Continue to expand the number of threatened plant species being propagated in the tree nurseries and planted in the restoration areas.

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ANNEX 1. Aquatic Report Methodology.

Aquatic Survey Methods. Land use and land cover as well as habitat, flora, and fauna encountered on the way to each site is noted. At each sampling site, field data forms are filled out to record site location and access, water chemistry, substrate condition, fish, macroinvertebrates, aquatic vegetation. Velocity and discharge volume of springs and streams are estimated using the float method. Photographs are taken of all observed aquatic flora and fauna when possible, as well as examples of the prevalent and pertinent land use and land cover.

Workflow. Once a site is confirmed by maps and GPS, a water sample is collected for bacteria, then *in situ* water quality measured before entering the water or causing disturbances that could affect water chemistry. After all water quality measures and samples are completed, macroinvertebrates and fish area collected for later identification. Instream channel conditions are measured and recorded in the vicinity of the water quality samples. Finally, land use and cover is assessed.

Fecal coliform – Presence of *E. coli* indicates fecal contamination.

1. From the shore, a 100ml grab sample of water is obtained with a sterile Whirlpak, with care taken to avoid touching the lip or inside of the bag.
2. Immediately, using a sterile pipette, a 1 ml sample is transferred onto a 3M petrifilm labeled with the site code, date, and time, which is also recorded on the field form.
3. The petrifilm is placed between two pieces of cardboard and secured for later incubation following the methods of Metcalf and Stordal (2010) which suggests incubating on the body for 10 – 18 hours by placing in the waistband of the pants. However, due to the long days spent in the field this is not practical. The petrifilm will be incubated by placing near the body during sleep.
4. 18 to 48 hours after sample placement on petrifilm, the number of blue colonies with gas bubbles (*E. coli*), number of red colonies with gas bubbles (non-*E. coli* coliform bacteria), and number of red colonies without gas bubbles (non-coliform Gram-negative bacteria) are recorded (Metcalf and Stordal 2010). These numbers are used to classify the site as to risk of disease from fecal contamination as indicated in Table 1. Because it won't be possible to incubate the petrifilm on the body, longer time will be needed before recording the colony counts – about 40 to 48 elapsed hours after the samples are taken.

Table 1. Risk of disease from *E. coli* presence in 1 ml of water sample (Odonkor & Mahami, 2020).

Risk level	*E. coli* colonies
Safe	0
Low	0.1 – 1.0
Medium	1.1 – 10.0
High	> 10.0

Nutrients and Heavy metals. We will attempt to measure nitrate, nitrite, phosphorus, pH, alkalinity, and heavy metals with test strips at the site following instructions provided on the test kits (LaMotte, WaterWorks and SenSafe^{R} products). High levels of nitrogen causes excess algae growth which can, when it dies off, depletes water oxygen, killing fish and other aquatic organisms. Heavy metals and excess nitrogen/phosphate levels is a product of soil conditions and human inputs.

***In situ* Water Temperature.**

1. At each sample point, water temperature will be taken with a tube thermometer at least 30 cm of water depth. This temperature will be compared with ambient air temperature. The temperature differences will reflect the hydrogeology and source of water.
2. The following parameters were measured at each site: water temperature, pH, alkalinity, dissolved oxygen (DO) and water clarity as early in the day as possible (due to the desired DO daily minimum). Samples will be taken at the water's surface (@ 30 cm depth).
3. Measurements along with coordinates are recorded on the appropriate field sheet.

Macroinvertebrate Survey.

1. At the sampling site, using a 500-micron D-frame net, macroinvertebrates will be collected from a variety of habitats for a total of 2 minutes, in order to standardize sample effort across sites. The upstream rocks and woody debris in the water flow are brushed off by hand to dislodge the specimens. The soft substrate is sampled by gently disturbing the top cm with a foot, just upstream of the net.
2. The net contents are emptied in a sorting tray and the organisms are collected in proportion to their abundance in the sample, so that all taxa are collected.
3. A representative sample of specimens are preserved in diluted 95% ethanol for later identification, along with a label noting site and date.
4. The remainder of the sample is returned to the site.

Fish and Terrestrial Vertebrates.

1. With the macroinvertebrate net, an attempt will be made to catch any fish seen at the sampling site.
2. Specimens will be positioned on the sorting tray to photograph their left side, next to a ruler for scale. The site number and possible name will be included on a piece of paper under the ruler.
3. A representative of each taxon will be preserved in formalin or ethanol.
4. The specimen will be recorded on the field form.
5. Local assistants will be recruited to help collect specimens and share their knowledge of fish and invertebrates they might have collected for food or other uses.
6. Vertebrate and plant species of concern will be noted for their presence/absence.

Physical habitat. Physical habitat is evaluated using a subset of protocols and forms from the USEPA National Rivers and Streams Assessment - Wadeable Streams (USEPA 2017). See relevant sections in those documents for protocols. Data includes substrate cross-sectional information to capture depth and substrate type, bank measurements to capture channel width and bank height and angles, and land use notes. The densitometer will measure canopy cover for the buffer areas of the springs and streams.

ANNEX 2. Fixed point aerial photos for each of 6 locations to study changes in vegetation cover as a result of ecosystem restoration.

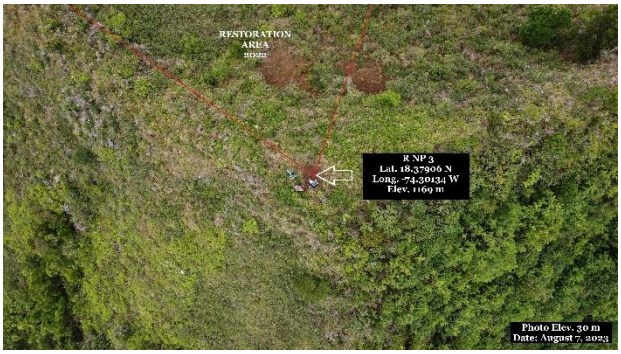
Nan Koulèv 1

Nan Koulèv 5

Nan Panm 1

Nan Panm 2

Nan Panm 3



Nan Panm 4