2017

BEST 2.0 Regeneration Study

Jessie Foest, 2017

Acknowledgements

Firstly, I would like to thank Echo's director Lauren Schmaltz and general manager Quirijn Coolen for providing me with the precious opportunity to complete my MSc internship within their organization. It has been most valuable for me to learn about nature conservation outside of the University's classrooms, to test my skills, and, indeed, to be able to actively participate in the restoration and conservation of the wonder that is Bonaire's nature. Moreover, I would like to express my sincere gratitude to Nick Verhey, who taught me the native flora with such joy and patience, and without whom I could not have completed the baseline inventories that needed to be performed for the current project.

Furthermore, I would especially like to thank to prof. dr. Pieter Zuidema, my academic and personal supervisor during this internship, on who I could count whenever I needed support.

My stay at Echo Dos Pos would not have been the same without the wonderful volunteers who lived with me and who worked so very hard to protect the Yellow-shouldered Amazon Parrot and Bonaire's ecosystems. Thank you, Zac Maynard, Adam Curry, Izzy Sheppard, Georgina Standing, Carina Kmet, and my love Joep van Dormolen.

Contents

Introduction

Habitat degradation and destruction, as well as the introduction of invasive species remain amongst the key threats to the world's biodiversity (Gurevitch & Padilla, 2004; Morrison & Mathewson, 2015; Secretariat of the Convention on Biological Diversity, 2014; Tilman, May, Lehman, & Nowak, 1994; World Resources Institute, 2005). Unfortunately, Bonaire's ecosystems have not been spared from these anthropogenic influences; Freitas et al. (2005) describe that during the colonization by Europeans, Bonaire and Klein Bonaire's trees were (selectively) felt to such an extent that the islands were almost completely cleared of their tree cover. Moreover, herbivores (i.e. goats (*Capra hircus*), sheep (*Ovis aries*), donkeys (*Equus africanus africanus*), pigs (*Sus scrofa*)) were introduced in order to build (and feed) the colony, and were left to roam the island (Freitas, Nijhof, Rojer, & Debrot, 2005; Hartog, 1978). Moreover, Bonaire's history includes periods of extensive charcoal burning, *Caesalpinea coriaria* seed collection – as these seedpots are a natural source of tannin, *Aloe* and salt production, as well as increasing tourism (Freitas et al., 2005; Stoffers, 1956; Westermann & Zonneveld, 1956). This has left a significant mark on Bonaire's vegetation and, consequently, wildlife: currently, the vegetation is dominated by a small number of grazing resistant species, and palatable species – on which fruits many birds depend - have become scarce (Freitas et al., 2005; Williams, 2009).

Nowadays, the – be it illegal – roaming of introduced herbivores remains the greatest threat to Bonaire's terrestrial biodiversity (Debrot, Graaf, Henkens, Meesters, & Slijkerman, 2011). In 2015, it was estimated that the goat population on Bonaire ranged between 19.800 and 52.600 (Lagerveld, Debrot, Bertuol, Davaasuren, & Neijenhuis, 2015). Many of these goats are owned by Bonairians since they are a cheap source of food and income if they graze on communal land. Buying food on Bonaire is expensive, making it more attractive to own goats in this way (Gogaardt, Jong, & Heide, 2015). Goat owners do seem to be willing to constrain goats, but buying feed and building fences is costly. Fortunately, there are some local initiatives to reduce the costs of holding goats sustainably (Gogaardt et al., 2015). Data on the exact number of donkeys and pigs on the entirety of Bonaire are lacking, but are deemed relatively small; a recent study estimates that there are about 200 donkeys and 60 pigs present in the area of Washington Slagbaai National Park and Labra-Brazil, compared to 11.000 goats (Geurts, 2015).

To counteract the negative effects of anthropogenically induced habitat degradation, active measures can be taken. Human involvement might also accelerate the restoration of vegetation composition, as the harsh climatic conditions of Bonaire might limit the speed of natural development. Reforestation is one of the most important tools for forest habitat restoration, and Echo has successfully applied for funding from the European Commission through BEST (Voluntary scheme for Biodiversity and Ecosystem Services in Territories of the European overseas), to execute a habitat restoration project in the Roi Sango valley (Image 1). Due to Roi Sango's ecological importance – as exemplified by its designation as Important Bird Area (IBA-10) and Key Biodiversity Area (KBA-2 and KBA-3) – the project can especially benefit native and migrating birds by increasing the food availability year-round. Moreover, the project would aid the coral reef, through a reduced sediment influx (Borst & de Haas, 2005; Oleson et al., 2017). Besides the ecological impact of the reforestation, the project aims to create public awareness for the importance, the degradation and vulnerability of Bonaire's tropical dry forest.

The project has started in June 2017 and includes fencing off the 26 hectare valley area, removing exotic herbivores such as goats, donkeys and pigs, as well as planting 1.000 rare native tree species. To monitor the long-term successes of natural regeneration after exclusion of invasive herbivores, a comparison study is included in the project. The purpose of the current report is to propose the method of this study.

Firstly, a further elaboration on Echo and the Roi Sango area, including its vegetation, will be provided. Then, the report will turn to the evaluation plan, where the proposed study's objectives, and methods will be discussed. After this, the results of a baseline study investigating the quality of plot selection for the future study will be presented and examined.

Image 1: Overview of the Northern part of the lower valley of Roi Sango.

Echo

Echo was founded in 2010 by Dr. Sam Williams and has as main goal to safeguard a healthy population of the Yellow-shouldered Amazon parrot (*Amazonia barbadensis*) on Bonaire. Echo therefore conducts research to understand the ecological and human factors that threaten parrots and establishes conservation initiatives that provide long-term solutions for parrots and people. The Echo team operates from the Dos Pos conservation field camp located inside a Birdlife International Important Bird Area.

Conservation management of Echo focusses on a reduction of poaching and illegal pet trade, changing perspectives towards the Yellow-shouldered Amazon parrot, building community support for conservation, reducing the habitat degradation by non-native species such as donkeys, goats, and pigs and restoration through reforestation of the dry-forest habitat of the parrot on Bonaire.

Many of Echo's focus points are reflected in the project. Namely, whilst planting fruiting vegetation will directly contribute to parrot wellbeing, the project also involves the community by hosting a tree planting event where local people are invited to help plant native trees. This direct involvement in the project could help stimulate a sense of pride among locals about Bonaire's nature, and allows for an opportunity to raise awareness about the state of the ecosystem and its importance. The reopening and extension of walking trails, which allows everyone to experience the unique habitat, could further increase community support.

Roi Sango

General information

The project area, the natural heritage site Roi Sango, is situated in a unique canyon and is part of a large watershed (N.B. a 'Roi' is a local term for a seasonal stream or watershed which is temporary inundated during and after heavy rains).

Ecosystems

In the Roi Sango watershed, classified in Freitas et al. (2005)'s work as 'Higher Terrace and Plateau land (TH)', two clearly distinguishable ecosystems (or, more specifically, sublandscape types) can be identified (also see Image 2). On the higher terrace, which consists of mostly inaccessible sharp limestone rocks, the sublandscape type TH1 (*Haematoxylon – Croton,* following Freitas et al. (2005)) is found. This type consists of hardy but rare trees, such as the Wayaka shimaron (*Guaiacum sanctum;* Endangered, (IUCN, 2017)) and the beautifully flowering Kibra hacha (*Tabebuia billbergii*) (Image 3). The sublandscape type in the lower valley, TH2 (*Erithalis-Bourreria Roi*), is a habitat unique to this particular area, covering only 0.1% of the island's surface (Freitas et al., 2005). In the next chapter, we will turn to the vegetation types that make up these landscape types.

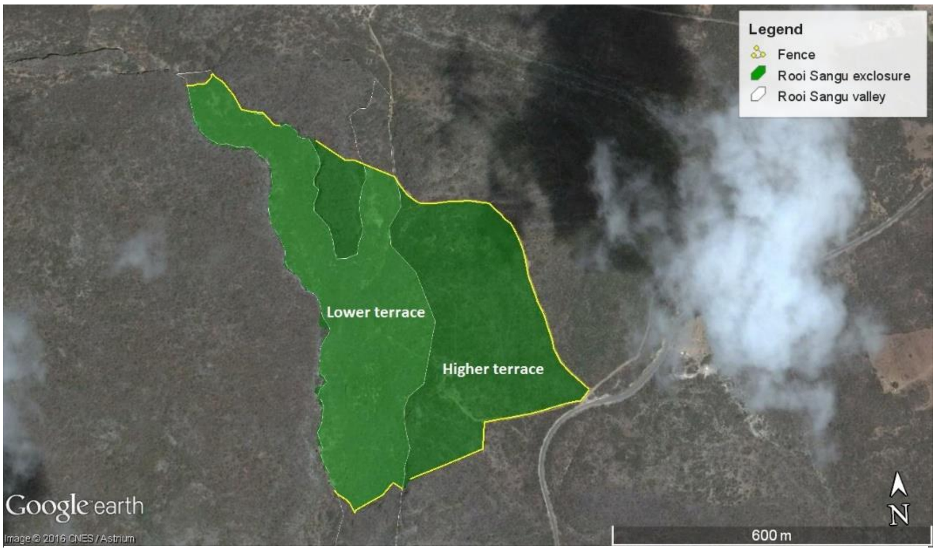

Image 2: Overview of the Roi Sango area and its terraces.

Wildlife

Besides housing rare tree species, the area is important for wildlife; birds (e.g. parakeets (*Eupsittula pertinax*), nightjars (*Caprimulgus cayennensis*), doves and pigeons (*Columbina passerine, Leptotila verreauxi, Patagioenas corensis, Patagioenas squamosa, Zenaida auriculate*), orioles (*Icterus nigrogularis*), yellow warblers (*Setophaga petechia*) and flycatchers (*Elaenia martinica, Myiarchus tyrannulus, Sublegatus arenarum, Tyrannus dominicensis*)) are frequently observed in the area. Moreover, owls (*Tyto alba*) and parrots (*Amazona barbadensis*) have been known to nest there. Furthermore, the area is a safe-haven for Bonaire's endemic wildlife (e.g. pearly eyed thrashers (*Margarops fuscatus*), Blau blau lizards (*Cnemidophorus murinus ruthveni*), and the Bonairean Anole (*Anolis bonairiensis*)) as well as for migratory birds such as the blackpoll warbler (*Dendroica striata*), saffron finch (*Sicalis flaveola*) and the American redstart (*Setophaga ruticilla*). Additionally, crustaceans (landcrabs, hermit crabs), reptiles (Iguanas (*Iguana iguana*), and compost lizards (*Gymnophthalmus lineatus*), snails (*Cerion uva*), bees and bats thrive in the area.

Image 3: On the left, a flowering *Tabebuia billbergii* and on the right, the *Guaiacum sanctum* (Blue oceans 2016; Dios 2017).

Geography

Roi Sango consists of a narrow, steep sided and rocky valley with two Limestone outcroppings. The gorge is surrounded by a limestone plateau, originating from the late Tertiary (the 'Seroe domi' formations which formed in the Neogene period) and/or Quarternary period (Buisonjé, 1956; Grontmij, 1967; Koomen, Dorland, & Makaske, 2012; Westermann & Zonneveld, 1956). The geological formation of the valley seems to be the result of various processes; the limestone plateau seems to have been deposited when water levels were low, and subsequently upheaved by tectonic movements (Hippolyte & Mann, 2011). The gorge is likely a result of erosion that took place in this watershed (Buisonjé, 1956).

Conservation

Intact Roi systems offer important ecosystem services, but are scarce on Bonaire: only 0.3% of land is comprised of this landtype (Freitas et al., 2005). Regulating services of major importance to the island's economy and aquatic wildlife are erosion prevention and sediment retention. The combination of porous limestone and a lush vegetation cover, especially in the upper valley, prohibits excess water to drain directly into the ocean – as both factors increase the permeability of the soil (Borst & de Haas, 2005). Moreover, vegetation stabilizes and covers soil which prevents soil erosion, resulting in less sediment flowing into the ocean (Borst & de Haas, 2005). Without such a vegetative cover, the valley has the potential to become an erosional drain. This could have a devastating effect on the coral reefs which are exceptionally abundant in the area and are a major tourist attraction (Oleson et al., 2017).

To achieve adequate nature protection of these valuable systems, not only the designation of conservation areas and the eradication of the main exotic herbivores (i.e. goats, donkeys and pigs) that threaten regeneration are required, also a system of corridors and buffer zones should be realized (Campbell & Donlan, 2005; Freitas et al., 2005; Gutzwiller & Barrow, 2003). The protection of Roi Sango through Echo's project would serve as an important step in the development of such a corridor; the Roi Sango area is part of a chain of reforestation areas realized by Echo through funding support from the local government (Image 4).

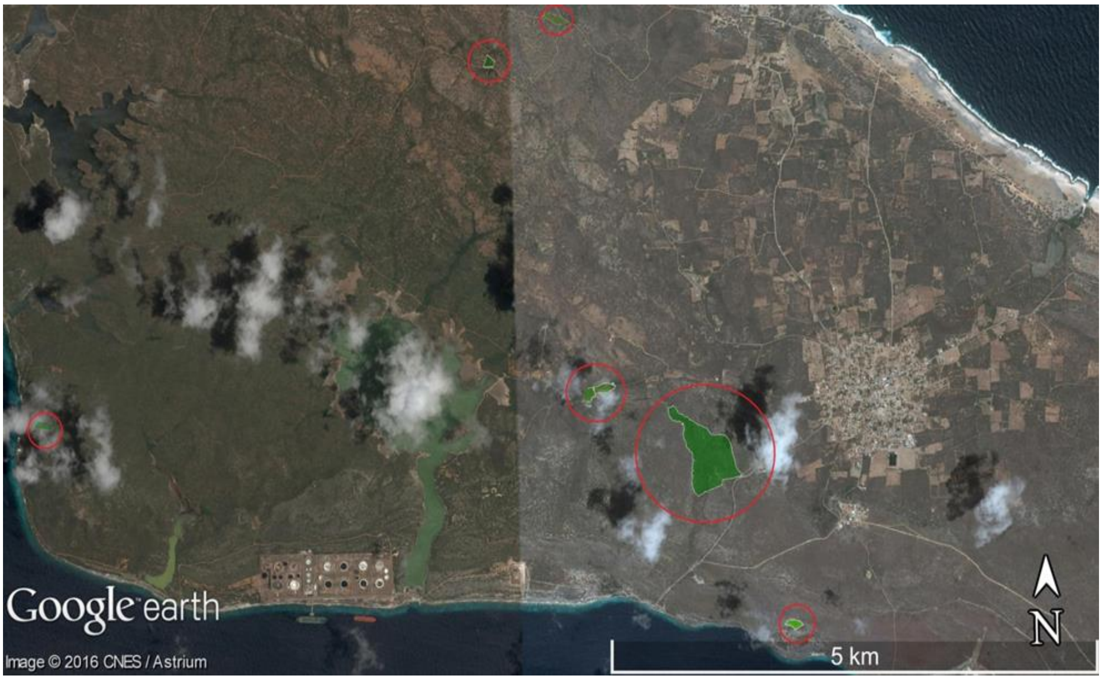

Image 4: Image of Northern Bonaire with existing and planned reforestation areas highlighted. The large green area central to the smaller sites is the proposed site for this project.

Vegetation types and Soils

In this section, vegetation type observations made by made by Freitas et al. (2005) will be compared with Echo's own observations of vegetation composition (and the soils on which they grow) within the exclosure area. Echo's observations, in turn, will be compared with those of Freitas et al., as to update the record of the current vegetation in the area.

Earlier observations by Freitas et al. (2005)

As can be observed on Image 6 – and as was mentioned earlier under '*Ecosystems'* – Freitas et al. (2005) have classified the Roi Sango area as Higher terrace and Plateau land featuring a *Haematoxylon-Croton* (TH1) terrace and a *Erithalis-Bourreria* (TH2) Roi. The TH1 sublandscape type is made up by various vegetation types. The main vegetation type is the *Haematoxylon-Antirhea* type, but the *Cordia-Melochia* and the *Croton-Haematoxylon* type are also regularly found here. More infrequently, *Coccoloba-Metopium* and *Aristida-Jatropha* occur. The accompanying vegetation type of TH2 is *Casearia-Bourreria.* Freitas et al. (2005) write that the average height of the trees in the gorge is above average for this vegetation type and for the island itself.

Echo's observations

Based on our observations, 4 distinct habitat types can be identified, namely, that of the higher valley, higher terrace, lower valley and slope & higher terrace (Image 5). In the next sections, the vegetation in each of these habitat areas will be described. In table 1, the actual and relative size of each area as well as the dominant species present in each area can be found,. In table 2, an overview of all species and their relative abundance per habitat is provided.

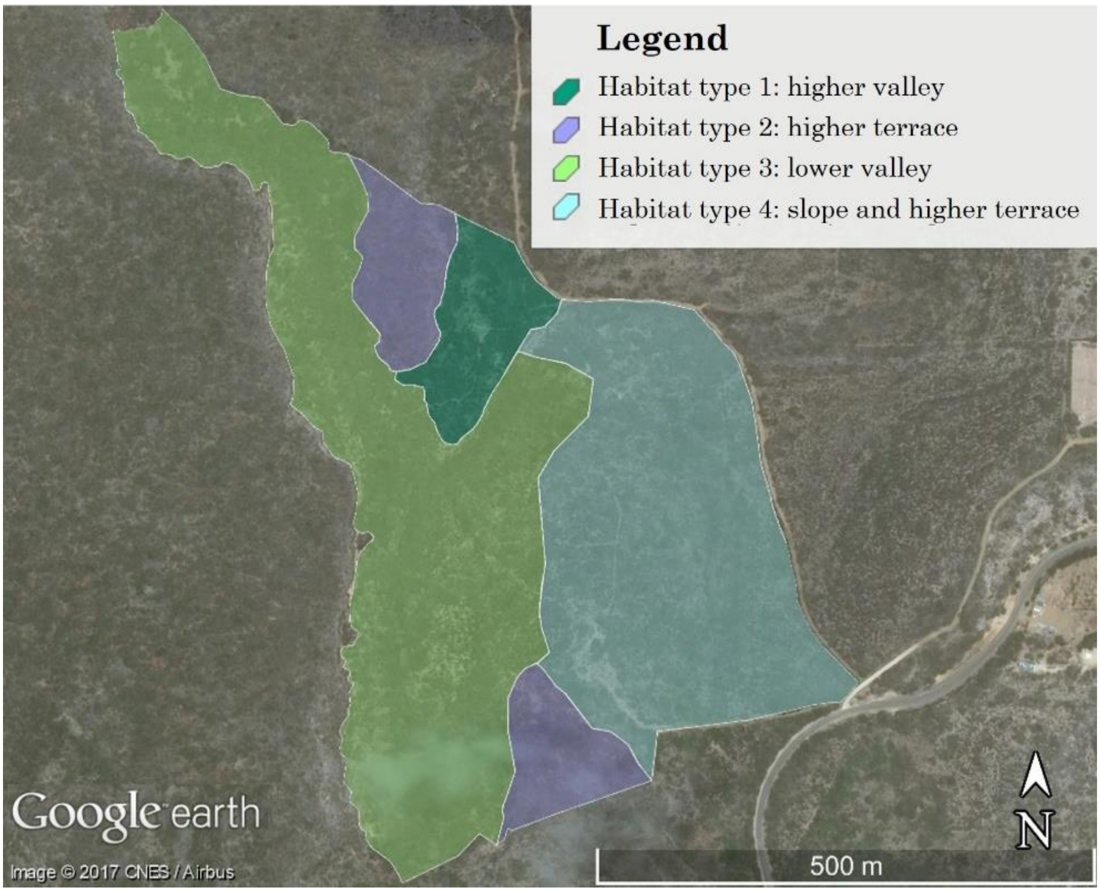

Image 5: Habitat types in the Roi Sango project area as observed by Echo.

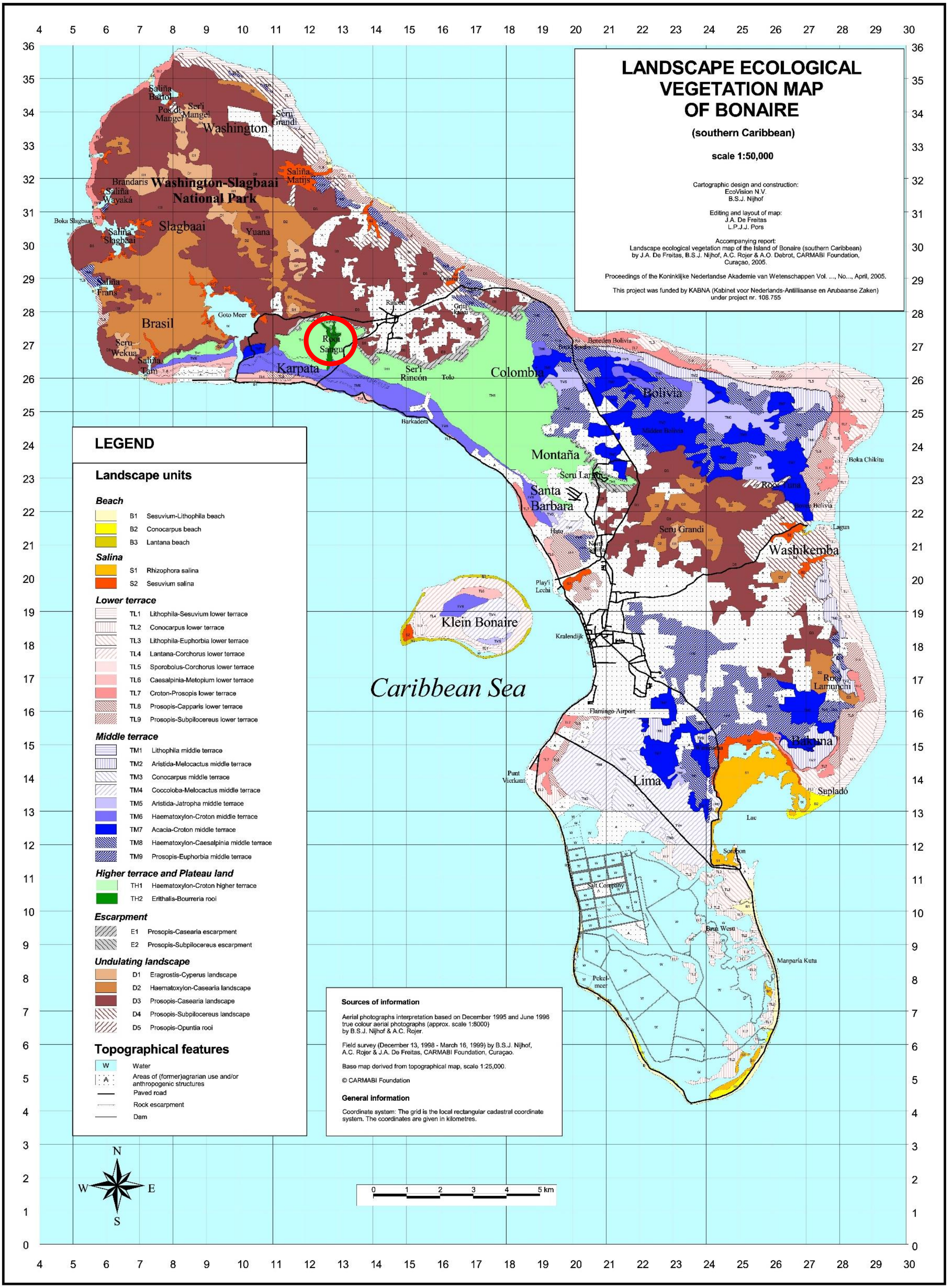

Image 6: Map accompanying Freitas et al. (2005). The red circle indicates the position of the Roi Sango valley.

Habitat type 1: Higher Valley

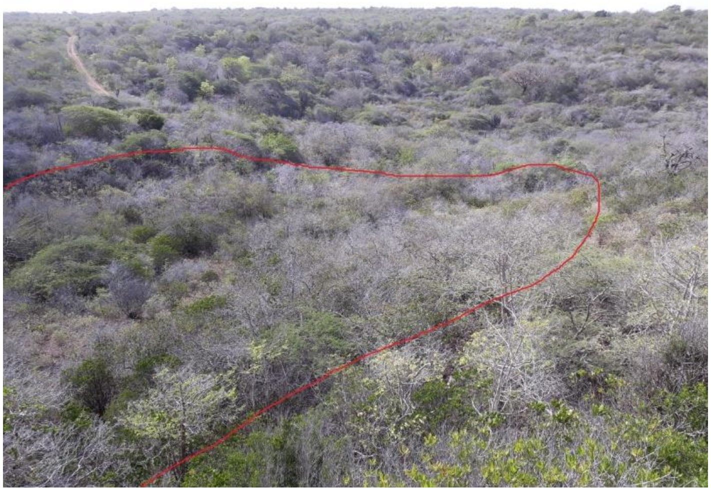

Image 7: Higher valley vegetation (area within red line) pictured from the limestone terrace.

This comparatively healthy valley habitat has a relatively high number of species compared to other habitats on Bonaire. Yet, it is clear that the vegetation is under stress and is undergoing secondary succession: the forest is characterized by large patches of small trees, and high tree mortality is observed.

Tree species

Bourreria succulenta is the dominant species in this area, and is most abundant in the canopy layer – which usually reaches about 6 meter in height. The canopy is generally closed throughout the length of the valley but slightly more so in the middle part. When reaching the outer slopes of the habitat type, open spots become more frequent.

Although *B. succulenta* is the dominant tree species in the area, *Casearia tremula* was also commonly found in the canopy layer and can be considered sub-dominant. *Prosopis juliflora* was found to be abundant, yet not as present as in many other parts of Bonaire. Of this latter species, mostly larger, older specimens where observed. Some *Caesalpinia coriaria* were encountered, but larger individuals had often died. Possibly, this is the result of a large fungal outbreak some years ago, which infected this species all over the island.

Other tree species that were occasionally observed included: *Bursera simaruba, Bursera karsteniana, Crescentia cujete, Cordia dentata, Haematoxylum brasiletto, Machaonia acuminata, Randia aculeata, Sideroxylon obovatum, Maytenus*

Table 1: General information on the habitats as identified by Echo.

	Habitat type	Actual size (ha)	Relative size (%)	Dominant species
1	Higher valley	1.71	6.5	*Bourreria succulenta*
2	Higher terrace	2.78	10.5	*Coccoloba swartzii*
3	Lower terrace	12.6	47.2	*Bourreria succulenta*
4	Slope and higher terrace	9.55	35.8	*Erithalis fruticosa*
Totals:		26.7	100	

tetragona, Quadrella odoratissima, Zanthoxylum monophyllum, Vachellia tortuosa, Guaiacum officinale and, higher up the slopes, an increasing amount of *Coccoloba swartzii*.

Understory

In the understory, *C. tremula* and *B. succulenta* were still found abundant, accompanied by *Phyllanthus botryanthus* and *E. fruticosa*. Other species present in the understory were juvenile specimens of C. Swartzii, *Condalia henriquezi* and *R. aculeata.*

Interestingly, the herbaceous and shrub layer of especially the centre of the valley was dense and high, reaching occasionally up to 2 meters in height. *E. fruticosa* and *C. flavens* where the dominant species encountered, but many other herbaceous and small shrub species were found. More towards the valley's outer slopes, as the canopy opened up, the vegetation changed towards a more shrub like composition. *E. fruticosa* was still found to be dominant in these parts, and *P. botryanthus* was observed more commonly. Some patches of *B. succulenta* and *C. tremula* were found in these open patches, but other species such as *Crossopetalum rhacoma, Pithecellobium unguis-cati, C. henriquezii, Vachellia tortuosa* and the cactus *Melocactus macracanthos* indicated that the vegetation type changed towards that of the higher terrace ecosystem (Type 2).

Bromeliads and/or Cacti

Image 8: Juvenile specimen of *T. flexuosa* found in the higher valley.

In some of the trees, the bromeliad species *Tillandsia flexuosa* was found in the thicker part of the valley vegetation (Image 8). The columnar cacti *Cereus repandus* and *Stenocereus griseus* which are usually common in most other vegetation types on Bonaire were found notably rare in the valley. Some individuals of both species were encountered, but without rejuvenation in other parts. The cactus species *Opuntia caracassana* was abundant, yet not as plentiful as it is in other vegetation types on Bonaire.

Soil

Especially in the middle part of the valley, the soil consisted mostly of chunks of limestone rubble and outwash from the higher terrace area, mixed with volcanic clay and some rocks from the lower bedrock layer. Altogether, some soil layer was present in the middle part of the valley. Reaching closer to the upper slopes of the valley, more and more limestone bedrock was visible at the surface. The same transition was appearing in the leaf litter layer. Leaf litter cover as high as 90% was observed in the middle of the valley, and was virtually absent in the barer parts closer to the limestone cliffs.

Habitat type 2: Higher terrace


Image 9. Windswept trees and a sparse vegetation cover on the weathered surface of the limestone terrace edges.

The vegetation composition observed in this patch is characteristic of the upper limestone terraces which are common on Bonaire. The area with this vegetation composition is separated by part of the Roi Sango valley in 2 different areas (Image 5). Both patches are situated on a similar limestone terrace, which surface is characterized by the many cracks in the outcropping bedrock– a typical karst feature – and a relative absence of soil. This makes it difficult for larger trees to develop. The vegetation in this habitat is therefore characterized by a spotted canopy and many singular trees with some shrub and herbaceous vegetation in between. Exceptions to this observation included some denser patches of *P. botryanthus* and *P. juliflora.*

Trees

The dominant tree species is *C. swartzii,* reaching only 3 meters in height on the windswept edges of the terrace and up to 6 meters on the more sheltered parts of this habitat. Other common tree species included: *C. coriaria, P. juliflora, C. tremula, P. botryanthus, T. billbergii, Metopium brownei, B. succulenta, H. brasiletto, B. simaruba, G. officinale, R. aculeata,* and *Z. monophylum*. Of the species *Guaiacum sanctum, C. rhacoma, C. cujete* and *B. karsteniana* only a single individual was spotted. For the Southern limestone terrace, additional species were *B. succulenta* and *M. acuminata.*

Understory

The understory vegetation predominantly consisted of lower shrubs and herbaceous vegetation, reaching about 1 meter in height near the windswept edges of the limestone terrace and up to 2 meters in more sheltered spots. The dominant species in this layer was *E. fruticosa*, which was accompanied by *P. botryanthus, C. tremula, Stenostomum acutatum* and *C. flavens*.

Image 10. *Tillandsia flexuosa* and *T. recurvata* growing together in a *Zanthoxylum monophyllum* tree.

Bromeliads and/or Cacti

The columnar cactus species *Pilosocereus lanuginosus* was found relatively abundant, although not common. Both *Opuntia curassavica* and *O. caracassana* were occasionally observed and also several individuals of *M. macracanthos* were found growing on limestone (bed)rock. In some trees, bromeliad species *T. flexuosa* and *T. recurvata* were found.

Soil

The soil consists mostly of partly weathered limestone surface and bedrock. As described above, the weathered surface in this part is particularly rough, with a plethora of small cracks and sharp edges present. Within some small dents in the surface a little limestone wash, often with an orange-red color, is present. These 'pockets' also collect the relatively small amount of leaf litter present.

Habitat type 3: Lower terrace

The lower valley of the Roi Sango area consists by far of the most promising and diverse vegetation in the region – and possibly of Bonaire. The sheltered, remote position ensures that most trees have been able to grow without excessive disturbance, including herbivory by goats as well as human influence. However, some remnants of human activity were found, such as small boulder walls and old fences. Furthermore, a patch with fruit trees including *Melicoccus bijugatus* and *Spondias mombin* also reflects human influence on the area.

Image 11. Overview of the vegetation in the lower valley in the Roi Sango area.

Trees

When entering the valley from the North, *B. succulenta* clearly is the most dominant species present, but this changes gradually towards the South. When moving southwards, the canopy layer becomes dominated by both *B. succulenta* and *C. tremula.* In the main valley, *C. tremula* and *B. succulenta* remain common, but *P. juliflora* becomes the dominant species. The overall canopy height ranges from 6-7 meters in the North, where the canopy is mostly closed and many older trees are found. In some parts of the valley however, the canopy occasionally opens up and the average height is reduced to only 3 meters.

In the northern part of the valley, *Z. monophyllum* and *M. acuminata,* present in patch-like communities, are surprisingly abundant. Other common tree species in this part are *C. cujete, B. simaruba, B. karsteniana, R. aculeata, C. coriaria, C. dentata, C. henriquezii* and some remarkably large individuals of *P. botryanthus.* Among the occationally observed species were *Cynophalla flexuosa, P. unguis-cati, Melicoccus bijugatus, Spondias mombin,* and *M. tetragona.*

In the main valley, *Z. monophyllum* and *M. acuminata* become generally rare, and while the species composition changes from a *B. succulenta* dominated canopy to the more abundant presence of *C. tremula* and *P. juliflora,* other species become more frequent too. *C. cujete* is commonly observed, together with *B. simaruba* and *C. dentata. B. succulenta* remains highly abundant. Other, occasionally observed, tree species are similar to the species composition in the rest of the valley: *P. botryanthus, R. aculeata, C. coriaria* and *C. henriquezii.* Other species observed were *Schoepfia schreberi, Quadrella indica, Coccoloba swartzii, Malpighia emarginata, B. karsteniana, C. rhacoma, Q. odoratissima, S. obovatum, P. unguis-cati, M. brownei* and *C. flexuosa.*

Image 12. A high abundance of *C. tremula* can be observed in the main valley of Roi Sango.

Understory

The understory layer of the Northern part of the valley consisted of mainly juvenile trees of the tree species mentioned earlier, together with the occasional presence of *E. fruticosa.* In the main valley, the understory was comparable to the rest of the valley, except for a higher wealth of juvenile tree species as well as a more diverse herbaceous cover.

Bromeliads and/or Cacti

The columnar cacti species *S. griseus* and *C. repandus* where occasionally observed but rarely abundant. A similar spread was seen for *O. curassavica* and *O. caracassana* although the latter was found very abundant in some places close to the cliff edges, most likely dispersed there by roaming goats.

Soil

A developed soil layer can be found in this part of the Roi Sango area. This, combined with favorable soil-moisture conditions, has probably played a major role in the favorable species composition and the high canopy height observed today. Similar to the soil composition in the higher valley, the soil has developed from (and still contains) chunks of limestone rubble and outwash from the higher terrace area, as well as volcanic clay and limestone rocks from the lower bedrock layer. Especially in the middle of the valley, the limestone particles have degraded into a relatively deep soil layer, with, occasionally, a fair organic matter content. Leaf litter was most abundant underneath larger trees and, more generally, in the centre of the valley. It became significantly less abundant towards the slopes of the limestone cliff faces.

Habitat type 4: Slope and higher terrace

This habitat was the most diverse in terms of sub-habitats. Clusters of trees (often different from the dominant tree species), shrubs and herbs were observed. In one part of this habitat type, the remnants of an old Kunuku[1] where still visible. The area was more recently re-vegetated and some old metal roof sheets and trash were present. Furthermore, several larger trees of the invasive *Leucena leucocephala* and few specimens of the invasive milkweed *Calotropis gigantea* were seen. As part of the BEST project, both species have been removed from the area.

Trees

In places with abundant tree cover, a canopy height of up to 6 meters was found. More frequently, however, a height of only 3 meter was observed. The canopy, generally, was open and trees were less tall when compared with tree height in the valley. In some patches, no tree canopy was present at all.

[1]Local terminology for farm(house).

Although *B. succulenta* was the dominant tree species in the overall habitat, several clusters were dominated by different species, such as *P. unguis-cati, H. brasiletto,* and *C. rhacoma*. These three species were also abundant throughout the entire area.

Image 13. Overview of the slope towards the higher terrace. A dense canopy and, occasionally, a large trees such as the *B. simaruba* can be observed.

Other common species included *C. coriaria, C. tremula, P. botryanthus,* , *P. juliflora R. aculeata* and *V. tortuosa.* and the shrub *S. acutatum.* Occasionally encountered species include *C. cujete, Q. odoratissima, C. henriquezii, B. karsteniana, B. simaruba, C. swartzii, M. brownei, S. schreberi, Jacquinia arborea, Z. monophyllum, C. flexuosa, S. obovatum* as well as single specimens of *G. sanctum C. dentata* and *Q. indica.*

Image 14. The occasionally very open higher terrace vegetation only dominated by the shrub *E. fruticosa* and accompanied by some herbaceous plants.

Understory

E. fruticosa was almost always present throughout this habitat type, and reached heights of up to 2 meters. Occasionally, if no tree canopy was present, this shrub dominated the vegetation, which consisted of shrubs and herbs. Also commonly present was the shrub *S. acutatum.*

Soil

As this habitat type is comprised of both the sloping terrain that connects the valley with the higher terrace and a part of the higher limestone terrace itself, some differences were observed in the soil type. The characteristic karst surface that is common on the higher terrace vegetation habitat was absent, but the entire area was exclusively comprised of limestone (bed)rock. Between the edge of the slope and higher terrace, some small rock escarpments where visible on the surface, but in most places loose piles of limestone rocks and boulders cover the bedrock. In the flatter areas as well as lower down on the slope, an increasing amount of limestone-based soil and smaller particles where observed, which favors tree growth and allows for a more diverse plant composition. A litter layer was commonly observed under larger trees, especially large specimens of *M. brownei* and *C. swartzii.*

Image 15. A mature specimen of *S. schreberi*, a species rarely seen on Bonaire, but surprisingly abundant in this area.

Comparison

In this section, the vegetation composition of the habitats described above will be classified utilizing Freitas et al. (2005). Where the fit is an uneasy one, this will be discussed.

Habitat type 1

The abundance of *B. succulenta, C. tremula, and P. juliflora,* as well as the presence of, amongst others, *B. simaruba, C. dentata*, *R. aculeata* and *Z. Monophyllum,*, matches the description of Freitas et al. (2005)'s rare *C. tremula– B. succulenta* type. Thus, the vegetation type found here corresponds with earlier observations (Image 5,6).

Interestingly, in Echo's observations, the *P. botryanthus* was abundant in this vegetation type. To the best of the author's knowledge, there has not been any research on the palatability of the leaves of this plant, apart from the master-thesis performed by Coolen (2015), where this species was slightly less abundant in herbivore exclosures than in the control plots although this finding was not significant due to a lack of statistical power. Thus, it could be hypothesized that the vegetation composition in this area is changing due to herbivore pressures.

Habitat type 2

Due to the abundance of *C. swartzii*, *M. brownei*,*H. brasiletto,* and *M. macracanthos*, the vegetation composition matches that of *Coccoloba swartzii-Metopium brownei* type (which occurs on 3.9% of Bonaire's surface area and is considered a climax community of high conservation value) (Freitas et al., 2005). This type falls under the TH1 type that Freitas et al. (2005) have indicated to be present in this area.

A notable problem with the fit is that Freitas et al. mention that *P. juliflora* is absent from this type, while this species was abundant in some patches and common throughout this habitat type. Freitas et al. (2005) do note that *P. juliflora* is an unpalatable species to invasive herbivores (due to its spines); therefore, it is possible that the introduction of this species within this patch is a sign of (recent) disturbance.

Habitat type 3

This habitat type is more diverse than habitat type 1, yet it matches with the same vegetation type (*C. tremula– B. succulenta*). The different species that co-occur in this area do display a gradient in distribution, but Freitas et al. (2005)'s type is a broad one that seems to allow for this. The determined vegetation type does therefore correspond with Freitas et al. (2005)'s vegetation map (Image 6).

Habitat type 4

The vegetation composition of this habitat shares the most similarities with the *Haematoxylon brasiletto-Antirhea acutata* type. Namely, it is not dominated by trees, contains the differentiating species *Antirhea acutata* (a synonym for *S. acutatum*), has a high abundance of *E. fruticosa* and *H.brasiletto*, and lastly species such as *B. simaruba, C. coriaria, C. dentata,* and *C. swartzii* were present too. This vegetation type, which has a significant conservation value as it is one of the least disturbed vegetation types of the island, also falls within the TH1 sublandscape that is indicated on the vegetation map (Image 6) (Freitas et al., 2005).

	Vegetation type				
	Dominant	Abundant	Common	Rare	Most similar vegetation type
1	*B. succulenta*	*C. tremula, P. juliflora*		*C. coriaria, B simaruba, B. karsteniana, C.cujete, C.dentata, H. brasiletto, M. acuminata, R. aculeata, S. obovatum, M. tetragona, Q.odoratissima, Z. monophyllum, V. tortuosa, G. officinale*	Type 18
Outer slopes	*E. fruticosa*	*P. botryanthus*	*B. succulenta, C. tremula, C. swartzii*	*C. rhacoma, P. unguis-cati, C. henriquezii, V. tortuosa, M. macracanthos*	
Understory	*B. succulenta, C. tremula, E. fruticosa, C. flavens*	*P. botryanthus*	*C. flavens*	*R. aculeata, C. swartzii, C. henriquezii, C. tremula, O. caracassana*	
Bromeliads and Cacti			*T. flexuosa*	*C. repandus, S. griseus*	
2	*C. swartzii*	*Some patches: P. botryanthus, P. juliflora*	*C. coriaria, P. juliflora, C. tremula, P. botryanthus, T. billbergii, M. brownei, B. succulenta, H. brasiletto, B. simaruba, G. officinale, R. aculeata, Z. monophyllum*	*G. sanctum, C. rhacoma, C. cujete and B. karsteniana, M. acuminata, B. succulenta*	Type 9
Understory	*E. fruticosa*	*P. botryanthus, C. tremula, S. acutatum, C. flavens*			
Bromeliads and Cacti			*P. lanuginosus, O. curassavica, O. caracassana*	*M. macracanthos, T. flexuosa, T. recurvata*	
3: North	*B. succulenta*	*Z. monophyllum, M. acuminata*	*C. cujete, B. simaruba, B. karsteniana, R. aculeata, C. coriaria, C. dentata, C. henriquezii*	*P. botryanthus, C. flexuosa, P. unguis-cati, M. bijugatus, S. mombin, and M. tetragona.*	Type 18
3: South	*B. succulenta, C. tremula, P. juliflora (gradient)*	*C. cujete, B. simaruba, C. dentata,*	*P. botryanthus, R. aculeata, C. coriaria and C. henriquezii*	*S. schreberi, Q. indica, Coccoloba swartzii, M. emarginata, B. karsteniana, C. rhacoma, Q. odoratissima, S. obovatum, P. unguis-cati, M. brownei, C. flexuosa*	
understory North	Juveniles above mentioned species		*E. fruticosa*		
understory South	Similar to north, more juveniles, more diverse herb cover.				
Bromeliads and Cacti			*O. caracassana*	*S. griseus, C. repandus, O. curassavica*	
4	Patchy, but: *B. succulenta*	*P. unguis-cati, H. brasiletto, C. rhacoma*	*V. tortuosa, P. juliflora, C. coriaria, C. tremula, P. botryanthus, R. aculeata* and the shrub *S. acutatum*	*C. cujete, Q. odoratissima, C. henriquezii, B. karsteniana, B. simaruba, C. swartzii, M. brownei, S. schreberi, Jacquinia arborea, Z. monophyllum, C. flexuosa, S. obovatum* and a single specimen of *G. sanctum C. dentata* and *Q. indica.*	Type 10
Understory	*E. fruticosa*				

Table 2: Overview of vegetation in the Roi Sango valley.

Evaluation plan

The objective of the study is to examine the effect of herbivore exclusion in the Roi Sango area on its vegetation in terms of natural regeneration of trees and tree species diversity. Natural regeneration is our topic of interest as it determines the vegetation composition of the future. Its diversity is important, as a more diverse forest is likely to provide a steadier food supply to wildlife, and many of the tree species themselves are of high conservation value.

Additionally, to enhance our understanding of broader impacts of herbivore exclosure on vegetation composition, this study would like to briefly explore the subtopic of the effect of herbivore exclusion on the cover of cacti that are said to be spread by goats (i.e. *Opuntia caracassana* & *Opuntia curassavica*) as well as on the cover and height of the herb layer.

Set-up

To achieve the objective stated above, ten plots (10 x 10 m) located in exclosure area (from here on, treatment plots) and ten control plots (i.e. accessible to herbivores) of the same size have been established in the Roi Sango area. These control plots have been selected to match a treatment plot in terms of location – preferably as close together as possible, substrate, and vegetation composition – with, if possible, the same species of larger trees. This was done to control for potential confounding variables. All 20 plots have their corners marked by rebar stakes with white tips, and their GPS coordinates have been recorded. Each plot was given a unique name, and its terminology is explained as follows. All plot names start with 'RS', meaning Roi Sango. This is followed by the pair (consisting of a treatment and control plot) number (1-10), and, in case of a control plot, the name ends with 'C'. Each pair, furthermore, receives a name referring to the most conspicuous species present in the plot. The plot names are summarized in Table 3.

Table 3: Plot names.

Plot code Treatment	Plot code Control	Name plot pair
RS1	RS1C	Erithalis
RS2	RS2C	Schoepfia
RS3	RS3C	Metopium
RS4	RS4C	Crescentia
RS5	RS5C	Coccoloba
RS6	RS6C	Monophyllum
RS7	RS7C	Bourreria
RS8	RS8C	Prosopis
RS9	RS9C	Cordia
RS10	RS10C	Machaonia

The selection of the sampling sites is based on a proportional stratified sampling design. This ensures that vegetation types are sampled more if they are more abundant, but all vegetation types are represented in the sample.

Field measurements

In order to test the effects of herbivore exclosure on the vegetation, a vegetation inventory is preformed twice: the first time to gather baseline data, and the second time, 5 years later, to record the changes. Within each plot, the species name, the height, the leaf area cover (cm^2), and the diameter (cm) at breast height (DBH) (if DBH >5) will be recorded of every tree (seedling). It should be noted that the DBH is not expected to change much in 5 years, as the effects of herbivore exclosure will most likely be noticeable in the trees that have not yet reached such a diameter. However, the DBH is quick to measure, and can provide more insight if it is decided to track the effects for a longer period of time.

The height (cm) is measured with a measuring tape for trees up to 2 meters. If trees exceed this height, it will be estimated by 2 observers and rounded up to decimal centimetres. To calculate the leaf area cover, firstly the longest diameter of the area that contains leaves and the diameter perpendicular to the first measurement are recorded. Then, both measurements are averaged, and the resulting average diameter is used to calculate the area of the circular hypothetical tree that contains leaves (Image 16).

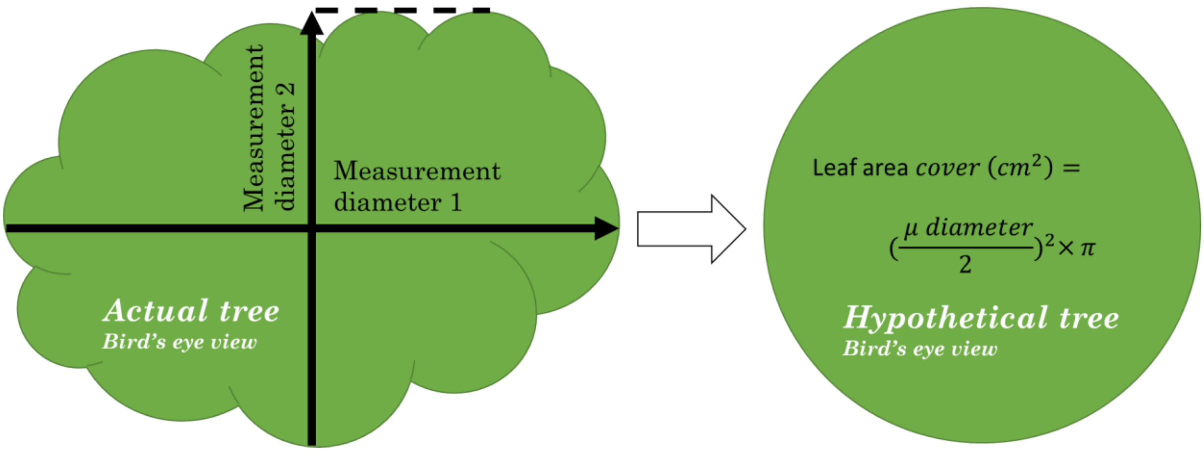

Image 16: Illustration of the calculation of leaf area cover.

The plot boundaries will be taken as 'definitive boundaries'. In other words, the height or leaf area cover of overhanging trees will only be measured within the plot area. If the base of the tree is situated outside, the DBH will not be recorded. Moreover, the native vine Stoki, (*Cynophalla flexuosa*), will be considered a tree. This was done, because Stoki, in its appearance, resembles a tree with branches and a broad canopy. Even if its support tree dies, it continues to live in this 'tree-like' form. The tall Pilar cacti (i.e. *Cereus repandus, Pilosocereus langinosus, Stenocereus griseus*), which often reach heights greater than native trees and are significantly affected by herbivores as their bark is removed will be counted as trees) will be counted as trees as well (Debrot et al., 2011).

The abovementioned parameters do not include any recording of the herbaceous vegetation (including grasses) inside the plots. However, the initial change in vegetation between the control plots and herbivore free plots will likely be most visible in the herbaceous vegetation. Herbs and lower plants are best accessible for invasive herbivores and are suppressed by them (Coolen, 2015). Including some measure of the effects of herbivores on this vegetation could therefore enhance to illustrate the magnitude of their impact on the tropical dry forest ecosystem. However, as testing the effect is of a lesser priority for the current project, only basic characteristics will be noted, including the number of species, a cover percentage, the estimated average height, and the species name of the three most abundant herbs or grasses.

Similarly, the presence and abundance of Tuna (*Opuntia caracasana)* and Pupu di pushi (*Opuntia curassavica)*, two native cacti, might be affected by invasive herbivore presence. Therefore, we will record Tuna's height and cover, and as it is difficult to establish whether Pupu di pushis are separate individuals *and* as their abundance can be extremely high, recording every individual was judged to be too time-consuming.[2] Therefore, its abundance will be recorded as a surface cover (% of surface area).

Furthermore, some general information about the plots will be recorded. This data allows for further analysis, and can be used to verify that the variation between plot pairs is minimal – as in nature, finding two exact copies is a rare occurrence indeed. The data that will be recorded (as a percentage of surface area) are: the (bed)rock cover, leaflitter/deadwood cover, visible soil cover, which, combined, add up to 100%, and a general canopy/shade cover.

Hypotheses, Tests and Variables

Regeneration and Diversity

Regeneration and biodiversity are the main variables of interest. Yet, these can be measured in numerous ways. Here, it is proposed that regeneration is measured by looking at the total number, the average height and the cumulative cover of seedlings (height ≤ 100)

[2] Although both height and cover were measured for the Cordia, Crescentia and Machoania pairs.

and, more importantly, saplings (height >100, DBH < 5). While both variables are hypothesized to increase for both size classes, testing saplings is deemed of more importance because a single rain event can cause many seeds present in the seedbank to germinate, which could, perhaps, cloud an existing trend, and the number and leaf area cover of adult trees are not likely to change because of the invasive herbivores in the short term (i.e. 5 years). In the longer term, however, adult number, height and cover *are* likely to be affected.

Tree size class distribution histograms will be made for the in- and exclosures, which will allow for visual interpretation of the underlying trends. Apart from a general size distribution histogram, a more specific size distribution histogram could be made of the rare/endangered tree species that can be found in Table 4 (Freitas et al., 2005; Dutch Caribbean Nature Alliance (DCNA), 2014).

Table 4: Rare tree species and their current occurrence in the treatment and control plots.

Species	Number outside	Number inside	Total
Guaiacum officinale	3	4	7
Guaiacum sanctum	10	9	19
Maytenus tetragona	1		1
Schoepfia schreberi	6	3	9
Tabebuia billbergii	6		6
Zanthoxylum monophyllum	35	24	59

Biological diversity comprises both species richness and evenness. Therefore, both the count of species present per sample plot (*S*), as well as Simpson's index of diversity[3] ($1 - D$; $D = \frac{\sum n(n-1)}{N(N-1)}$ where *n*= number of organisms of a particular species and *N*= total number of organisms of all species) are used as variables. The species richness is hypothesized to increase in the exclosure plots as the more palatable species will have a higher chance to establish. The evenness is also supposed to increase, as the plots will become less dominated by plants with herbivore defence mechanisms if other species have a relative advantage when the herbivores are no longer a threat.

As the statistics of richness and evenness do not provide information on *what* species are present, it is meaningful to assess the number of rare/endangered organisms between treatments.

[3] Which calculates the probability that two randomly selected organisms belong to the same species and is therefore an index of evenness.

The 10 paired samples will be tested for all above mentioned variables with a paired-samples t-test if the differences (for a particular variable) between the matched-pairs (i.e. plots) are normally distributed, using a Shapiro-Wilk test for normality (N.B. approximately, as a paired-samples t-test is relatively robust in this aspect), and no significant outliers are present.[4] If these assumptions are violated, the non-parametric Wilcoxon matched-pair test is appropriate.[5]

Subtopics: Herbs and Opuntia

Herbs

It is expected that the herb layer will become denser and will increase in average height as browsing is prevented in the exclosure, although it is possible that the latter effect is not as straightforward since many taller herbs (e.g. *Lantana* spp., *Croton flavens*) are unpalatable to the introduced herbivores (Coolen, 2015; Freitas et al., 2005; Quattrocchi, 2016; Sharma, Makkar, Dawra, & Negi, 1981). This possibility needs to be checked by looking at the dominant species in each plot.

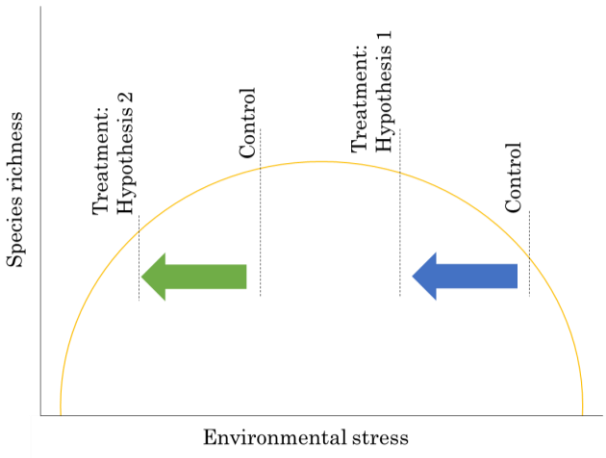

Image 17: Hypotheses concerning herb richness, based on Connell (1978)'s Intermediate Disturbance Theory.

While acknowledging that Connell (1978)'s 'Intermediate disturbance theory' is not without its critics, it is a useful framework to help envision what would happen to herb richness when the herbivore exclosure is realized (Image 17). The first hypothesis is that the number of species is estimated to increase in the exclosures, as the herbivores no longer selectively remove specific species from the composition (the blue arrow on Image 17). However, as it is yet unknown how much herbivorous pressure the introduced herbivores exert on the herb layer, it is also possible – though less likely – that the number of species will go down (the green arrow on Image 17) in the exclosures. This could theoretically happen if the current stress was intermediate, as less niches might be available if stressors are taken away from the system.

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[4] A paired-samples t-test is a statistical test that assesses whether the mean difference between paired observations is zero. When this is the case the two observations cannot be said to differ.
[5] A Wilcoxon matched-pairs test assesses if two group averages differ significantly, using a ranking system which eliminates the need for a normal distribution of the data.

Opuntia

Earlier work by Coolen (2015) shows that *O. caracassana* and *O. curassavica* could be affected by the introduced herbivores, in terms of dispersal and survival. Following his findings, it is expected that *O. caracassana* will be less numerous, and have a lower cover area within the exclosures, as their dispersal via herbivores is lessened, while their average height is likely to be taller – since their cladodes will not be broken off by herbivores. The surface cover of *O. curassavicavica* is expected to increase within the exclosure, as they are less likely to betrampled by goats.

The hypotheses will be tested with a paired-sampes t-test or a Wilcoxon matched-pair test, depending on the distribution of the data.

Preliminary Baseline study

Given that the study will make use of matched plots to establish the effect of herbivores on the regeneration and diversity of native vegetation, it becomes important to check whether these plots are indeed comparable. This will be the purpose of this preliminary baseline study – the results of which can be found in the next sections 'Regeneration', 'Biodiversity' and 'Other vegetation: Herbs and *Opuntia*'.

For each section, the tests that have been proposed in the evaluation plan will be performed on the acquired baseline data (i.e. the vegetation data obtained within and outside exclosure areas, as was described in the 'Field measurements' section) for the treatment and control plots. Hypothetically, no effect should be observed between these plots, as the real treatment (i.e. herbivore exclosure) has not yet taken place. If a significant difference is detected between the treatment and control plots in their current state, a solution will be proposed.

Regeneration

The variables of interest in terms of regeneration are the total number, the average height and the cumulative leaf cover of seed- and saplings. A paired-samples t-test was performed, and the only significant effect that was detected was that the leaf cover of Saplings was lower (p = 0.01) in the plots within the future exclosure (Table 5). This means that the results on effect of herbivore exclosure on Sapling leaf cover will be on the conservative side. While this is by no means problematic, it is possible to correct for the difference in leaf cover that was detected in this preliminary data exploration; to correct for the difference in future tests, one can subtract the mean difference from the future control plot data.

Table 5: Overview of tests comparing the regeneration between matched study plots.

Regeneration			
Variable (Treatment-Control)	Mean	Std. deviation	*p* Value
Number of Saplings	0,40	19,59	0,95
Number of Seedlings	-69,10	162,46	0,21
Average height Saplings	-9,12	38,31	0,47
Average height Seedlings	-0,76	5,97	0,70
Leaf cover Saplings	-314813,33	308070,20	0,01**
Leaf cover Seedlings	516,73	43708,42	0,97

Moreover, tree size class distribution histograms were made, to allow for a comparison of vegetation structure between the future treatment and control plots (Image 18).

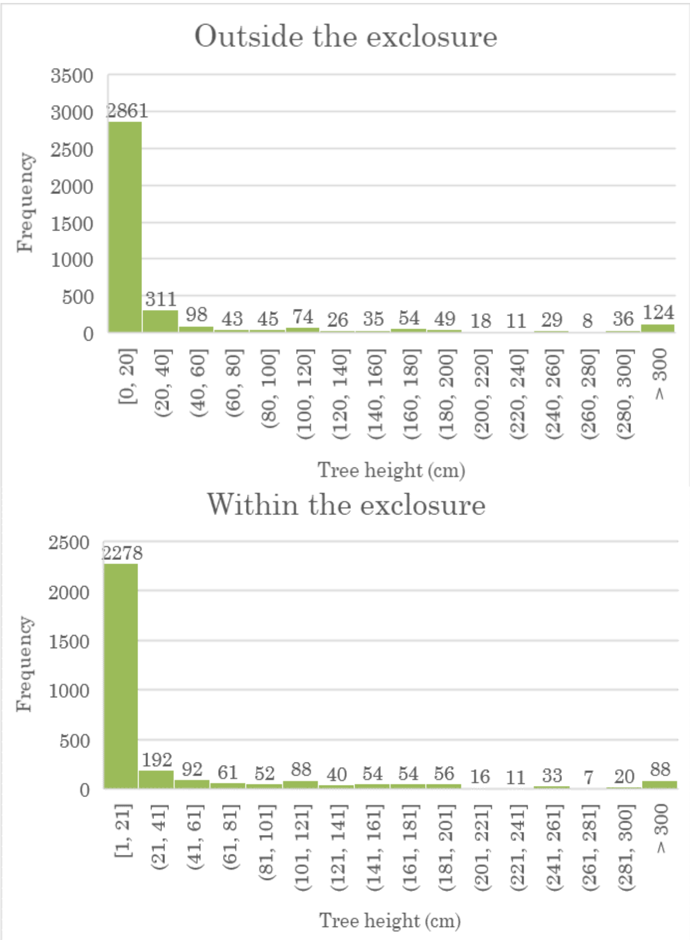

Image 18: Tree size class distribution for both the future treatment and control plots.

A visual inspection shows that overall, the distribution is very similar: there is a high abundance of small newly germinated seedlings (between 0-20 cm), and the count of organisms declines rapidly with an increase in size class. An explanation for this rapid decline could be that vegetation is under herbivorous pressure – which drastically increases seedling mortality – limiting the amount of trees that will progress into larger size classes. The high amount of seedlings in the smallest size class can be explained by recent rainfall events, which activate the germination of seeds present in the seedbank. The herbivores might not have had the chance to eat these seedlings.

From the graph, it seems that there are slightly more seedlings and 'tall trees' (i.e. over 3 meters in height) outside the exclosure. Having more adult trees present in the control plots might distort the observed effect of herbivory exclosure in the future study as adult trees produce seeds that will likely germinate in their close proximity. If this is the case, the future study will give a conservative estimate of the effect of herbivore exclosure.

Yet, the tests performed above show that the number of seedlings did not statistically differ between the treatment and control plots. Similarly, an additional paired-samples t-test found no significant difference (p = 0.88) between the number of adult trees within and outside the exclosure. Furthermore, an additional Pearson's correlation test shows that the number of adult trees and the number of seedlings are only weakly, but not significantly, correlated in the acquired dataset (r = 0.17; p = 0.47), tempering fears that such a structural difference will influence the proposed study (Appendix D).

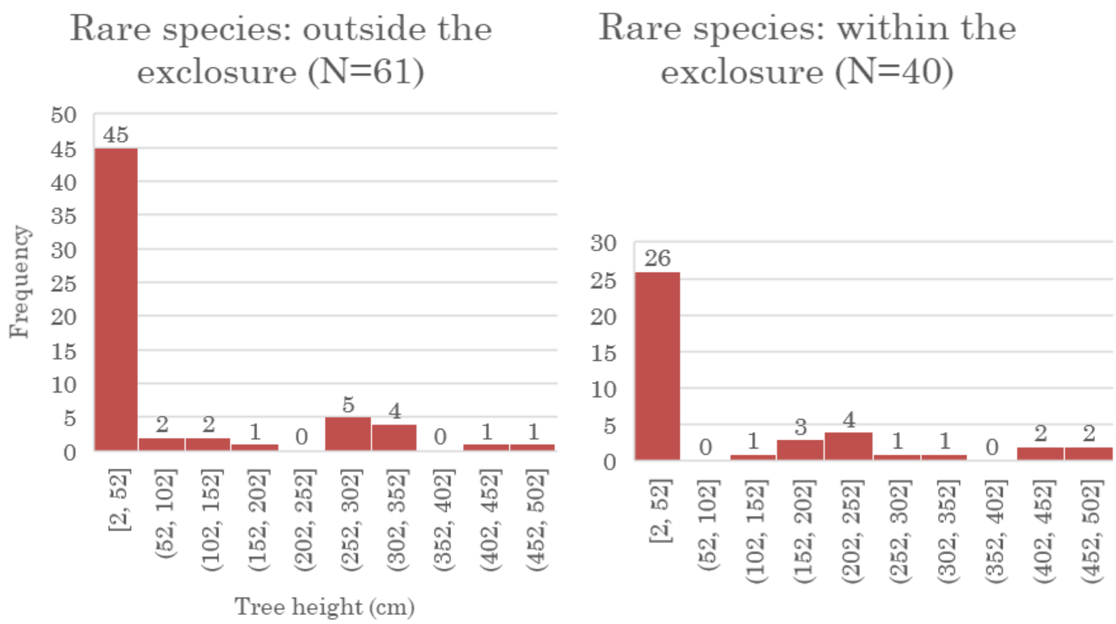

Image 19: Tree size class distribution for rare species, within and outside the herbivore exclosure.

When we look at the size class distribution of the 6 rare species specified in the evaluation plan, on Image 19, a worrying trend is visible: while the overall count of rare organisms is low, 61 and 40 for the control plot and treatment plot respectively, there are scarcely any seedlings that survive past the 52 cm. This signals that the rejuvenation of the stocks of these species are hindered.

Biodiversity

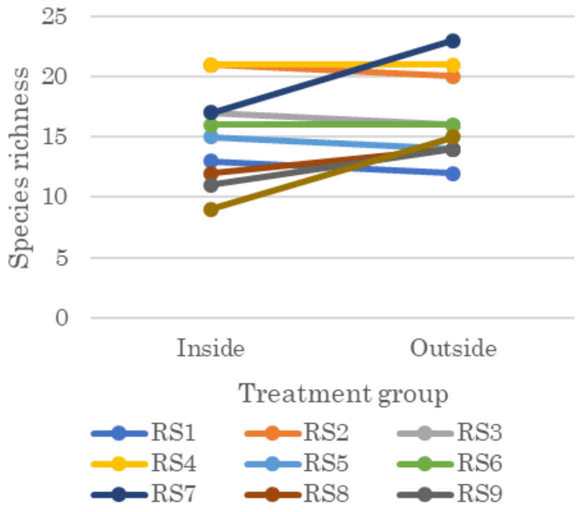

Image 20: Comparing species richness within and outside the exclosure.

The biodiversity of the treatment and control plots was captured by examining species richness, Simpson's evenness, and the number of rare species. Species richness did not differ significantly between treatments (paired-samples t-test: treatment – control mean: -1,3, t = -1,45, p = 0.96) (Image 18). Simpson's evenness, too, did not differ between treatments (Wilcoxon matched-pairs: Z = 27, p = 0.96) (Image 19). Also the number of organisms of rare species did not differ significantly between the future herbivore exclosure plots and the control plots (Wilcoxon matched-pairs: Z = 20, p = 0.31) (Image 19).

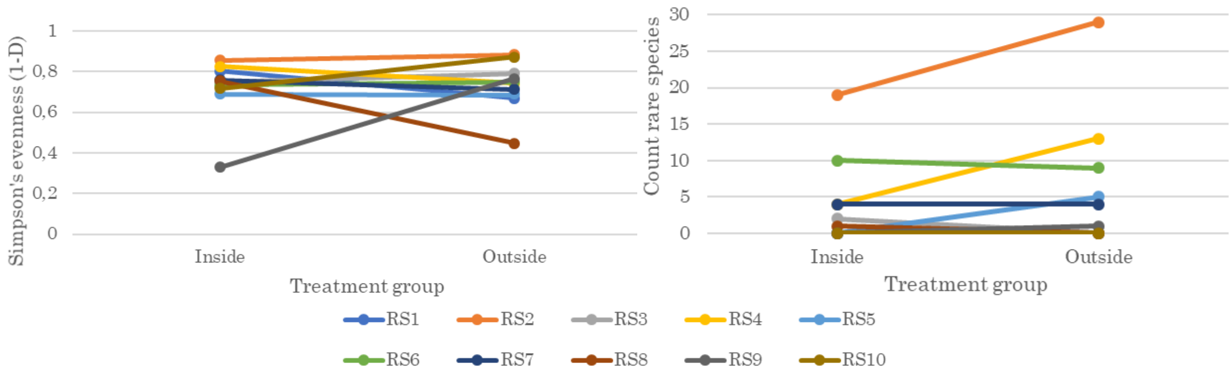

Image 21: Simpson's evenness and count of rare species comparison between treatment and control group.

Other vegetation: Herbs and Opuntia

Herbs

The data revealed that the treatment plots contained slightly more herb species, but this effect was not significant (Wilcoxon matched-pairs: Z = 8, p = 0.08). The cover of herbaceous vegetation, too, did not differ significantly between treatments (Wilcoxon matched-pairs: Z = 22, p = 0.95).

Opuntia

The two examined species were *O. caracassana* and *O. curassavica*. As described previously, tests were performed to detect differences in the count, average height, and cover of *O. caracassana* between the treatment and control plots. The count of *O. caracassana* was found not to be significantly different (Wilcoxon matched-pairs: Z = 28, p = 0.16), and neither was the average height of *O. caracassana* (paired-samples t-test treatment – control: μ = -2,67, t = -0.51, p = 0.57). While the cover of *O. caracassana* tended to be higher within the planned exclosure, this result was not significant (Wilcoxon matched-pairs: Z = 31, p = 0.07).[6] Similarly, the median of differences between treatment and control in terms of *O. curassavica* cover did not significantly differ from 0 (Wilcoxon matched-pairs: Z = 0, p = 0.180).

Conclusion

Testing the effectiveness of conservation measures is of vital importance, as existing conservation funds have limits and many threats to nature's diversity and functioning exist. Efficiency assessments allow nature conservation organizations such as Echo to find the most effective way of preserving that part of nature they are focused on. With the current invasive herbivore exclosure project on Bonaire, it chooses to pursue an ecosystem based conservation path to conserving the Yellow-shouldered Amazon parrot. By examining the effectiveness of this approach – of which the presented proposal forms an important first step – the organization tests the practicality of its efforts.

The results of the preliminary study that is part of this proposal suggest that the selection of plots allows for a robust analysis of the effects of herbivore exclosure on Roi Sango's vegetation; the majority of tests concerning regeneration and biodiversity show that, as of yet, no significant differences exist between the future treatment and control plots. The sole exception to this, namely a significantly lower leaf cover of saplings in future exclosure plots, does not threaten this robustness, as using this slightly different leaf cover would lead to a more conservative estimation of the effect of herbivores, and if it is desired to correct for this uneven starting position, this is easily achieved.

Moreover, the preliminary baseline study suggests that there are no obstacles to using the currently selected study plots to investigate the effect of invasive herbivores on the herbaceous vegetation and *Opuntiae*.

[6] This analysis was performed with 6 pairs only, due to missing data.

Figures and Tables

Figures

Tables

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Appendices

Appendix A: Inventory of trees present in study plots

Inventory of trees study plots (N= 7022)

Species	N	Species	N	Species	N	Species	N
Bourreria succulenta	409	*Cordia dentata*	50	*Machaonia acuminata*	177	*Quadrella odoratissima*	20
Bursera karsteniana	95	*Crescentia cujete*	19	*Malpighia emarginata*	2	*Randia aculeata*	1207
Bursera simaruba	13	*Crossopetalum rhacoma*	191	*Maytenus tetragona*	1	*Schoepfia schreberi*	9
Bursera tomentosa	11	*Cynophalla flexuosa*	5	*Melocactus macracanthos*	49	*Sideroxylon obovatum*	2
Caesalpinia coriaria	38	*Erithalis fruticosa*	912	*Metopium brownei*	32	*Stenocereus griseus*	4
Casearia tremula	1978	*Guaiacum officinale*	7	*Phyllanthus botryanthus*	817	*Stenostomum acutatum*	33
Cereus Repandus	10	*Guaiacum sanctum*	19	*Pilosocereus langinosus*	2	*Tabebuia billbergii*	6
Coccoloba swartzii	155	*Haematoxylum brasiletto*	427	*Pithecellobium unguis-cati*	37	*Vachellia tortuosa*	3
Condalia henriquezii	151	*Jacquinia arborea*	29	*Prosopis juliflora*	43	*Zanthoxylum monophyllum*	59

Appendix B: Tree count per treatment

Tree count per treatment

Pair	Exclosure	Control	Total
1	107	135	242
2	364	481	845
3	396	435	831
4	391	861	1252
5	242	166	408
6	230	353	583
7	595	706	1301
8	124	231	355
9	368	176	544
10	342	319	661
Total	3159	3863	7022

Appendix C: *O. caracassana* summary table

	Treatment			Control		
Pair	Average height	Cumulative cover	Count	Average height	Cumulative cover	Count
1	0	0	0	0	0	0
2	33,2308	4876,73	26	16,3333	363,639	6
3	0	0	0	0	0	0
4	22	268,803	2	19,25	1172,4	16
5	12	50,2655	1	29,9216	12628,2	51
6	34,4	3665,65	20	25	5233,89	23
7	21	191,244	5	9	15,9043	1
8	52,1667	19750,2	24	58,5455	28951,5	33
9	19,5	819,17	6	35,0156	20392,9	64
10	0	0	0	27,9231	16746,8	13
Total	19,4297	29622,1	84	22,0989	85505,3	207

Appendix D: Correlation (Pearson's *r*) of variables

	N Seedlings	Av hgt Saplings	Av hgt Seedlings	Leaf cover Sapling	Leaf cover Seedling	Species cunt	Cover O. Caracassana	Av hgt O. caracassana	Cover O. Curassavica	Count rare trees	Simpson's 1-D	N adult trees	N O. caracassana	N herb species	Cover herb
N Saplings	0,04	- 0,51	0,30	,59**	,56**	0,31	-0,27	-0,25	-0,30	,46*	0,29	-0,28	-0,23	0,21	-0,12
N Seedlings		0,26	- ,57**	0,36	0,15	,67**	-0,42	-0,22	-0,27	0,33	0,09	0,17	-0,31	0,12	-0,06
Av hgt Saplings			- ,69**	0,24	-0,41	0,06	0,42	,60**	0,45	0,00	- ,48*	,78**	0,30	0,25	0,29
Av hgt Seedlings				-0,26	,45*	- ,541*	0,08	-0,17	-0,06	-0,25	- 0,02	-0,43	0,01	- 0,09	-0,05
Leaf cover Sapling					0,32	,516*	0,13	0,21	0,03	,64**	0,08	0,27	0,09	0,08	0,05
Leaf cover Seedling						0,07	-0,08	-0,05	0,18	0,43	0,27	-0,18	-0,10	0,11	-0,02
Species count							-0,27	-0,01	-0,37	,60**	,45*	0,02	-0,11	0,12	-0,07
Cover O. Cara-cassana								,83**	0,57	-0,21	- 0,19	,54*	,73**	0,01	0,15
Av hgt O. cara-cassana									,58*	0,11	- 0,19	,71**	,70**	0,27	0,27
Cover O. Curassa-vica										-0,24	- 0,05	0,50	0,23	- 0,05	,79**
Count rare trees											0,41	-0,04	0,07	0,07	-0,11
Simpson's 1-D												-0,41	-0,07	- 0,33	0,00
N adult trees													0,32	0,19	0,38
N O. caracassana														0,07	0,01
N herb species															0,03