Sabalpalm (*Sabal antillensis*) Recovery Over 40 Years: Lessons for Successful Palm Conservation

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Sabal antillensis **is endemic to the Dutch Caribbean islands of Curaçao and Bonaire. Both island populations were thoroughly assessed in 1979, and subsequent management of both sites differed over the last forty years. Resurvey of these palms in 2018 clearly shows the value of exotic herbivore management for palm conservation: exclusion and management of introduced herbivores coincides with a vast increase in palms on Curaçao. We recommend a similar program for the much smaller and much more vulnerable population on Bonaire, as well as continued propagation of seeds for outplanting.**

The floras of Curaçao and Bonaire include only one native palm species, locally called Sabalpalm or Kabana. There had been much debate about the identity of this palm. Winkelman (1979) thought that the species on Curaçao and Bonaire was endemic only to these islands, yet De Freitas (1996) proposed the possibility that it was *Sabal palmetto*, common in Florida and the Caribbean, while Van Proosdij (2012) mentioned it as *Sabal* cf. *causiarum*. The distinct taxonomic status of Sabalpalm was only recently determined, and it is now described as *Sabal antillensis* (Griffith et al. 2017). Remarkable also for the species is its very localized occurrence on both islands (Winkelman 1979, Griffith et al. 2017). On Curaçao, it is only found on the higher Knip hills (Knip geological formation), mostly within and partly outside the southern part of the Christoffelpark. On Bonaire it is restricted to the Lima area, on a limestone terrace near sea level, west of Lac Bay and north of the solar salt works. It is not clear what causes the limited distribution on both islands. In both locations Sabalpalm is a prominent, iconic and emergent feature of the native flora (Figs. 1 & 2).

Christoffelpark, a nature conservation area in the western part of Curaçao, is the most biodiverse region on the island (de Freitas 2010). This park has been managed by Carmabi Foundation (www.carmabi.org) since 1978, the year in which the park was opened. Development and planning for Christoffelpark included a survey for rare trees (Voskens 1972) and detailed census and mapping of Sabalpalm (Winkelman 1979). Both studies were designed to obtain insight into the relative rareness and distribution of important tree species present in Christoffelpark. Winkelman's single-species emphasis also led her to travel to Bonaire and apply the same census methodology. Her work established a critical early record of the abundance and distribution of these rare palms, and also documented their ethnobotanical uses. According to Winkelman (1979), the total population on both islands in 1979 consisted of 1062 individuals, of which 354 were mature palms – with only 31 of these larger palms on Bonaire. Winkelman (1979) found no dead specimens on Curaçao, and three palms which were burnt and felled on Bonaire.

Winkelman (1979) suspected that goats were the main threat to the palm seedlings on both islands. In Christoffelpark goat and donkey populations have been actively managed since

Opposite page:

2. Sabalpalm (*Sabal antillensis*) on limestone terrace in southern Bonaire. Photo by Q. Coolen.

1. Sabalpalm (*Sabal antillensis*) on Seru Bientu, Curaçao. Photo by Carel de Haseth, used by permission.

the mid-1980s via exclusion and removal. The goat population around Christoffelpark is estimated to be 1 individual per 10 hectares, greatly reduced from a much higher past density (van Buurt & Debrot 2012, Verbeek 2016). Bonaire's donkeys (*Equinus asinus*) are abundant within and near the Sabalpalm population and have demonstrated a reductive effect on local vegetation (Roberts et al. 2018). Management of these introduced herbivores has prompted public controversy (DeSalvo & DeSalvo 2013, DeSalvo 2014).

Both before and since 1979 not much was known about the population status of the endemic palm, and whether populations were increasing, declining or stable – essential information for conservation assessment (IUCN Standards and Petitions Committee 2014). Nevertheless, it can be concluded that there are threats to the palm and there have been occasional sightings of dead palms (Winkelman 1979). Nature management authorities on both islands have a vested interest in preserving this iconic endemic due to its vulnerability, limited distribution on both islands, as well as the presence of the invasive red palm weevil (*Rhynchophorus ferrugineus*) on Curaçao (J. de Freitas, pers. comm.).

These gaps in knowledge motivate the current study, designed to determine the population status of the endemic palm species and compare this with the records from 1979. We seek to register all *Sabal antillensis* palms of Bonaire and Curaçao and compare this information with the prior record. Thus, the main question of the present research is: how has the population of the native *Sabal antillensis* palm changed over 40 years? This main question prompts the following sub-questions: Do the palms occur in the same locations Winkelman found them, or have these ranges changed? What does this information suggest for palm conservation? How can we further improve the conservation status of Sabalpalm?

Methods

Census: A survey was conducted on Curaçao from May 2 through June 25, 2018, and a survey was conducted on Bonaire between November 20 and December 4, 2018. Travel by car was used to get as close as possible to each survey site. Often a lookout point was used to spot the palms and plan how to carry out the survey in that specific area. Mature palms are often emergent plants in the vegetation and because of their unique habit are easily spotted in the landscape (Figs. 1 & 2). The basis for the present survey was the locations where Winkelman (1979) found specimens of the Sabalpalm, as well as other locations reported to us by a group of amateur and professional archaeologists and naturalists.

Demographic categories: In order to categorize the demographics of the population, Winkelman used a classification that combined size and phenology, assessing reproductive phases of the palms by the visual presentation of the plants (see Table 1). The same classes used in Winkelman (1979) were employed in the present study (Figs. 3–5) with modification; two overlapping classes of young plants were combined into one class (Table 1), and the phenological subclasses were not parsed. In the field, trunk lengths were estimated by comparing the tree height with our known body heights.

Data collection and record: Every palm was registered as a waypoint in a GPS receiver and noted on a field form. In order to speed up the data collection due to the limited time available, the decision was made that in case there were more than one specimen in an area of 10 square meters, the group was registered as one waypoint, and noted in the record. These palm locations were archived in GIS maps, along with measurement data from field survey. The complete field data (locations, measurements, classes) were filed and archived at Carmabi and Openbaar Lichaam Bonaire, and is also available from the authors by request.

Geographic range: GPS data was used to map the locations of the palms for comparison with the 1979 maps provided by Winkelman (1979). These data were used to create minimum convex polygons (Sergio et al. 2007) to estimate and compare the extent of occurrence on each island.

Evaluating change over time: Based on the discrete boundaries of the islands and habitats, the person-hours invested in the 1978 and 2018 field surveys, the emergent habit of Sabalpalm within its vegetation types, and the knowledge of land managers and citizens solicited, we are confident that these data represent two complete censuses of the palm species (i.e. not two samples of larger populations), especially with regard to the Adult class, separated by 40 years. Thus, comparison between these complete censuses does not require evaluation of sampling error

Table 1: Demographic classification. For the current study, we emphasize and report size/maturity (numbered classes), and do not report phenological observations (lettered subclasses per Winkelman 1979). We also combined Winkelman's (1979) classes "Jong Exemplaar" and "Zeer Jong Exemplaar" into class 3, Juveniles.

Class	Type	Description
1 Adult		
1a	Adult palm with new inflorescences and/or fruits	All Adult palms: Trunk Length ≥ 70cm with clearly visible tree trunk.
1b	Adult palm with Seedlings in the direct area	Trunk completely or partly uncovered by leaves (1 or more sides)
1c	Adult palm based on length and/or presence of old inflorescence	Seedling within a 15-m radius
2 Semi-adult	Clear trunk not visible	Trunk length 40–70cm, or total leaf length > 1m. Trunk completely covered by leaves. No fruits or flowers.
3 Juvenile		≥ 15–40cm. No clear tree trunk Some leaves present
4 Seedling		1–4 very small grass-like leaves ≤ 15cm. Most often appears as 2 grass-like leaves sticking out of the ground.

(e.g. p-values). We therefore directly compare the two complete censuses to evaluate if populations and population categories are decreasing, stable, or increasing. We also use these comparisons to infer the success of Seedling recruitment into subsequent classes. Geographic data was also compared between 1979 and 2018 to ascertain trends in the range of the species.

Results

Changes in Census: Tables 2 and 3 present the census results by class, summarizing the 1979 and 2018 data. Considering the Adult class (reproductive palms), the population in Curaçao increased to 318% of its original size over forty years, while the population on Bonaire decreased by 19%. Considering all classes together shows great increases on both islands, but this is largely due to large increase in Seedlings in both locations. Excluding Seedlings, total population on Curaçao increased nearly fourfold (383%), and decreased by 8% on Bonaire.

Changes in range: Fig. 6 compares the range of *Sabal antillensis* between 1979 and 2018. These maps show a reduction in the geographic range of this species on Bonaire, as well as an increase of the occupied habitat on Curaçao.

How has the census of *Sabal antillensis* changed over 40 years? Obvious recovery and recruitment of palms is seen on Curaçao but not on Bonaire. Considering only reproductive (Adult class) palms, Bonaire shows an alarming loss, especially considering the already small numbers of palms present. Curaçao palms have seen expansion and recovery, greatly improving their conservation status since 1979.

3 (top). Seedlings of Sabalpalm, Christoffelpark, Curaçao. 4 (bottom). Example of the Juvenile age class for Sabalpalm, Bonaire. Photos by M.P. Griffith.

The increase in Seedlings at both locations is notable but may be an artefact of phenology. On Curaçao it is likely that the increase in Seedlings between 1979 and 2018 correlates with increase in the number of reproductive Adults. On Bonaire, it is possible that more Seedlings were seen in December 2018 than in May 1979 because of the timing of the rainy season, with November being the wettest month. While there is some understanding of the timing of reproduction for Sabalpalm, the peak seed germination season is not well

5. Example of the Semi-adult age class Sabalpalm, Bonaire. Photo by Q. Coolen.

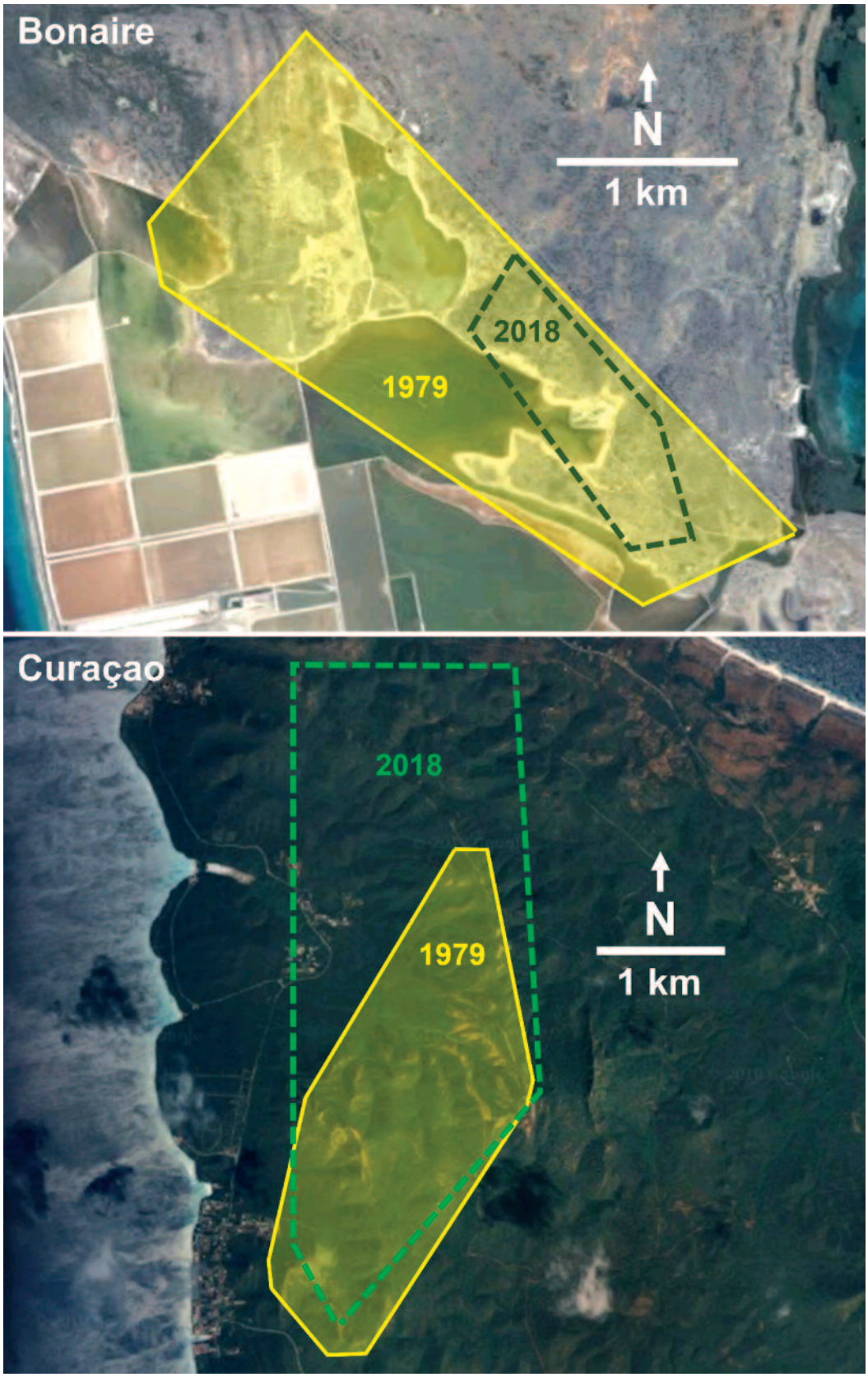
known. Seedlings are the most vulnerable life stage of most plants, and the number within a population can be quite variable year to year, compared to the number of reproductive perennial adults. Because of these highly variable aspects of seedling recruitment and mortality, we prefer to exclude the Seedling class in inferences about changes in population health between 1979 and 2018. As reported above, Tables 2 and 3 show clear differences in the Adult class on both Curaçao and Bonaire.

Nevertheless, seedlings are critical for long-term population health, as are each of the demographic classes in Table 1. The structure of age classes on Bonaire is consistent with herbivore pressure supressing Seedling recruitment into more mature age classes. Even perhaps with sufficient seeds germinating each year, not enough of these survived long enough to sustain the number of Adult palms over the forty-year period.

During the survey four dead Sabalpalms were found, one each on Seru Bientu, Seru Gracia, Seru Batata (all in Curaçao), and one at the southeast end of the range in Bonaire. The cause of death was not clear. There were no signs or symptoms of infestation by the red palm weevil, which is known as a pest of cultivated palms around Willemstad. While dead palms are a normal part of demographic turnover, the loss of any single mature palm on Bonaire significantly reduces the very small reproductive population, and as discussed below, can reduce the limited geographic range of these palms.

How has the range of this palm changed? On Bonaire, the decreasing number of palms coincides with a reduction in the extent of occurrence on the island (Figure 6). Over the 40-year timeframe, the range of these palms has been reduced from nearly 5 km^2 to less than 1 km^2. Even considering the limits of pre-GPS resolution of the 1979 maps, the 2018 survey demonstrates a reduction in occupied range, perhaps correlated with a reduction in suitable habitat (de Freitas et al. 2005). Most of the remaining Adult palms on Bonaire occur at the northwest end of the 2018 range shown in Figure 6. It is not known to what degree this has been caused by increased grazing pressure or increased human disturbance.

The opposite trend is noted on Curaçao; increased census values coincide with an increase in geographic range, from less than 5 km^2 in 1979 to over 8 km^2 in 2018. In both surveys, the vast majority of palms were


Bonaire
N
1 km
2018
1979
Curaçao
2018
1979
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1 km

Table 2. *Sabal antillensis* census results from Curaçao.

Class	1979 Census	2018 Census
Adult	323	1030
Semi-adult	283	662
Juvenile	254	1604
Seedling	153	3144

Table 3. *Sabal antillensis* census results from Bonaire.

Class	1979 Census	2018 Census
Adult	31	25
Semi-adult	0	7
Juvenile	8	4
Seedling	10	53

centered around Seru Gracia, in the area around the antenna array west of Christoffelberg. Three hills without Sabalpalm in 1979 were colonized by 2018: Seru Male, Seru Un Blachi, and Seru Wau, with Seru Male located outside of Christoffelpark.

This range expansion prompts the question of how the palms could have dispersed to those hills. Two bird species (northern mockingbird [*Mimus polyglottos*] and white-crowned pigeon [*Columba leucocephala*]) mentioned as dispersers of *Sabal* by Zona & Henderson (1989), have related species on the island: tropical mockingbird (*Mimus gilvus*), bare-eyed pigeon (*Patagioenas corensis*) and scaly-naped pigeon (*P. squamosa*). White-tailed deer are known to eat fruit and flowers of palm species in the Florida Keys (Klimstra & Dooley 1990, Barrett 2004), and perhaps this species also does so in Christoffelpark. Other possible seed dispersal agents are rodents and the quite common green iguana (*Iguana iguana*). Rodents on Curaçao include house mouse (*Mus musculus*), *Baiomys hummelincki,* black rat (*Rattus rattus*) and Norway rat (*R. norvegicus*) (Husson 1960). Of these rodents the black rat is a more probable disperser due to its arboreal lifestyle. Rodents are known to remove ripe fruits and hide them far from the fruit-bearing plant as a future food source. These hidden fruits are not always retrieved and thus get the chance to germinate (Brewer 2001). However, rats have also been shown to be palm seed predators rather than dispersers in some island systems, including Lowe Howe Island (Auld et al. 2010).

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6. Comparison of ranges of Sabalpalm observed in 1979 (Winkelman 1979) and 2018 (current study). All ranges shown as minimum convex polygons that include all data points.

What does this study suggest for palm conservation? This study provides a clear demonstration of the positive effects of herbivore management: active exclusion of herbivores in Christoffelpark coincides with very successful recruitment, maturation, and range expansion of *Sabal antillensis*. By contrast, uncontrolled access by feral herbivores coincides with scarcer demographic depth to replace the few remaining palms on Bonaire. This scarcity manifests as a near 20% decline in Adult palms over forty years and a contracted range.

We conclude that the recovery of native Curaçao Sabalpalm was enabled by the removal of goats which began around the Christoffelpark area in the mid-1980s (J. de Freitas, pers. comm.; Meyboom 1994). Coblentz (1980) described the negative effects that the estimated 3000 goats had on the vegetation of the Christoffelpark before the removal program, including lack of herbaceous vegetation and erosion problems. Feral donkeys are also known to cause serious damage to vegetation by grazing and trampling (e.g. Department of the Interior 1979). Debrot and de Freitas (1993) showed that livestock access (exotic mammals) resulted in reduced vegetation and soil cover and dominance of annual species, while ungrazed rocks are characterized by the dominance of perennial species and higher vegetation cover in the Christoffelpark. Those negative effects are typical consequences of overgrazing (reviewed in Debrot & de Freitas 1993).

We also expect that the generally recovered vegetation cover in Christoffelpark has increased *Sabal* seed germination. Van der Hurk (2016) found lower *Sabal antillensis* seed germination for exposed seeds (seeds lying around in the open in the vicinity and under mature palms) in comparison to seeds from ripe fruits taken from the trees (30% vs. 73%). Orozco-Segovia et al. (2003) also found a limited germination period for seeds of the similar *Sabal causiarum*.

The effects of herbivory on plant communities can be variable (Russell et al. 2001), but

carrying capacity appears to be the common principle – especially in island habitats such as those examined here. Among palms, a similar challenge is noted in the Mascarene Islands, which have been under intense herbivore pressure (Maunder et al. 2002). Many positive examples of recovery are known, such as the re-emergence of island flora after feral sheep removal (Beltran et al. 2014) and goat removal (Hamman 1979). Specifically, for Bonaire, Coolen (2015) documented pronounced vegetation recovery after herbivore exclusion, especially with regard to tree seedlings and juvenile trees.

Despite well-established benefits to vegetation as well as to animal welfare (Hampton et al 2016), the largest challenge for feral herbivore management is securing broad social acceptance (Roberts et al. 2018). Of specific relevance for this controversy on Bonaire is the work of Freeland and Choquenot (1990): keeping a feral donkey population below capacity keeps those donkeys healthier!

How can we further improve the conservation status of Sabalpalm? To conserve the remaining Bonaire Sabalpalms, *herbivores must be managed*. Here we provide that recommendation, as well as other recommendations informed by our experience with similar challenges.

Recommendation 1: exclude feral herbivores from the Sabalpalm habitat. A fence of approximately 3.5 km around the northwest, northeast, and southeast of the Bonaire Sabalpalms would provide opportunity for natural recruitment of Seedlings into Juvenile and later age classes, augmenting and replacing the aging few Adults that remain. We respectfully propose that such a fence would not conflict with other land uses in that area and could also provide positive benefits to other native vegetation as well as local avifauna of concern (e.g. Flamingo). As the vegetation in the Lima area has high natural value for the island (de Freitas et al. 2005), perhaps this landscape enhancement can also improve the experience of visitors, which can be of essential value to a tourism-based economy.

Recommendation 2: monitor health and recruitment of Sabalpalm. Regular re-survey of the known Adults and any potential progeny can provide assurance that recruitment is being realized.

Recommendation 3: cultivate local Sabal antillensis *at other sites on Bonaire.* Conservation horticulture and restoration efforts by Echo Conservation Centre and others to plant *S. antillensis* at other suitable sites should be encouraged, continued and expanded. Having an offsite reserve of germplasm for restoration efforts is a vital part of an integrated plant conservation plan. Growing this native species more widely – both in Bonaire's cultivated landscapes as well as other managed natural areas – can help prevent irretrievable loss of genetic diversity and protect against extirpation (Assmussen-Lange et al. 2011).

Recommendation 4: continue and promote the very successful management program in Christoffelpark. Active exclusion and management of goats has allowed Sabalpalm to flourish in its natural habitat, providing a wonderful example of in situ conservation. This positive success should be raised up as an inspiration for the many similar conservation challenges faced by palms in the Caribbean and elsewhere.

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