Goat culling project Slagbaai, Bonaire: 1 st Year Progress Report, Field Assessment and Key Recommendations

Technical Report · May 2016

DOI: 10.13140/RG.2.2.13348.09602

CITATIONS
2

READS
812

1 author:

Adolphe Oscar Debrot
Wageningen University & Research
227 PUBLICATIONS **2,588** CITATIONS

SEE PROFILE

Goat culling project Slagbaai, Bonaire: 1st Year Progress Report, Field Assessment and Key Recommendations

Adolphe O. Debrot

IMARES
WAGENINGEN UR

Goat culling project Slagbaai, Bonaire: 1st Year Progress Report, Field Assessment and Key Recommendations

Adolphe O. Debrot

Report number C052/16 **CONFIDENTIAL**

IMARES Wageningen UR

(IMARES - Institute for Marine Resources & Ecosystem Studies)

Client: Stinapa Bonaire
Barcadera z/n
P.O.Box 368, Bonaire

Publication date: 3 May 2016

IMARES WAGENINGEN UR

STINAPA BONAIRE NATIONAL PARKS FOUNDATION

IMARES vision:

- 'To explore the potential of marine nature to improve the quality of life'.

IMARES mission:

- To conduct research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas.

IMARES is:

- An independent, leading scientific research institute.

IMARES Wageningen UR is ISO 9001:2008 certified.

Photo cover: Adolphe. O. Debrot

IMARES, institute of Stichting DLO is registered in the Dutch trade record nr. 09098104,
BTW nr. NL 806511618

A_4_3_2-V14.2

Contents

1. Summary

There are many clear indicators of the deleterious impacts of grazing livestock on the flora and vegetation of Slagbaai, Bonaire. The Washington-Slagbaai National Park has seriously degenerated vegetation, second only to the vegetation of the Arikok National Park of Aruba. Similar degraded landscapes previously existed in the Christoffelpark of Curacao into the 1970s but have since largely disappeared due to vegetation recovery following livestock removal**.** Livestock densities in Slagbaai are estimated at 2.69 goats/ha. Based on comparative studies from arid ecosystems elsewhere, these livestock densities well-exceed the ecological carrying capacity of the semi-arid vegetation of the Washington-Slagbaai National Park. If goats are not culled, then ecological restoration of the park will not be possible. Prior trials using grazer exclosures inside Slagbaai prove that vegetation recovery will be rapid following goat removal and prove that reforestation with rare native species is possible using simple methods.

Baseline studies were conducted by four Wageningen University students. The main results are briefly presented in this report and will provide a solid baseline from which to work as the culling program is implemented over the course of the next few years. Based on these studies, several recommendations are made for monitoring project progress and further follow-up research.

Several infrastructural needs to enable culling of the Slagbaai goat population were achieved by the end of the year (2015)- such as restoring roads for access and securing the perimeter fencing- but other critical needs-such as closing watering holes to control and restrict grazer access- were largely not achieved. Documented goat catches for the culling program amounted to a total of 937 animals in 2015. At present goat removal rates remain well-below projected intrinsic population growth rates. The numbers of animals caught represent a large increase compared to prior years but still fall greatly short of the 2400 goats that minimally should have been caught in the first year to be able to meet project goals.

Goats are currently almost exclusively being caught using small funnel traps. This method is labour-intensive and has significant (but recently reduced) impacts on the native vegetation, particularly on plants that are being used as bait to attract goats into the trap.

New and improved goat catching methods need to be introduced as soon as possible in 2016. There are a variety of tried and tested systems by which to trap and remove goats. For this, the remaining planned infrastructural improvements (closing freshwater access) are essential as is the use of new and more effective techniques for goat control and eradication. Several of these have been discussed or even already partially tried but must be effectively implemented in 2016. Goat trapping and removal rates must significantly surpass intrinsic population growth to be able to significantly decrease population size within the project period.

2. Introduction

Within the Caribbean Netherlands overgrazing by goats is considered the most serious threat to the terrestrial ecosystems (MinEZ 2013, Smith *et al.* 2014). This is also the case on Bonaire where in the recent past several attempts were made to start addressing this critical problem. Aside from being a direct threat to the natural vegetation and rare plants, grazers have many other ecologically and economically deleterious effects. The roaming livestock issue is often a major impediment to agricultural development (Debrot *et al.* 2015). This problem is shared with many islands in the Caribbean, where the roaming livestock imparts damage to not only vegetation and wildlife but also crops and public landscaping (Grenada Govt 2007).

Since the early 1950s, the negative ecosystem impacts of overgrazing by feral livestock have been well-known (Gilliland 1952, Kolars 1966, Pisanu *et al*. 2005, Bakker *et al*. 2010, Müller *et al*. 2011). Coblentz (1977 and 1978) was one of the first to highlight the special vulnerability of island ecosystems to introduced grazers. Since then many others have documented the negative consequences of feral grazers on island ecosystems (Gould and Swingland 1980, Debrot and De Freitas 1993; Fernández-Lugo *et al*. 2009, Carrion *et al*. 2011). A recent world-wide review of 251 invasive mammal eradications also show clearly that removal of invasive mammals has almost always been very effective in restoring biodiversity values to threatened island ecosystems (Jones *et al*. 2016).

Goats are the most adaptable of the introduced grazers in ecosystems that have never had large herbivores. Aside from Klein Curaçao and Klein Bonaire, where goats have been eradicated, and the Christoffelpark of Curaçao where goats are structurally controlled by shooting, this herbivore is a threat to biodiversity and ecosystem functioning on all of the islands of the Caribbean portions of the Dutch Kingdom (Coblentz 1980). Goat grazing totally alters the original orchid and bromeliad ground vegetation native to these islands (Fig 1 A,B) into cactus and acacia thorn scrub (Debrot and de Freitas 1993) (Fig 1C).

Fig. 1. How the vegetation of Bonaire was (A,B) and how it has become (C) due to overgrazing. How it originally looked, with thick ground-growing bromelias and orchids, we learn from goat-free areas in Curaçao (Debrot and de Freitas 1993). Today the lack of tree regeneration and selection for toxic and grazer-resistant plant species has left the vegetation of Slagbaai seriously impoverished, and unable to recover if goats remain.

On Bonaire the situation is extremely acute and many tree species are no longer able to regenerate young plants. Many plants species have likely already died out but many more will likely follow if measures are not taken (Lo Fo Wong and de Jongh 1994, Proosdij 2001, Freitas *et al*. 2005). While the problem has long been recognized (Anonymous 1985, 1986, 2006, 2009), up to now little concrete action has been taken to address this problem. Particularly worrisome is how goats and donkeys will strip columnar cacti of their bark and thereby cause their death (Fig. 2).

Fig. 2. Removal of the succulent bark from columnar cacti by ungulate herbivores leads to the death of these keystone tree species.

The Washington Slagbaai Park is essentially composed of two bordering former plantations where in addition to the culture of aloe, the harvest of salt and the burning of charcoal, goat husbandry was a key form of exploitation (Figs. 3, 4) The first one is the Washington plantation which was given in ownership to the government of the Netherlands Antilles by Julio (Boy) Herrera upon his passing away in 1967, for the purpose of nature conservation. Management was accorded to Stichting Nationale Parken (STINAPA), Nederlandse Antillen. Herrera had as a condition that his heir would be allowed to continue keeping goats in a limited area of the plantation for the rest of his life. This meant limits to the ability of park management to control livestock density in the Washington area of the park, which last to this day. In 1979 the adjoining Slagbaai plantation was bought from the Beaujon and Forbes families, heirs of Jean-Jacques Debrot who had bought the plantation in 1892 together with Jean Luis Cadieres.

As usual with the sale of plantations in those times, the plantation was sold "lock, stock and barrel", ie. with all infrastructure, such as wells, buildings, fields, forests and remaining roaming livestock. Raising and harvesting goats was a key source of income on the Slagbaai plantation during whole the colonial period. But removal of all animals was not possible prior to sale and many animals remained at loose in the hilly terrain. The unmarked roaming goats, referred to as "orea largu" (literally "long ears" but….meaning "feral") on Bonaire (Neijenhuis *et al*. 2015) were then free to multiply. In 1980, Coblentz visited the island to provide an initial assessment of the goat issue. It was judged to be very serious, and he stressed the need to remove all goats and donkeys.

In fitting with the (emancipation) trend of the times, in the mid-1980s the Bonaire commission of the STINAPA Neth. Ant. was established as a new, independent foundation, namely STINAPA Bonaire. Management was transferred from STINAPA Neth. Ant. to Stinapa Bonaire under condition that the goat problem would be solved.

The problem was ultimately not addressed as Stinapa Bonaire largely used the goat herds as a source of income for the park. More recently STINAPA has become aware of the grave consequences of livestock and of the need to cull goat densities, and efforts were rekindled to finally start addressing the goat issue in both parts of the Washington-Slagbaai plantation. An additional incentive to solve this problem was

provided when Stinapa Neth. Ant. (though now largely merged with the Curaçao CARMABI Foundation) indicated it would be willing to transfer its ownership of Slagbaai to Bonaire once the goat problem was sustainably addressed and solved.

In the recent past, thanks to donations by the DOEN Foundation, STINAPA was able to invest in fencing to prevent movement of animals between the Washington and Slagbaai sections of the WSNP. While on the Washington side of the park, the long-standing grazing-rights issues are an impediment to management, this is not the case on the Slagbaai side where all of the free roaming goats and other livestock are at the full disposition of STINAPA. Consequently, in Slagbaai the minimal requirements exist to actually be able to harness the goat issue. Once the grazing rights are bought out, the ability to harness the goat issue in the Washington area will also be very high. But that concerns a separate initiative.

This project specifically only concerns the goats of Slagbaai and the neighboring former plantation of Labra/Brasiel. The latter areas are a large former plantation bordering Slagbaai that was also bought with Dutch development funds in the 1980s for the purpose of nature conservation. While the government of Bonaire has still not officially transferred management of Labra/Brasiel to Stinapa, the area is of limited access to goats as it is bordered by the waters of Goto, has no other parties legally keeping goats, and is formally designated for nature conservation in the Bonaire zoning plan. This provided favourable conditions for STINAPA and the island government to include Labra/Brasiel in the goat culling project. Consequently goat culling activities also pertain to Labra/Brasiel.

Fig. 3. Loading live goats for shipment to Curaçao. Photo: A. Debrot, Sr.

Figure 4. Salting slaughtered goat carcasses to make "yorki" for local consumption. Photo: A. Debrot Sr.

3. Terms of reference, context and scope

In 2013, the Government of the Netherlands made an additional € 7.5 million available to the islands of the Caribbean Netherlands to develop and implement key projects for nature management. This was based on the realization that natural resources play a pivotal role in island economies as a basis for nature-oriented tourism (MinEZ 2013). This project originated in 2013 when IMARES assisted STINAPA and the Government of Bonaire to design a project to address the longstanding need for **"Goat eradication and control in Washington Slagbaai National Park"**. The project was approved in 2014 and on that basis Stinapa and IMARES drafted a project agreement **GOAT ERADICATION AND CONTROL IN WASHINGTON SLAGBAAI NATIONAL PARK BONAIRE** (OLB/STINAPA 2014) to further define IMARES' role in project implementation. The major contribution of IMARES, agreed to by the parties, concerned the design, guidance and execution of a number of critical outputs as listed in Table 1.

One of these (4) is a final assessment due mid-2018, one is due in April 2016 and two are due in December 2015. To address these deliverables, IMARES, together with Dr. Milena Holmgren and Dr. Pim van Hooft from Wageningen University designed and guided four student interns during 2014 and 2015. This resulted in 4 student theses. A time-line for milestones and events in the project up to December 2015 is given in Table 2.

Table 1. Key deliverables for IMARES in the goat project for Washington-Slagbaai National Park.

	OUTPUTS	**DATE DUE**	**FORMAT**
1.	Report initial baseline goat-problem assessment, recommendations and approach. Including documenting feral livestock density, distribution as well as current and required removal rate for goats Including documenting current goat food composition and selection in the park.	Dec 2015	STINAPA/IMARES report
2	Report documenting and discussing the first years of vegetation recovery in response to grazer exclusion from already-established experimental plots.	April 2016	STINAPA/IMARES report
3	Report mapping cactus composition, size-structure, distribution and health status in different vegetation units of the park	Dec 2015	STINAPA/IMARES report
4	Final assessment, lessons learnt and the way forward to structural goat control in Slagbaai	Mid 2018	STINAPA/IMARES report

In the next section I lists the four resulting theses and highlights the most salient findings of each of these baseline studies.

The four theses summarized below, fully address deliverables 2 and 3 but only address part of deliverable 1 as agreed between Stinapa and IMARES. This assessment is based on a field visit in November 2015 and particularly concerns those matters not addressed in the student theses but necessary as part of output 1.

Hence, the main questions addressed here towards the end of project year 1 are:

- What is the status of the infrastructural upgrading required for successful goat eradication?
- Status of selected other limits or issues
- What is the removal rate for goats required for successful eradication?
- What is the current goat corralling system and is the current goat removal rate sufficient to meet project goals?
- If not what can be done about it?
- Can goat removal (eventually) be financially self-supporting on Bonaire as it is on Curacao?
- Recommendations for further monitoring and research.

Table 2. Time-line of key milestones and events in the Slagbaai goat culling project 2013-2015.

	2013
August 5	Initial contact for project idea with Frank van Slobbe
August 6	STINAPA Board approves project cooperation
September 11	First draft plan by Debrot
September 19	Final draft with STINAPA and DRO Bonaire
	2014
March-October	Field orientations and trapping trials Chris Schmitz
End of 2014	Project approval by Ministry of Economic Affairs
July 27	First contact Johan Afman, new interim director
September 15	Evo Cicilia appointed Stinapa Project manager
September 18	Schmitz signals problems encountered in practical implementation
September 20	Press story abt Slagbaai goat concerns (source unknown)
October 2	Internship subjects formulated and mailed to Wageningen UR
October 13-20	Project kick-off
October 16	presentation to Stinapa Board
October 16	presentation to Stinapa staff and personnel
October 17	consultation with key island partners (DRO, RCN)
October 22	Debrot mails key info on wells and water holes
October 29	First contact with students Wageningen
	2015
February 12	Four baseline field studies start
February 12-20	Wageningen UR supervisors visit Bonaire
February 13-14	John de Freitas of Carmabi visits for guidance
March	Stinapa goat catching begins
December	Road repair finished
December	Exterior fencing Slagbaai completed
December	Fencing Washingto-Slagbaai fixed
March 1	Chris Schmitz begins again after delay due to personal reasons
March 10	Chris Schmitz withdraws from project
March 16	Debrot expresses concern about loss of Schmitz
April 19-24	Research project leader Debrot visits Bonaire
April 23	Interview with Boi Antoin
April	Criticism appears in Extra
April 30	rebuttal to Extra approved by Stinapa
April 30	rebuttal submitted to Extra
May	Rebuttals placed in Extra
November 10-13	Research project leader Debrot visits Bonaire
November 12	Update presentation to Park personnel
November 12	Update presentation to Stinapa staff of the results of this report
November 13	Update presentation to key island partners (DRO, RCN)
November 18	Four baseline Theses completed and submitted
December 16	First draft Progress report for Year 1

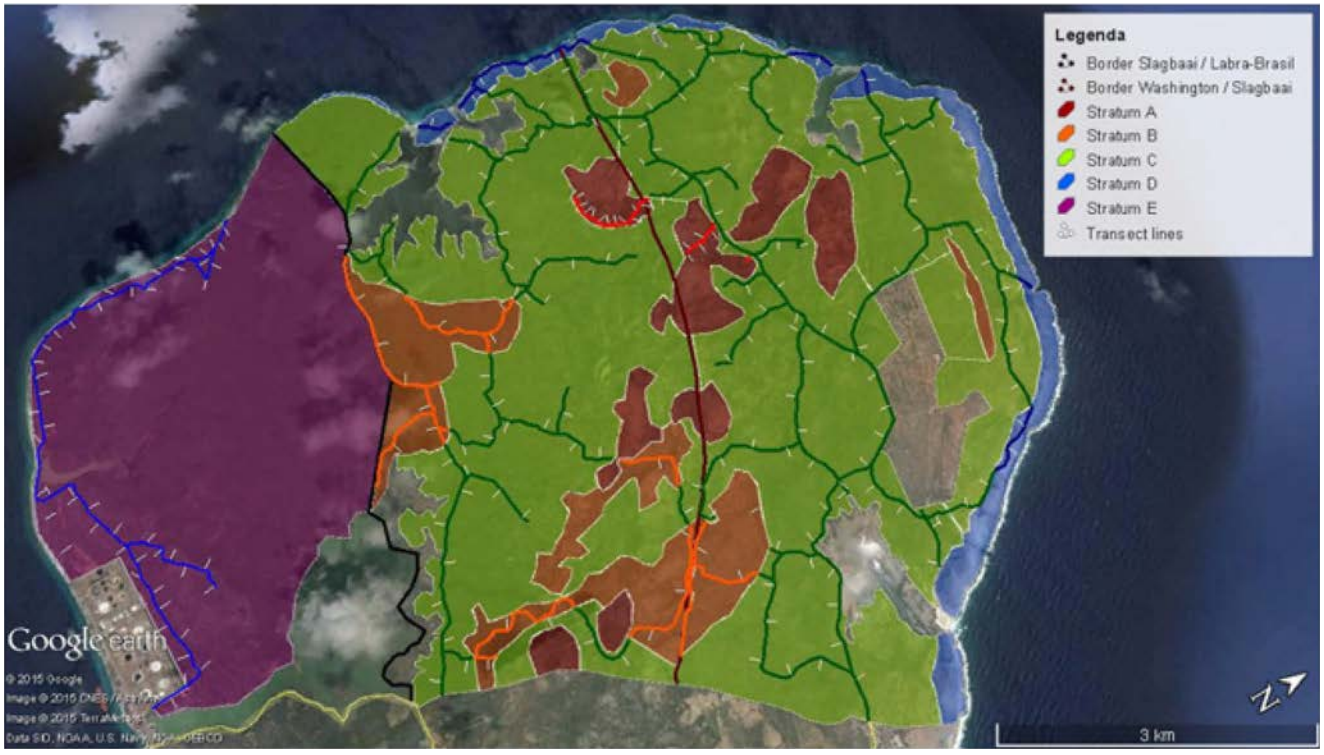
4. Highlights from four Student Theses: 2014-2015

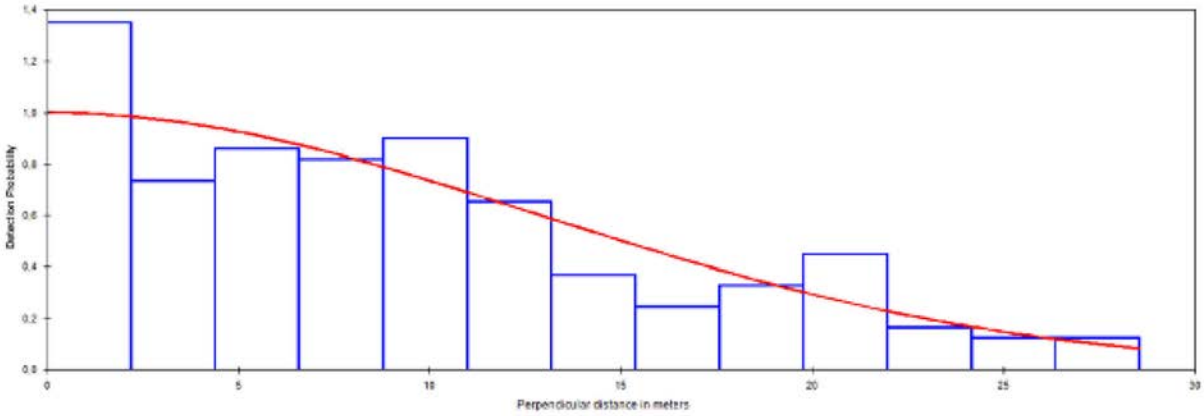
4.1 Kevin Geurts:

The abundance of feral livestock in the Washington Slagbaai National Park, Bonaire.

Wageningen University, Master Thesis, November 2015. 52 pp. Supervisors:
Dr. WF van Hooft, Dr. NM Holmgren, Dr. AO Debrot

In this study, the population density of feral livestock was estimated for the park and the Labra/Brasiel area using the Distance method. A total of 250 transects of 100 m were surveyed and 183 goats, 3 donkeys, 12 sheep, 1 swine and 3 cats were counted. The results indicate a goat density of 2.7 goats per hectare in the national park, corresponding to an abundance of about 11000 goats. Slagbaai-Labra/Brasiel, the areas of concern for this goat culling project, are estimated to have a total of 5200 goats. The population density of the other animal species was much lower and less problematic. The *Opuntia* distribution was also assessed in the study area, a density dependent relation between *Opuntia* density and goat density was found. Finally, seasonal differences in diet composition of goats were observed; goats seem to become less specific and eat only cacti in the dry period, as this is all that is left. The study concludes that control of the goat population is urgently needed and a more effective way of catching the goats should be used. Next to bringing down goat population density, it is also important to cull and monitor the development of the populations of other introduced feral species.





Estimates goat per stratum					
Stratum	N	95 % CI	D (1/km2)	95 % CI	D (1/ha)
A	859	395 - 1870	280	129 - 609	2,8
B	1510	700 - 3260	366	169 - 789	3,66
C	7589	5626 - 10237	254	188 - 342	2,54
D	603	209 - 1741	251	87 - 725	2,51
E	502	161 - 1566	45	14 - 140	0,45
Sector	N	N LCL	D (1/km2)	95 % CI	D (1/ha)
Washington	5886	4262 - 8127	265	192 - 367	2,65
Slagbaai	4685	3114 - 7046	269	179 - 405	2,69
Labra	502	161 - 1566	45	14 - 140	0,45

4.2 Nikkie van Grinsven:

Diet preference of roaming goats (Capra hircus) on columnar cacti in Bonairian scrublands.

Wageningen University, Master Thesis, November 2015. 22 pp. Supervisors: Dr. WF van Hooft, Dr. NM Holmgren, Dr. AO Debrot

In this study, the diet preference of goats was investigated with respect to three columnar cacti; kadushi, *Subpilocereus repandus*, jatu *Stenocereus griseus*, and kadushi pushi, *Pilosocereus lanuginosus*, in relation to associational resistance, spine characteristics and foraging by the green iguana. The dietary preference was assessed through food choice experiments using choice options, such as with or without spines on cacti, with or without Opuntia to interfere with accessibility, and evaluation of additive damage effect from the native green iguana.

The study consisted of a combination of field and enclosure experiments. Three different field experiments were simultaneously conducted within Washington Slagbaai national park during which diet preference, association resistance and additional browse damage were assessed. Goats were free to enter and leave the experimental locations during these field experiments. In enclosure experiments, 18 goats were monitored in captivity during which the first 2 field experiments were replicated and herbivory reduction due to cacti spines was added as third enclosure experiment.

The results indicated that a higher density of spines was associated with a decline in spine thickness. This may indicate a trade-off between shade (density of spines) and defensive traits (thickness). After that, Opuntia and spines were tested as factors, and their presence was shown to have no reducing effect on goat herbivory. Field experiments with iguana showed no observations of cactus biomass consumption. Therefore it is safe to assumed that the Iguana rarely if at all, browse on cacti, with the exception of their fruit and flowers.

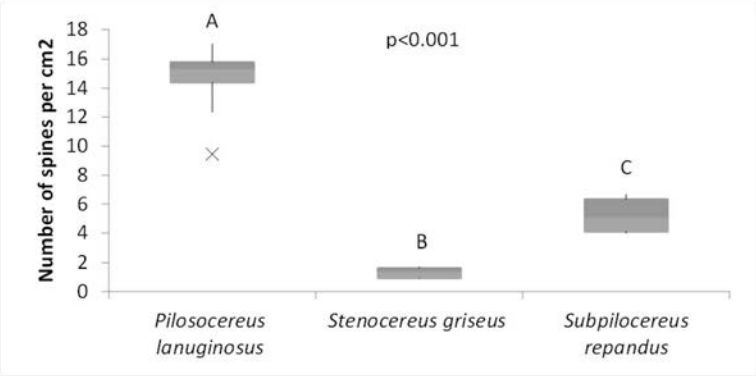
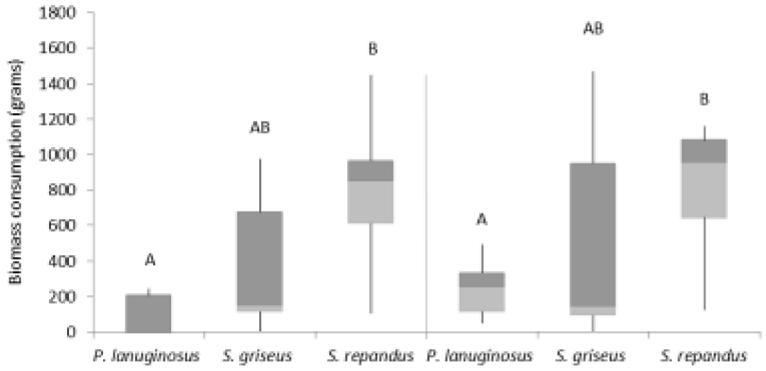


Figure 3.1 The number of spines per cm^2 per cacti species. Line in box: median, box: 25^{th} and 75^{th} percentiles, whiskers (Tuckey style). Boxplots not sharing the same letter are significantly different. Kruskal-Wallis, N = 5, $x^2 = 92.365$, df =2, p <0.001.

During all field and enclosure experiments goats showed a diet preference for *S. repandus* over other cacti species, and this preference was not influenced by the removal of spines or the presence of *Opuntia*. A 60% rate of browsing damage was observed within 48 hours of cacti placed in the field, and when restricted to compulsory enclosed conditions, 100% of available cacti were damaged within 24 hours. The findings in this report provide quantitative evidence of cacti consumption, severe goat herbivory on *S. repandus*. When the *S. repandus* has been eaten goats will move to the *S. griseus* and *P. lanuginosus.*



4.3 Barry van den Ende:

How do the distribution and abundance of columnar cacti relate to microsite types and goat grazing pressure?

Wageningen University, Master Thesis, November 2015. 50 pp. Supervisors: Dr. WF van Hooft, Dr. NM Holmgren, Dr. AO Debrot

This study investigated the effect of goats on the columnar cacti population. This was done by collecting data on distribution, damage and abundance of columnar cacti in both Washington-Slagbaai National Park and Klein Bonaire. As it was hypothesised that facilitation by microsites could prove important in an arid ecosystem with grazers, microsites and abiotic amelioration by microsites was studied as well. As expected, goats impacted the columnar cacti populations in a negative way. Using Klein Bonaire as a control area where no goats have been roaming for almost 30 years, significant differences were found when comparing columnar cacti populations with Washington-Slagbaai National Park.

The population of *P. repandus* in WSNP is unhealthy with only 27.7% of the population being juvenile in WSNP-Limestone. In Klein Bonaire, the population is a lot healthier with 75.2% of the population being juvenile. The WSNP population of *S. griseus* is healthy and most common with nearly 9000 individuals documented and 86% being juvenile and 95% being juvenile in Klein Bonaire. *P. lanuginosus* is the least abundant columnar cactus species in WSNP and is absent in Klein Bonaire. However, this is likely to be due to environmental stressors instead of herbivore pressure as *P. lanuginosus* is regenerating well with over 89% of the WSNP population being juvenile.

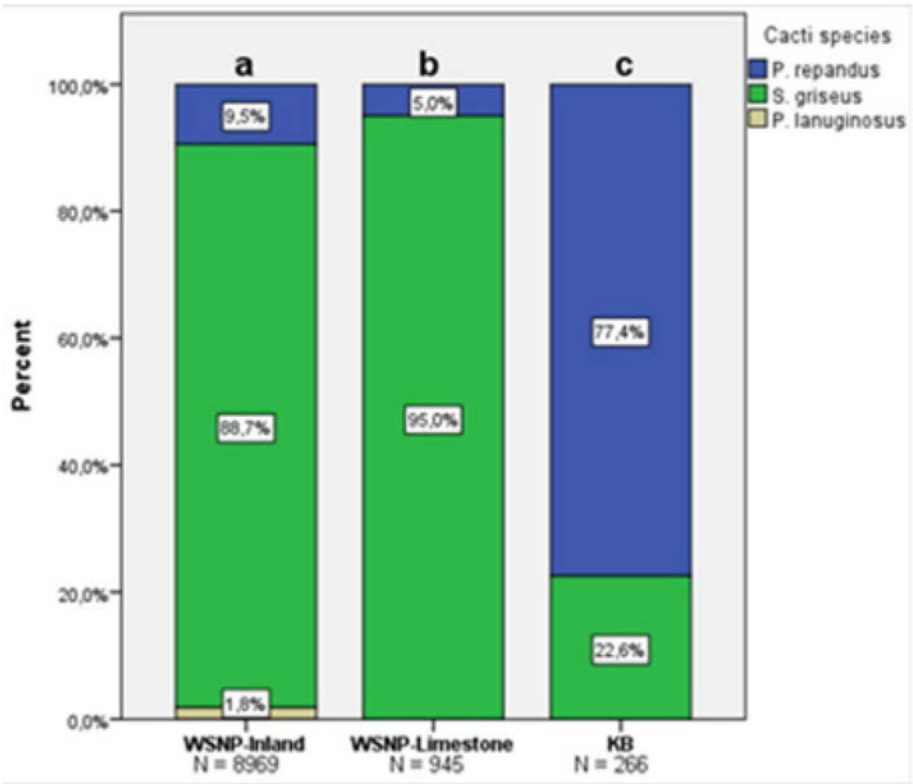


Figure 16: Species composition in WSNP and Klein Bonaire

A significant difference on *P. repandus* also exists in the amount of damage between Klein Bonaire, where a mean damage of 4% was found, and Washington-Slagbaai National Park where the mean damage on *P. repandus* was 24%. For *S. griseus,* a mean damage of 19% was found in WSNP and a mean damage of 7% was documented in Klein Bonaire. However, this difference was not significant due to the small sample size. This was also the case with the proportion of dead adult *S. griseus* which was 8.8% in WSNP and 0% in Klein Bonaire. As for *P. repandus*, the difference was significant with 10.2% of the adult *P. repandus* population being dead against only 1.9% in Klein Bonaire. These observations are likely to be attributable to foraging by goats as they seem to prefer *P. repandus* above the other two cactus species judging from the relatively high amount of trunk damage for *P. repandus* (3.9% against 1% and 1.8% for *S. griseus* and *P. lanuginosus* respectively).

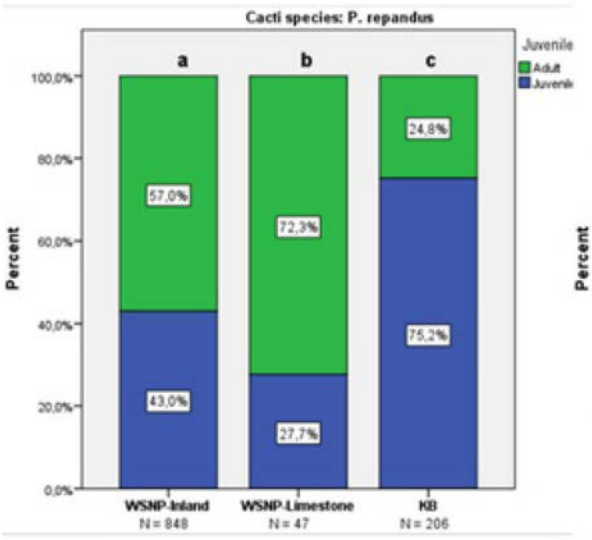


Figure 21: Relative regeneration of *P. repandus* between Klein Bonaire and WSNP

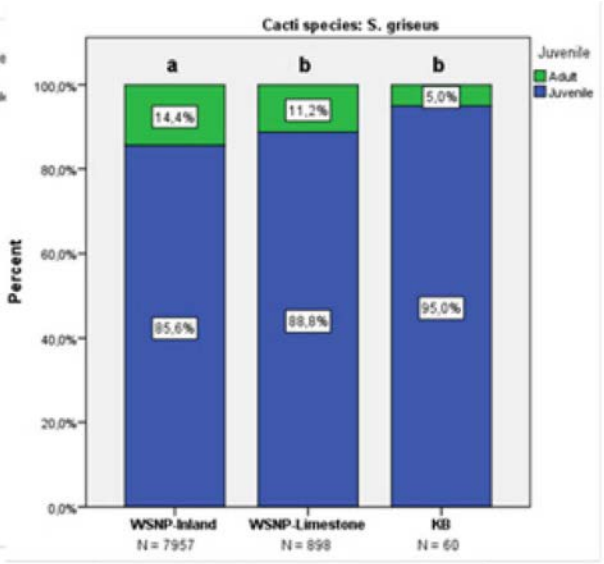


Figure 22: Relative regeneration of *S. griseus* between Klein Bonaire and WSNP

As a result, *P. repandus* seems to be in direct danger, which is concerning as this columnar cactus is favored by birds, bats and people. Although the other cacti species are likely to be targeted by goats once *P. repandus'* population has declined even more.

Furthermore, results show that increasing damage leads to a decreased fruit production, which links the goats indirectly with the native bats and birds which depend on the fruit in the dry season.

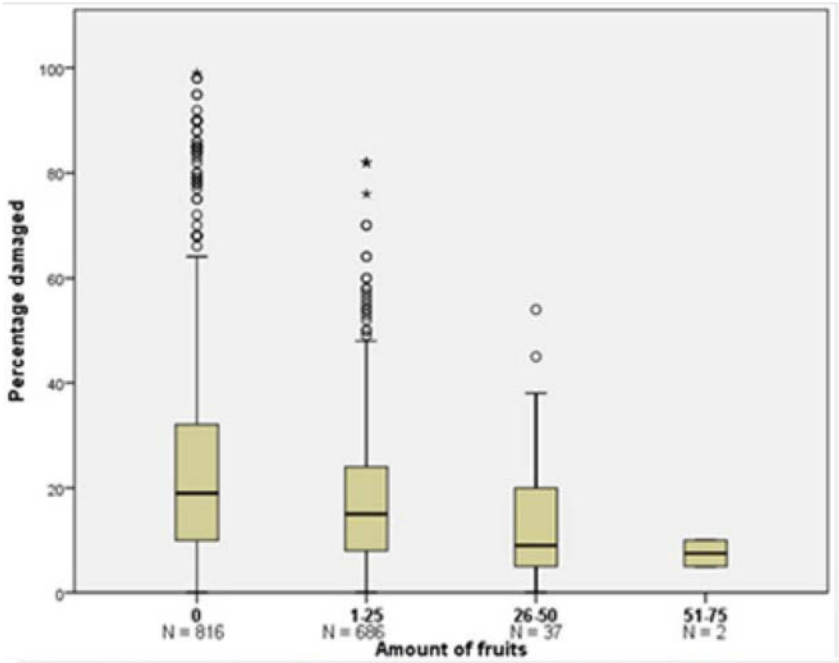


Figure 29: Percentage of visual damage against fruit production

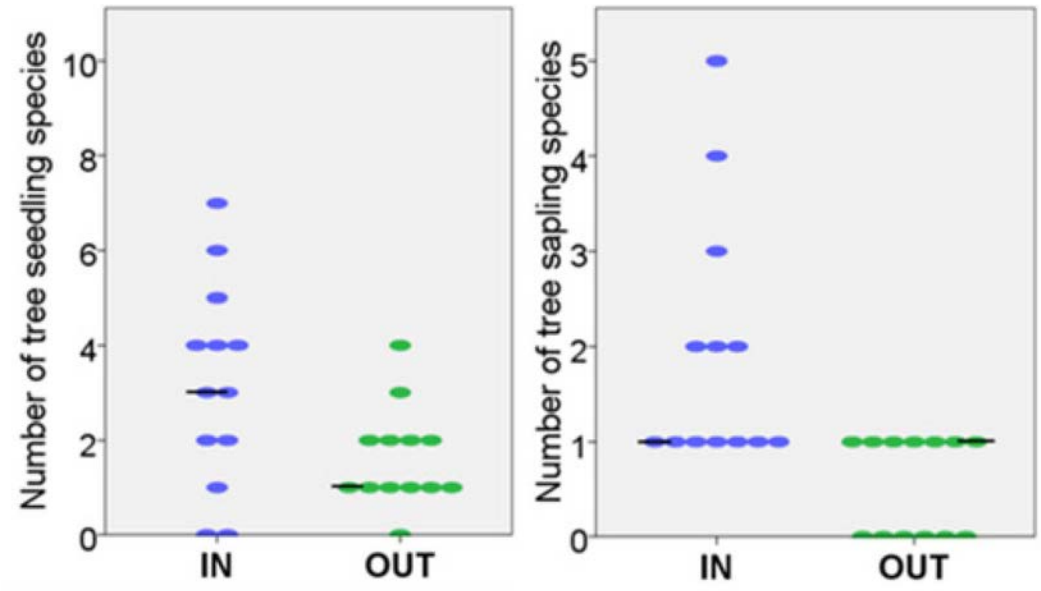
All these results add up to conclude that the exotic goat has been affecting Bonaire's columnar cacti in a way which has been detrimental to its native flora as well as its fauna. Therefore, stringent measures need to be taken to eradicate goats from Washington-Slagbaai National Park

4.4 Quirijn T. Coolen:

The impact of feral goat herbivory on the vegetation of Bonaire: An experimental study in the Washington-Slagbaai National Park.

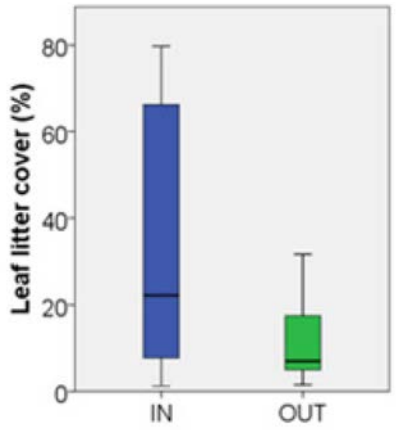
Wageningen University, Master Thesis, Resource Ecology Group, November 2015. 51 pp. Supervisors: Dr. WF van Hooft, Dr. NM Holmgren, Dr. AO Debrot, Drs. JA de Freitas.

In this study the impact of feral goats in the park was assessed by comparing control and treatment sites using a goat exclosure experiment. It included the analysis of 13 areas where goats had been excluded for a period of 8 years. This study revealed the negative impact of feral goats on the vegetation of the Washington-Slagbaai national park. Recovery of the vegetation in the exclosures was found to be significantly higher in comparison with areas accessible to goats. Vegetation rejuvenation within the exclosures increased dramatically for tree species such as *Quaderella odoratissima*, *Randia aculeata* and *Guaiacum officinale*. *Quaderella* and *Guaiacum* are key evergreen virgin forest tree species.



Direct and indirect positive relations with goat presence were observed for Opuntia wentiana and Croton flavens (IN: inside goat exclosure), OUT (outside goat exclosure).

Figure 1. Differences in presence of (juvenile) trees in plot 7. OUT plot on the left (A.) and IN plot on the right (B). Note the presence of *Guaiacum officinale* (bright green, front) and *Capparis odoratissima* (dark green, back) in the exclosure plot (Coolen 2015).



A comparison of leaf litter cover inside (IN) and on control plots outside (OUT) goat exclosures which have been fenced for 8 years.

5. Status of Infrastructural Requirements

Key infrastructural preparations for the effective culling of goats in the Slagbaai and Labra/Brasiel areas are:

1) the restoration of former roads to allow vehicular access to areas for goat catching
2) repairing the fences along the eastern border of Slagbaai and between Slagbaai and Washington. This is essential to avoid re-immigration by goats from adjacent areas once culling begins. The integrity of these fences is of vital interest to livestock keepers in bordering areas. So it is anticipated that they will cooperate in keeping the fences intact, once culling begins in earnest. Otherwise they run the risk that they will lose their animals.
3) Preparing the existing permanent and temporary water holes as traps for goats.
4) Watering holes that are temporary but not useful for catching should be blocked for access by herbivores.

In November 2015 objectives 1 and 2 had been fully achieved (Fig. 5).

Fig. 5. Closure of the fence line between Slagbaai and the Dos Pos area at the Saliña of Goto. This was done by the traditional method using wood. Metal stakes and fencing would rust in no time in the saline waters of Goto. In contrast, under these conditions wood will last as even termites do not survive in high salinity areas. Photo: P. Hoetjes.

Control of watering holes and closing access to these (to large herbivores) is a key strategy used to control feral herbivore distribution and numbers (Benjamin *et al*. 2011). These key sites need to be listed, mapped and fenced off either to use as traps or to totally exclude feral herbivores.

Key known freshwater sites in Slagbaai-Labra/Brasiel are the permanent freshwater spring of Bronswinkel, on the border between Washington and Slagbaai, and Pos Labra where there is dug well and a seasonal pool located behind a dam (Figs 6, 7), Based on conversations with Cecilio Thodé who used to work on Washington plantation when it was still in commercial production, and examination of

the 1919 Werbata map of Bonaire, on 22 October 2014, I listed six additional freshwater springs and pos di pia that need to be taken into account for effective control of herbivore productivity. The 1919 Werbata map is only partially relevant as many former freshwater sites have filled-in with sediment. According to Cecilio Thodé, many became useless after the early 1930s (33-36) when intense rainy seasons flooded and filled many of these former freshwater sites. All listed sites are known to George (Kultura) Thodé, chief ranger. According to Cecilio Thodé, Pos Nobo (see Werbata 1919) is dry today mainly due to faulty maintenance. All wells need to be periodically cleaned from the inflow of sediment from above and this has not been done for years.

Fig. 6. Seasonal water pool behind the dam at the well of Labra. Photo: P. Bertuol.

Fig. 7. The dug well of Pos di Labra. Photo: P. Bertuol.

List of additional fresh water wells to control.
a) Pos Salu (at the saliña of Playa Funchi (see Werbata 1919)

b) Pos Rooi Hoeba (see Werbata 1919) spring (Fig. 8). The location is intensively used by poachers. It is the most idyllic location of Slagbaai, much more picturesque than Bronswinkel. The former pos di pia was lost out of sight after Stinapa purchased Slagbaai in 1979.

Fig. 8. Spring of Pos Rooi Hoeba, Oct 2014; dry. This spring has not been maintained for decades but provides freshwater seasonally and is a major site used by goat poachers. Photo: M. Beenhakker.

c) Pos di tras di Juwa...Called Pos Palmiet by Kultura Thodé located close to Juwa pass. It is a seasonal spring in disrepair. Visited in October by Poulo Bertuol and myself.

d) Pos di Seru Juwana: spring. South of Seru Juwana. Not visited but Kultura knows it.

e) Pos di kabritu, see Werbata 1919). Shallow foot-well. Lies on the east side of Saliña Slagbaai and discharges into Rooi Baki. Not personally visited but known to Kultura.

f) Mulina Kora. The windmill no longer stands. It is a beaten well and has a small cement water basin. Located south of Juwa pass and well known to Kultura. Is not a natural water source but a potential location as artificial watering site. The basin also collects rainwater and may unintentionally serve as a seasonal water source.

Conclusions:

- **Objectives 1 and 2 have been achieved as of November 2015**
- **Objectives 3 and 4 had hardly been addressed as of November 2015.**
- **Only the spring of Bronswinkel was fully prepared as a livestock trap and preparations were underway at Pos Nobo and at the pool of Pos Labra.**
- **The conclusion is that as of November 2015, most key water sources still need to be closed and controlled to make goat removal effective.**

6. Other Issues

6.1 Slaughterhouse capacity

The issue of slaughterhouse capacity has been a longstanding point of concern to this project. This is because the capacity of the slaughterhouse of Bonaire is structurally very limited. This raised the possibility that the culling program could be limited/restricted by slaughter capacity, assuming a) that most animals caught in the program must be slaughtered and b) that most slaughtering takes place at the slaughterhouse. In fact, based on livestock counts for all of Bonaire and goat productivity it has since become clear that most slaughtering on Bonaire does not take place at the slaughterhouse (Neijenhuis *et al*. 2015). In addition, many of the animals captured and removed concern lambs. These are not immediately slaughtered but bought by Bonairians to keep on their own plantations. However it may be that this combination of factors means that the slaughterhouse concern forms no practical impediment to goat culling in Slagbaai. The goat herd of Slagbaai ultimately is only a small part of the total Bonaire goat herd (Lagerveld *et al*. 2015).

Conclusion:

- **Elevated culling of the Slagbaai herd has no net effect on either slaughter capacity or even local goat meat prices on Bonaire.**

6.2 Potential exportation of the grazing problem

One early point of concern was the possibility that removal of goats from Slagbaai, particularly the females and lambs that are not slaughtered might effectively only result in exporting the goat grazing problem away from the park into conservation areas outside the park. For instance, it could be that animals purchased for keeping would be set loose again in the border areas of Lasana and cause grazing pressure in Lasana to increase. As discussed with stakeholders in the 20 April 2015 meeting and explained by myself and Evo Cicilia, this is unlikely to be a problem for several reasons:

a) Most animals removed are for slaughter
b) Those animals purchased for keeping will certainly be looked after with care as they have cost the new owner money. There is no incentive for people to buy a goat and then lose it again.
c) Most animals purchased for keeping are kept in areas designated agrarian lands. These lands are designated for agrarian purposes so the keeping of animals in these areas is not contrary to their legal and planned purpose

The decision was taken that aside from the data already monitored by Kultura with respect to the goats sold, Kultura Thodé would also monitor:

1) Who buys the goats
2) Where the goats will be kept
3) What the mid to long-term plans of the new owner are with respect to the purchased goats.

Such data are sufficient to allow a thorough diagnosis of the problem, which as explained above is likely not an issue of concern.

Conclusion:

- **According to communication by Evo Cicilia on 29 May 2015, data are now being collected to allow diagnosis, but the problem is likely negligible.**

6.3 Christian context for goat removal

Bonaire is a strongly Christian, and principally Catholic island. Goat husbandry is deeply embedded in the local culture and way of life (Neijenhuis *et al*. 2015) and the goat is often seen as "native" and referred to as "a gift of God" (B. Antoin, pers. comm.).

In many culling programs world-wide, it is normal that feral animals like goats are shot or killed and not harvested for consumption. On Bonaire this is viewed as a squandering of food which can bring bad luck/punishment (from God). To receive public support, it is important that the food value goats represent is respected (E. Cicilia).

Another question is what Christian scriptures say about the abuse of land by overgrazing?
Here are some answers from the Christian scriptures:

In Genesis 1:31, on the sixth day of creation "God looked over all he had created and saw that it was excellent in every way". At that time Bonaire was without the goat and looked totally different from the way it is today. The goat is not native to Bonaire but was introduced by man.

In Genesis 2:15. God gives man the stewardship over nature. "The Lord God placed man in the Garden of Eden to tend and care for it"

In Exodus 23:10, 11. God instructs man that land, fields and nature need rest (from exploitation).
"Plant and harvest your crops for six years but let the land rest and lie fallow for the seventh year".

When Gods' people fail to listen and abuse the land they suffered grave consequences.
Leviticus 26: 33-35 "Your land will become desolate, and your cities will lie in ruin. Then at last the land will make up for its missed Sabbath years as it lies desolate during your years of exile in the land of your enemies. Then the land will finally rest and enjoy its Sabbaths". Today most born Bonaireans live elsewhere than on Bonaire.

Conclusion:

- **Key citations of Christian scripture warn against abuse of the land and the consequences this can have to man. The project is in agreement with the Judeo-Christian context but culling should not squander the food value of the harvested goats.**

6.4 Lower goat densities in Labra/Brasiel

It has long been casually noted and remarked that goat densities in Labra/Brasiel area are much lower than in Slagbaai and/or Washington. This is corroborated by the counts made by Geurts (2015) (d = 0.45 goats/ha instead of 2.69/ha). The area has no resident goat keepers and is publically known to be heavily poached. The apparent lower goat density raises interesting questions.

- Is this due to lack of freshwater sources in Labra/Brasiel?
- Is this due to more effective goat removal there due to free poaching?
- Is this due to lack of kadushi or other food plants in Labra/Brasiel?
- Is it a combined effect of different factors?

Conclusion:

- **Answers to the question of a documented lower goat density in Labra/Brasiel still remain unknown but could potentially help guide the STINAPA removal effort. They particularly suggest that poaching in this area may help keep goat densities down.**

7. Required Goat Removal Rates

Population densities and size of the goat herd of Slagbaai and Labra/Brasiel are clearly well beyond sustainable levels for biodiversity conservation in Slagbaai and Labra/Brasiel (Geurts 2015). As a consequence of lasting livestock densities in this unmanaged park area, the vegetation of Slagbaai is among the most impoverished of all conservation areas of Bonaire and many tree and plant species are threatened with extirpation (Freitas and Rojer 2013). Fortunately, this is about to change, thanks to the current project that intends to greatly and sustainably reduce livestock densities in Slagbaai and Labra/Brasiel. The combined roaming goat herd of these plantations currently amounts to about 5000 goats. This number needs to be drastically reduced in a relatively short period.

Several studies provide insight into the carrying capacity of semi-arid landscapes. For instance, in semi-arid areas in Australia goat densities of less than 0.1/ha are already considered as a serious agricultural and environmental pest (Southwell *et al*. 1993; Southwell and Pickles 1993). On the semi-arid Sta. Catalina Isl. in California natural vegetation was impoverished and overgrazed at goat densities of 0.25/ha (Coblentz 1977). On Pinta Galapagos a goat density of 1.69/ha was deemed excessive and after eradication led to a rapid recovery of the vegetation and flora (Hamann 1993). In arid areas of southern Australia Pople *et al*. (1996) indicate average goat densities of 0.25/ha and higher as a serious agricultural and environmental pest. Finally, Brennan *et al*. (1993) describe the need to cull goats to even lower densities than 0.16/ha. On Curaçao culling goats to a density of 0.1/ha has been found to be sufficient to allow rapid ecological recovery (Debrot and de Freitas, pers. comm.). In Labra/Brasiel where average densities are currently 0.45 goats/ha recovery is still obviously seriously impeded. This provides evidence that goat densities must go lower than 0.45 goat per ha.

In population dynamics, there are four major factors that determine the population size of a group of animals in a given area. These are **reproduction** and **immigration**, which tend to increase population size, and **emigration** and **mortality** which tend to decrease populations size (Fig. 9). Most natural populations of vital animals have an innate tendency to increase in size. A key question is then how fast animals need to be minimally caught to be able to effect a population decrease. This depends most importantly on the so called "intrinsic rate of increase".

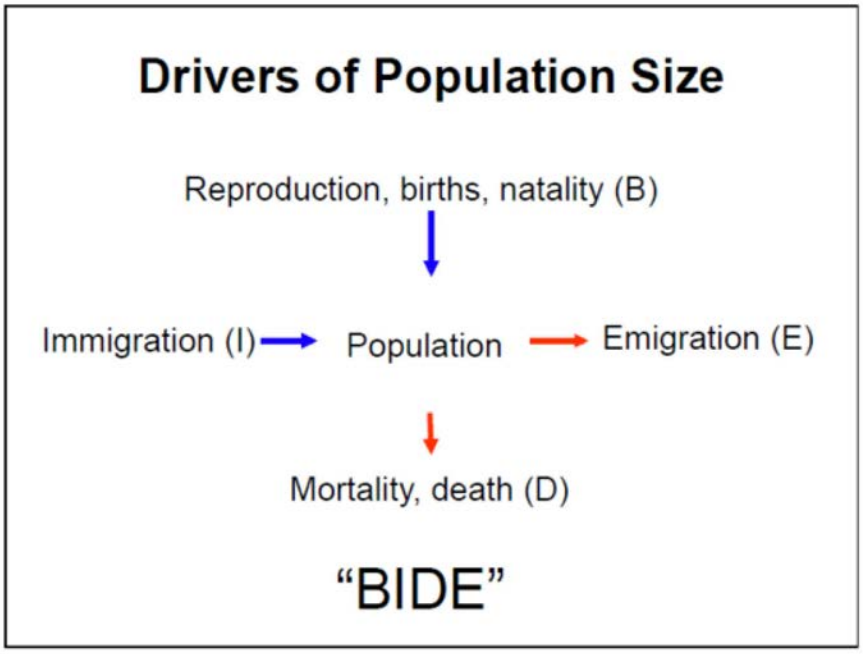


Fig. 9. Diagram of key population processes determining population size and density in a given area. (From Univ. Washington, ESRM 350 Demography and Population Growth lecture series)

General models of intrinsic rate of population increase (r_m) versus body-weight in mammals predict goats to have an r_m of 0.38 (Caughley and Krebs 1983), but empirical measurements show that this can be considerably higher (Henzell 1983). Intrinsic rates of increase can be much higher as goats have been found to increase annually by 60-75% per year in absence of control (GSA 2005). Parkes (1984) also estimates a high intrinsic rate of increase (0.424) for healthy culled populations on tropical Raoul Island in the Pacific Ocean. This means that population doubling occurs every 20 months which can make extermination difficult. Under stressed and unfavourable environmental conditions feral goats of course may also show a low intrinsic growth rates (e.g. Southwell and Pickles 1993). The actual displayed rate of increase witnessed depends age-specific mortality and fecundity. These in turn depend on many factors such as food availability, general health, fecundity and sex-ratios. Considering the generally good health state, fecundity and a possibly female-biased sex ratio for Slagbaai (Geurts 2015), goat population doubling time may be as short as 1-1.5 years. As a consequence, to effect population decline, 50% or more of the goat population might need to be culled annually to actually reduce the goat population measurably. For the purpose of our calculations we use the theoretical and conservative prediction by Caughley and Krebs (1983) and an intrinsic annual instantaneous rate of increase, r_m of 0.38, which translates to a discrete annual rate of increase of 31% population change from one year to the next. This means that discrete annual capture rates (C) needed to counteract intrinsic growth is also 31% (Fig. 10).

Now that the combined area of Slagbaai and Labra/Brasiel have effectively been closed from the neighbouring areas where goats continue to roam freely, the factors of immigration and emigration no longer play a measurable role and can be disregarded. Under these assumptions, the 31% goat capture rate defines the line of net zero % population change. So with annual captures of 31% of the population (31% x 5200 = 1600 goats per year), there can be no net population decline of the goat herd. The number of animals removed each year will simply and perfectly compensated by the number added due to natural increase (ie. births – deaths). To realise effective population declines, capture rates must average more than 31% per year. Figure 11 shows the mathematically predicted relative effect of different rates of capture on population size. The calculations show that to achieve project goals of 0.1 goat per ha within 4-5 years, effective goat removal rates will need to be 60-70% per year . Assuming all is stable, no diseases or droughts, this means that for the first year upwards of 3000 goats should have been removed.

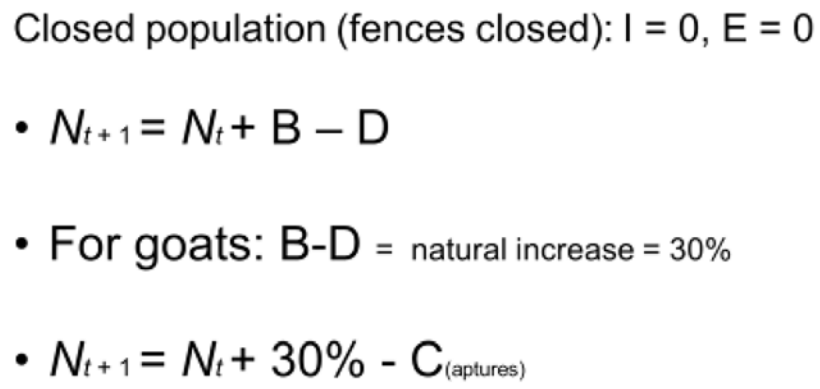


Figure 10. Simplified formula for population change in closed populations and the required capture rate (C) needed to compensate for the intrinsic natural increase (B –D).

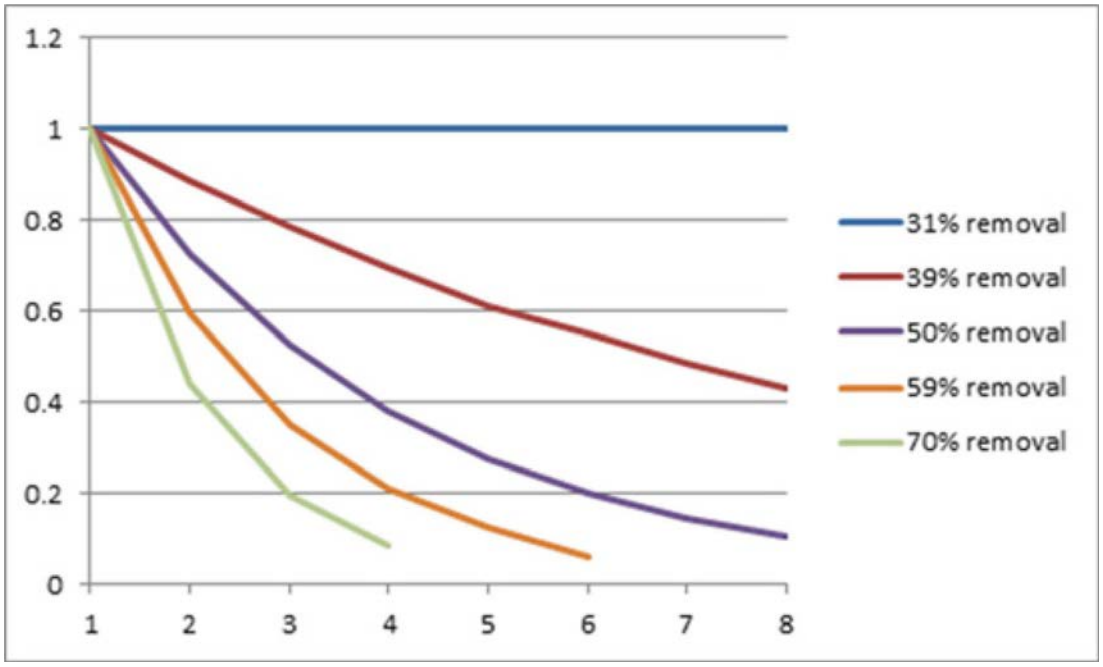


Fig. 11. Fractional population declines achieved year by year from the start of year 1 for different (discrete) culling rates.

Conclusions:

- **Assuming immigration of goats from and emigration into Slagbaai and Labra/Brasiel are zero, assuming an intrinsic discrete rate of increase of 31% and assuming no unusual favourable or unfavourable conditions affecting the goat herd, the stable state break even rate of removal is 31% per year.**
- **Under the same assumptions, the removal rates needed to reduce densities to 0.1 goat/ha within 5-6 years is upwards of 60%. To achieve project goals within the project time-frame the target-removal rate for goat culling is 60% per year or higher.**

8. Current goat removal methods and removal rate

8.1 Goat funnel traps

Current goat culling methods have not evolved in recent years. Goat culling largely takes place using small, funnel-shaped traps. These are set out in the landscape close to road access and consist of V-shaped structures made from a single 100 m roll of goat fencing. Three of these structures were visited and examined during my April 2015 field visit. Two arms of the structure, each of about 50 m are set out and culminate in a narrow V funnel-shaped section into which animals are herded for manual capture. In setting up the traps the brush is cut or trimmed to attach and support the fencing, which causes some damage to the vegetation. However, most plants affected are Lele, *Randia aculeata*, and Palu di Bonairu, *Casearia tremulans*. Neither of these are rare or endangered on Bonaire, and this type of constructional kind of damage is limited.

Constructional aspects of such a "fuik" or "trampa" takes almost a full week of man hours. This is for setting up the trap, placing forage in the trap, checking on the trap and to eventually remove the trap. Traps are set up and baited several days prior to use. On average the catch per event at each structure is 2-3 animals. Animals are attracted to the trap based on food. This consists of one or two columnar cacti which are cut down (Figure 12) and the branches of other tree species such as *Quaderella odoratissima*. Until April 2015, a total of 6 traps were operated simultaneously. Since then, 12 traps have been used simultaneously. After 1-2 weeks each trap is dismantled and set up anew in a different location.

The current method is inefficient, uses a great input of labor and yields few animals per trap. In addition, baiting traps with cacti causes great collateral damage to the vegetation of the park because so many traps are continually being constructed. Columnar cacti grow very slow but fulfil a keystone function within the ecology of the park as they main food source for frugi- and nectarivores during the annual dry season (Petit 1997). This concern was raised in April 2015, and the use of new and more effective goat trapping methods was urged.

Fig. 12. Part of the collateral damage to the vegetation caused by the use of current goat funnel traps. Wageningen UR student Nikkie van Grinsven demonstrating destroyed kadushi tree, Subpilocereus repandus. Photo: A. Debrot.

While the same method of small funnel-traps continued to be used, the goat-trapping teams indicated they could stop using cacti and fully use tree branches instead. This could not be verified during my November 2015 visit.

8.2 Catching results to date

All goats caught are weighed and sexed before sale or slaughter. These data are collected and recorded by Kultura Thodé, head ranger. The weights for all goats caught since the beginning of the project is shown in figure 13 for males and females separately.

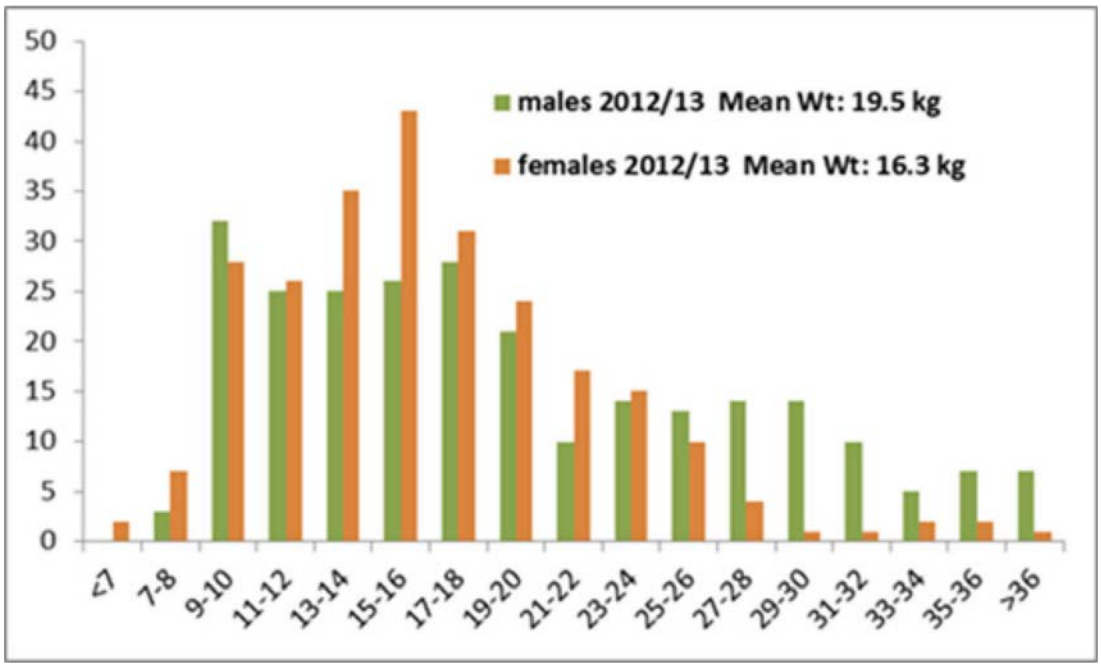


Fig. 13. Goat numbers (N) versus goat size in Kg shown for males and females separately.

The overall size of the animals caught is small, averaging about 18 kg, whereby males appear to be somewhat larger than females. This difference between males and females is expected. In time, the average weight can be expected to increase once populations are culled.

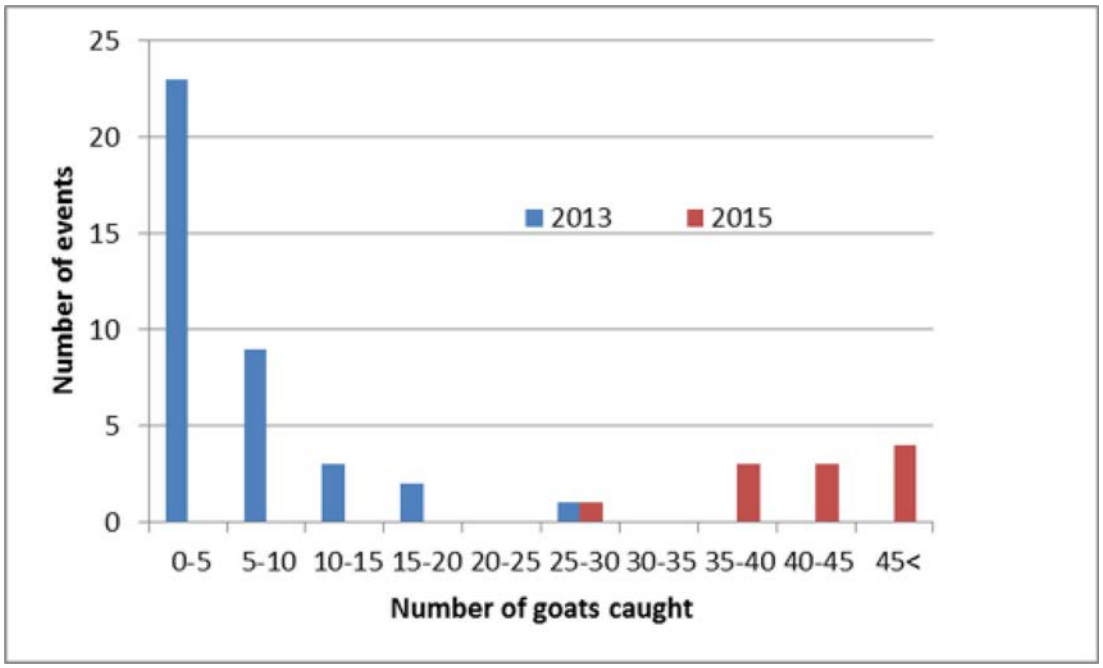


Fig. 14. number of goats captured per event-day for the project (2015) and for 2013 data.

When comparing effectiveness between current catching (2015) and previous catching that took place in 2013, clearly current catching has improved greatly. This can be ascribed in part to more traps being used per catch day "event", and possibly to better catch rates per individual trap set. So while there is a clear improvement in catching effectiveness per event day, it is not fully clear what the cause for this is.

Finally all catches since the start of the project are shown in table 1. The total number of goats caught so far from March-December in 2015 was 925. This number is significantly lower than the expected intrinsic rate of increase. Consequently at this rate of catching (93 per month) the goat population will never start to decline. These numbers of goats caught represent a large increase compared to prior years but still fall greatly short of the 3000 goats that minimally should have been caught in the first year to be able to meet project goals.

Table 3. Goat catches by month as supplied by Stinapa for the goat culling project, 2015 (* = kg), (**< 10 kg).

				Gender		Lambs				
Wks	Date	Number	Weight *	M	F	**	Sold	Donation	Abattoir	Rejected
1	15-Mar-15	29	479.50	17	12	3	16	13	0	0
2	22-Mar-15	42	604.00	21	21	9	19	5	18	2
	Total March	**71**	**1083.5**	**38**	**33**	**12**	**35**	**18**	**18**	**2**
3	12-Apr-15	39	542.50	14	25	9	23		16	1
4	19-Apr-15	71	1201.50	43	28	9	40	17	13	1
	Total April	**110**	**1744**	**57**	**53**	**18**	**63**	**17**	**29**	**2**
5	10-May-15	32	590.50	17	15		15		17	1
6	17-May-15	42	556.50	24	18	6	21	1	20	1
7	24-May-15	50	646.00	26	24	14	18	2	30	
8	31-May-15	47	788.00	24	23	3	33	2	12	
	Total May	**171**	**2581**	**91**	**80**	**23**	**87**	**5**	**79**	**2**
9	21-Jun-15	45	671.50	23	22	8	34	10		
10	28-Jun-15	41	618.00	13	18	3	30	5	6	1
	Total June	**86**	**1289.5**	**36**	**40**	**11**	**64**	**15**	**6**	**1**
11	19-Jul-15	77	1172.00	38	39	13	45		32	1
12	26-Jul-15	14	169.00	8	6	3	6		8	
	Total July	**91**	**1341**	**46**	**45**	**16**	**51**	**0**	**40**	**1**
13	2-Aug-15	49	804.15	29	21	4	26	5	18	
14	10-Aug-15	19	279.34	10	9	2	11	3	5	
15	23-Aug-15	28	431.20	10	18	4	18	7	3	
16	30-Aug-15	22	333.00	9	13	2	15	1	6	1
	Total August	**118**	**1847.69**	**58**	**61**	**12**	**70**	**16**	**32**	**1**
17	6-Sep-16	26	368.50	10	16	3	15	3	8	
18	20-Sep-16	36	487.00	16	20	7	18	6	12	2
19	27-Sep-15	34	463.50	11	23	3	12	3	19	
	Total Sept	**96**	**1319**	**37**	**59**	**13**	**45**	**12**	**39**	**2**
20	18-Oct-15	38	475.00	14	24	7	26	9	3	
21	25-Oct-15	26	280.00	5	21	7	14	12		
	Total Oct	**64**	**755**	**19**	**45**	**14**	**40**	**21**	**3**	**0**
22	5-Nov-15	9	121.00	2	7	2	9			
23	15-Nov-15	39	501.00	17	22	5	16	3	20	1
24	22-Nov-15	19	277.00	10	9	2	13	6		
25	29-Nov-15	19	317.70	11	8	2	11	8		
	Total Nov	**86**	**1216.7**	**40**	**46**	**11**	**49**	**17**	**20**	**1**
26	6-Dec-15	16	198.00	7	9	2	9	7		
27	10-Dec-15	25	286.00	9	16	8	14	10		
	Total Dec	**41**	**484**	**16**	**25**	**10**	**23**	**17**	**0**	**0**
	Totals	**934**	**13,661**	**438**	**487**	**140**	**527**	**138**	**266**	**12**

To achieve goat population declines commensurate with project goals (ie. to reduce density to 0.1 goat per ha by the end of the 4-year project), annual goat removal rates should be about 3 X higher than at present. Casual counts by my person during November 2015 suggest that goat densities might still have actually decreased since project inception. If that is so, then this must largely be ascribed to the effects the severe drought this year has had on reproduction and survival. So it appears as if the project has had a bit of luck so far.

Nevertheless it is clear to all involved that effective removal needs to be dramatically increased. The goat catching team indicate they have already reached the limit of the current labour-intensive and inefficient use of small funnel traps. This means that new and better trapping methods are critical to achieve project goals.

Conclusions:

- **Goats are currently almost exclusively being caught using small funnel traps.**
- **This method is labour-intensive and has significant (but recently reduced) impacts on the native vegetation, particularly on plants that are being used as bait to attract goats into the trap.**
- **Goats caught are small, but males are typically larger than females.**
- **Goat catches per event day has improved greatly in comparison to catching, using the same method, in earlier years.**
- **Goat catches amount to 925 animals in 2015 from March-December and hence about 93 goats per month.**
- **These numbers fall greatly short of the 3000 goats that minimally should have been caught in the first year to be able to meet project goals.**
- **The project appears to have benefitted from the drought which likely reduced goat fecundity and survival. However, this was not proven.**
- **New and improved goat catching method need to be urgently introduced.**

9. More efficient goat removal methods

The goat catching methods up to now can be described as labour-intensive, inefficient and small-scale. Further expansion by simple replication (use of more small funnel-traps) is not possible. This was mentioned during my November 2015 presentation by the current teams who complained about the labour-intensiveness of the method and the problem of trap interference when using many small traps. New methods need to be explored and developed quickly if this project is still to succeed.

9.1 Limiting water access and use of watering holes to trap goats

One key alternate method is to limit water access by closing water holes for herbivore access and to use water holes for trapping purposes. As explained above little specific progress has been achieved on this front as yet. These activities must be picked up with speed.

9.2 New options for catching goats

Using large landscape-level barriers to herd goats into traps.
This idea was explained again during my November visit to the park personnel and they thought the ideas were basically feasible. Their only doubt was that the new fencing could be stolen by thieves. The same suggestion was already recommended on 23 October 2014. Dipping the rolls of fencing wire in a paint bath before use can function to mark the wire so that it cannot be stolen for use elsewhere. The idea was introduced by illustrating two of several potential scenarios. It is based on the erection of essentially permanent trap-fencing which makes it possible to periodically and repeatedly sweep the landscape clean of goats without baiting and without construction costs each and every time. It is based on my experience using this approach many years ago when eradicating livestock on the plantation of "Chinchó" (more commonly known as "Oostpunt") in Curaçao.

Key in this system is to use existing landscape level barriers to your advantage: shorelines, border fences: i.e. fixed barriers. This is combined with permanent erection of trap fencing across a few hundred meters. Figure 15 sketches two of several possible scenarios.

Scenario at Playa Wayaká (left side sketch).
The lay of the land and natural water barriers at Playa Wayaká mean that it is possible to herd and concentrate goats with little fencing. At this location permanent fencing is erected at two narrow locations. It is then opened intentionally at two locations. This is done so that animals get accustomed to being able to move freely. Then on the day of herding, the fence lines are secured and a small catching funnel is installed. With minor work and relatively quickly goats can be shut off from their escape routes and herded into catchment pens near areas where they normally pass unobstructed.

Scenario Goto and Slagbaai plantation road (right side sketch)
The design here is to use the shores of Goto as a permanent barrier. Several goat herds sleep in the Juwa hills but come down daily to forage in the greener valley areas near Goto. A trapping fence of a few 100 meters is installed adjacent to the Slagbaai plantation access road. This runs parallel to the former fence between Labra and Slagbaai, but directly adjacent to the road for ease of work. At periodic intervals openings are established which can quickly be rolled shut when needed. At the east end along the shores of Goto the frame for a catchment pen is constructed and left. With the openings left open, the goats make use of the openings to get to the Goto shores and get accustomed to the presence of the fence. After the animals have habituated to the new situation, on one afternoon, when the animals are out foraging, the openings are shut. As the animals are herded from the Goto side and try to escape to higher ground, they encounter closed openings and are forced to follow the Slagbaai road fence until they are forced into the catchment pen.

After the operation, the openings are set back open and after a few weeks when the animals that are still at large get habituated again, the same catching activity can be repeated with limited investment of time or labour.

By making handy use of existing barriers and erecting semi-permanent trap fencing at a landscape level in several areas of the park, it becomes possible to repeatedly sweep large areas of the landscape free of goats quickly and with very little labour, compared to the current method, without the use of vegetation as bait.

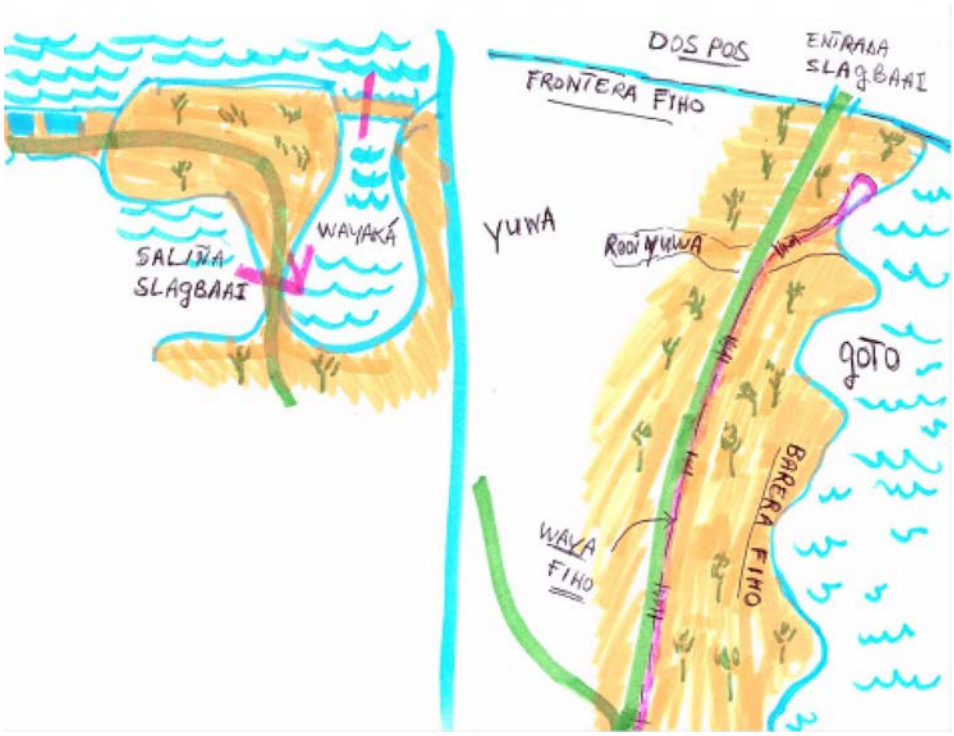


Fig. 15. Two landscape level setting amenable to large permanent traps for herding goats. Left: scenario at Playa Wayaká. Right: scenario at the Slagbaai plantation entrance at Goto.

Use of noose lines

Goats like many other animals travel on their own narrow paths when moving between their foraging areas and sleeping areas "geitenpaadjes". This provides the opportunity to install series of snares along these paths. The snares are armed in the evening. As the goats walk along these paths the next day, many animals will become snared one after the other along the lines of nooses set up along their pathways. There they will remain attached until the goat team comes by the next day to remove the goats and re-arm the nooses. This is a method commonly used to catch feral pigs in Curacao.

Portable traps using water to attract goats

Purchase is possible of trapping systems made of portable fence sections. These are specially designed to fit in a pickup and to be installed within 30 minutes by one person. They have been tried and tested in arid areas elsewhere. Chris Schmitz has all information and has experimented with this system. By installing such water-based round wire traps adjacent to main goat paths goat captures are certain.

Meat and Livestock Australia (MLA) lists key considerations when making such goat traps:

Important features of an effective trap

- Traps should be established in areas where there is limited availability to water. Alternative watering points should be fenced off.
- Traps should be large enough to avoid overcrowding and regularly checked and destocked as required.
- Traps should be constructed to allow for shade and shelter as goats can suffer when exposed to extremes of heat and cold.
- It can be useful to incorporate loading pens, holding yards and drafting facilities into the trap design, thus enabling on-site animal handling.
- Goats typically exhibit a following and circling behaviour. Round traps can be more effective as they aid the flow of animals and eliminate corners which are high-pressure points where goats may be forced.

Conclusions:

- **There are a variety of tried and tested effective systems by which to trap and remove goats.**
- **It is high time to bring in new people with new ideas and willing to try the various proven designs for use in Slagbaai and Labra/Brasiel goat culling.**

10.Financially self-supporting culling (estimating the costs of culling)

To be considered successful in the long-run, by the project end, the goat culling scheme ideally should be largely self-financing. This is a key objective to make it feasible to be continued without dependence upon continued subsidy support. Using basic prices for inputs of materials and labor (as provided by Stinapa), as well as the income generated by sale of animals caught during culling, it is possible to sketch the financial cost benefit of the current culling practice.

Stinapa has fuller data to provide more accurate estimates of the costs and income generated by culling. These data were not available at the time of this update, but will be made available for analysis at a later time.

Income from catching:
Average yield is 47 goats per catch day (typically 6-8 trapping stations).
Yield of catch:
- Lambs: 47goats x81/517 lambs/total goats x 10$/lamb = 73 dollar
- Adults: 18 kg av wgt. x 2.50$/ kg x 47 goats x(517-81)/517 adult goats/total goats= 1783 dollar

Total yield: 1856 $

Costs of catching:
Labor: 4 days x 5 men x 6 $/hr x 8 hrs = 960 $/catch
Catching fee : 8 $/goat x 47 goats = 376 $/catch
Slaughter costs: 5 $ per goat x 47 x 168/517 slaughtered/total goats = 76 $/catch
Material: afschrijving duurzame artikelen, expendables (ice and/or ice cream, food?)???? 100 $/catch
Transportation costs?.....???? 25 $/day = 200 $/catch
Administration/coordination costs: 8 hrs/ week: 8x 2 x 6 = 48 $/week x 18 week /11 = 156 $/catch
Total cost of catch: 1868 $

Benefit-cost: 1783 - 1868 = **netto 85 dollar loss per catch event.**

This result is not really surprising…Goat eradication and control has been done successfully for years in the Christoffelpark of Curacao at no cost to the park management. It is based on small-scale hunting. Uncontrolled small-scale goat poaching in Labra/Brasiel also takes place by poachers. Not only with reasonable success but also unquestionably to the financial benefit of the poachers.

Conclusion:

- **Based on this preliminary sketch (full calculations yet forthcoming) it is clear that even using the current inefficient catching system, the culling of goats is already financially self-supporting (or nearly so).**

11.Recommendations for monitoring and research

- There are large uncertainties in two key issues determining goat culling progress.

These are uncertainties in goat density and abundance, and in the intrinsic rate of increase of the Slagbaai goats. As a consequence, the estimates of required culling rates for population decline are only tentative. This means that it is critical to monitor project progress by monitoring probable population decline during the project period. Based on the results obtained here for population estimation and the wide margins of uncertainty that were obtained even with the extensive sampling that was done (Geurts 2015). I do not recommend periodic population assessment using the Distance method. A simplified standardized monitoring is suggested based on counts along the dirt roads in the park. This way quicker, easier and more frequent counts of only parts of Slagbaai can be conducted to see if goat catching is actually resulting in population decline. It is essential to know what catching rate will produce population decline. This is remains unknown due to inherent uncertainties and the fact that more extensive research was not conducted.

- Likewise, monitoring of actual catches and catch success for the new systems to be explored needs to be continued. This will help assess effectiveness of the different methods to be tried and used in the park.

- There are many plant species that are critically endangered in the park. For these species it is not feasible to wait till all goats are removed. Practical research is suggested to evaluate the use of exclosures built around seed sources to protect seedling establishment.

- Thick stands of *Opuntia* appear to provide partial refuges against herbivory for many plant species. Additional research is suggested to examine species facilitation by *Opuntia*.

- The impact of major vegetation removal and leaf litter removal by goat grazing on soil properties (such as temperature, organic content, water retention, nutrients etc.) is likely large but undocumented. Directed research into these effects would be highly beneficial to the project.

12. Final evaluation, conclusions and recommendations

There are many clear indicators of the deleterious impacts of grazing livestock on the flora and vegetation of Slagbaai. The Washington-Slagbaai park has seriously degenerated vegetation, second only to the vegetation of the Arikok National Park of Aruba. Similar degraded landscapes previously existed in the Christoffelpark of Curaçao into the 1970s but have since largely disappeared due to vegetation recovery following livestock removal. Livestock densities in Slagbaai are estimated at 2.69 goats/ha. Based on comparative studies from arid ecosystems elsewhere, these livestock densities far exceed the ecological carrying capacity of the semi-arid vegetation of the Slagbaai park. The need to cull the roaming goats is of the highest priority.

Prior trials using grazer exclosures inside Slagbaai prove that vegetation recovery will be rapid following goat removal and prove that reforestation with rare native species is possible using simple methods (Figs 16, 17; and Debrot 2015).

Fig. 16. Dramatic contrast between inside and outside of exclosure established for reforestation at Pos Nobo. Photos: P. Bertuol.

Fig. 17. Dramatic contrast in herbaceous cover between inside and outside of exclosure at Pos Nobo during the rainy season. Photo: A. Debrot

Principal conclusions:

Goat counts using the density estimation method show that goat densities in Slagbaai-Washington are highly excessive.
Additional studies of the vegetation show that goat presence has a large negative effect on the vegetation of the park while fencing trials show that goat removal has immediate positive effects.

Several infrastructural needs for controlling the goat population were achieved by the end of the year (such as restoring roads for access and securing the park fencing) but other critical needs (such as closure of watering holes for total control of this key production factor) were largely not yet achieved. Documented goat catches amounted to a total of 925 animals in 2015. At present goat removal rates remain well-below intrinsic population growth rates. These numbers represent a large increase compared to prior years but still fall greatly short of the 3000 goats that minimally should have been caught in the first year to be able to meet project goals.

Goats are currently almost exclusively being caught using small funnel traps. This method is labour-intensive and has significant (but recently reduced) impacts on the native vegetation, particularly on plants that are being used as bait to attract goats with into the trap.

New and improved goat catching methods need to be introduced urgently. There are a variety of tried and tested, effective systems by which to trap and remove goats. For this, the planned infrastructural improvements (closing freshwater access) are essential and it is high time to bring in new ideas and willingness to try the various proven designs for goat control and eradication. Several of these have been discussed or even already partially tried. Finally, several recommendations are made for monitoring project progress and for further research.

13. Acknowledgments

The rangers and personnel of the Washington-Slagbaai National Park are thanked for their critical contributions to this work and for providing their insights and suggestions on which much of this report has been based. They made my various visits to the park very pleasant and also provided extensive support to the four Master' s students who conducted various in depth baseline assessments drawn on in the text. As academic advisors to Kevin Geurts, Nikkie van Grinsven, Barry van den Ende and Quirijn Coolen, I thank Pim van Hooft and Milena Holmgren for suggesting several complementary lines of investigation that in the coming years should further deepen and enrich our understanding of goat impacts on the park flora and fauna. Particular thanks go to Chief Ranger George (Kultura) Thodé, Clifford Cicilia, Ruthsel Paula and George Saragoza. Director Johan Afman, Program manager Evo Cicilia and Chief park scientist Paulo Bertuol, and local historian Boy Antoin also provided critical input and data for this report. Jan Tjalling vd Wal reviewed the population model results. Key stakeholders who provided their insights and feedback during the 1st year of the goat culling program were Frank van Slobbe, Peter Montanus, Chris Schmitz, Paul Hoetjes and Guus Schutjes. I am deeply grateful to all for helping create an assessment which should help show the way forward.

14. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

Furthermore, the chemical laboratory at IJmuiden has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

References

Anonymous, 1985. Herbebossing. B&N-berichten 22 jan, 1985.

Anonymous, 1989. Vegetashon di Boneiru ta sigui bai atras. Extra: 30 aug, 1989.

Anomymous 2006. Carmabi biedt helpende hand bij herbebossing Klein Bonaire. Amigoe 11 februari, 2006.

Anonymous, 2009. Geiten-probleem Washington-Slagbaai. Amigoe, 13 october 2009, p. 7.

Bakker, J.D., Rudebusch, F. and Moore M.M. 2010. Effects of long-term livestock grazing and habitat on understory vegetation. Provo, Utah, USA. Western North American Naturalist, Vol 70, No 3, pp 334-344.

Benjamin G. Russell, B.G., Letnic M., and Fleming, PJS. 2011. Managing feral goat impacts by manipulating their access to water in the rangelands. The Rangeland Journal,33: 143–152.

Brennan *et al*. 1993; is dat Brennan, M., H. Moller, and J. P. Parkes. 1993. Indexes of density of feral goats in a grassland forest habitat, Marlborough, New-Zealand *New Zealand Journal of Ecology* 17 (2): 103-106.

Caughley, G. and Krebs, C.J. (1983). Are big mammals simply little mammals writ large? *Oecologia* 59: 7-17.

Carrion, V., Donlan, C.J., Campbell, K.J., Lavoie, C. and Cruz, F. 2011. Archipelago-wide island restoration in the Galapagos Islands: reducing costs of invasive mammal eradication programs and reinvasion risk. Smithsonian's National Zoological Park, USA. PLoS ONE, Vol 6, No 5, e18835, pp 1-7.

Coblentz, B.E. 1977. Some range relationships of feral goats on Santa Catalina island California. California, USA. Journal of Range Management 30 (6): 415-419.

Coblentz, B.E. 1978. The effects of feral goats on island ecosystems. Corvallis, Oregon, USA. Biological Conservation 13 (4): 279-286.

Coblentz, B.E., 1980. Goat problems in the national parks of the Netherlands Antilles. 16 pp.

Coolen, Q. T. 2015. The impact of feral goat herbivory on the vegetation of Bonaire: An experimental study in the Washington-Slagbaai National Park. Wageningen University, Master Thesis, Resource Ecology Group, November 2015. 51 pp.

Debrot, A. O. 2015. Slim samenwerken met de natuur: herbebossing op de Nederlands-Caribische benedenwindse eilanden. Vakblad Natuur Bos Landschap, apr 2015: 3-5**.**

Debrot, A.O. and De Freitas, J.A. 1993. A comparison of ungrazed and livestock-grazed rock vegetation in Curaçao 1993. Curacao, Netherlands Antilles . Biotropica 25 (3): 270-280.

Ende, B., van den. 2015. How do the distribution and abundance of columnar cacti relate to microsite types and goat grazing pressure? Wageningen University, Master Thesis, November 2015. 50 pp.

Fernández-Lugo, S., de Nascimento, L., Mellado, M., Bermejo, L.A. and Arévalo, J.R. 2009. Vegetation change and chemical soil composition after 4 years of goat grazing exclusion in a Canary Islands pasture. Agriculture, Ecosystems & Environment 132 (3–4): 276-282.

Freitas, J. A. de, B. S. J. Nijhof, A. C. Rojer and A. O. Debrot. 2005. Landscape ecological vegetation map of the island of Bonaire (Southern Caribbean). Royal Netherlands Academy of Arts and Sciences, Amsterdam. 64 pp. (+ maps)

Freitas, J.A. de & A.C. Rojer, 2013. New plant records for Bonaire and the Dutch Caribbean islands. Carib. J. Sci. 47(1): 114-117.

Geurts, K. 2015. The abundance of feral livestock in the Washington Slagbaai National Park, Bonaire. Wageningen University, Master Thesis, November 2015. 52 pp.

Gilliland, H.B. 1952. The Vegetation of Eastern British Somaliland. Johannesburg, South Africa. Journal of Ecology 40 (1): 91-124.

Gould, M.S. and Swingland, I.R. 1980. The tortoise and the goat Interactions on Aldabra island. Biological Conservation 17: 267-279.

Grenada Government 2007. LIVESTOCK GENETICS RESOURCES REPORT (prepared by A. David) 15 pp.

Grinsven, N. van. 2015. Diet preference of roaming goats (*Capra hircus*) on columnar cacti in Bonairian scrublands. Wageningen University, Master Thesis, November 2015. 22 pp.

GSA (Government of South Australia). 2005. Policy relating to feral goats.
Adopted by the Minister for Environment and Conservation 28 September 2005. 8 pp.

Hamann, O. 1993. On Vegetation Recovery, Goats and giant Tortoises on Pinta Island, Galapagos, Ecuador. *Biodiversity and Conservation* 2: 138-151.

Henzell, R.P. 1983. Biology and control of feral goats. Proc. 7th Vertebrate Pest Conference, Dubbo. pp 142-5.

Jones, H.P., N.D. Holmes, H.M. Stuart *et al*. 2016. Invasive mammal eradication on islands results in substantial conservation gains. PNAS, www.pnas.org/cgi/doi/10.1073/pnas.1521179113

Kolars, J. 1966. Locational Aspects of Cultural Ecology The Case of the Goat in Non-Western Agriculture. American Geographical Society. Geographical Review 56 (4): 577-584.

Lagerveld, S., A.O. Debrot, P. Bertuol, N. Davaasuren, F. Neijenhuis. 2015. (vertrouwelijk). Populatieschatting geiten op Bonaire. IMARES-report C115/15, Wageningen University, Wageningen, The Netherlands. 48 pp.

Lo Fo Wong, A.M.E. & J. de Jong 1994. Aspecten van natuurbeheer op Bonaire: Verslag van een stage natuurbeheer in het Nationaal Park Washington-Slagbaai op Bonaire, Nederlandse Antillen. Unpubl.thesis no: P259. Vakgroep Natuurbeheer, Landbouwuniversiteit Wageningen, The Netherlands, 66 pp.

MinEZ (Dutch Ministry of Economic Affairs) 2013. Natuurbeleidsplan Caribisch Nederland 2013-2017. The Hague, the Netherlands. 55 pp.

Müller, J.L., Babub, M.M., Saklanib, P.L., Mayera, A.C., Marquardta, S. and Kreuzera M. 2011. Forage resource use by cattle or goats at an Indian protected area: Differences and implications for conservation. Journal of Arid Environments 77: 130-137.

Neijenhuis, F. B. Bos, A.O. Debrot. 2015. **(vertrouwelijk)**. Beleidsadvies geitenhouderij op Bonaire. Wageningen UR Livestock International/IMARES. Wageningen University, Wageningen, The Netherlands. 44 pp.

OLB/STINAPA. 2014. Project plan Goat eradication and control in Washington Slagbaai National Park. 10 pp + app.

Parkes, J.P. 1984. Feral goats on Raoul island. I. Effect of control methods on their density, distribution, and productivity. New Zealand J. Ecology 7: 85-93.

Petit, S. 1997. The diet and reproductive schedules of *Leptonycteris curasoae curasoae* and *Glossophaga longirostris elongata* (Chiroptera: Glossophaginae) on Curaçao. Biotropica 29: 214–223.

Pisanu, P., Bayne, P., Harden, R. and Eggert, A. 2005. Feral goats (*Capra hircus* L.) in the Macleay River gorge system, North-eastern New South Wales, Australia. II impacts on rainforest vegetation. Armidale, Australia. Wildlife Research 32: 111-119.

Pople AR, Grigg GC, Cairns SC, Alexander P, Beard LA, Henzell RP. 1996. Trends in the numbers and changes in the distribution of feral goats (*Capra hircus*) in the South Australian pastoral zone. Wildlife Research 23: 687-696.

Proosdij, A.S.J. van, 2001. Arnoldo's zakflora: Wat in het wild groeit en bloeit op Aruba, Bonaire en Curaçao. Publ. Found. Sci. Res. Car. Reg. 144, Amsterdam, The Netherlands, 287 pp.

Smith, S.R., W.J. van der Burg, A.O. Debrot, G. van Buurt, J.A. de Freitas. 2014. Key Elements Towards a Joint Invasive Alien Species Strategy for the Dutch Caribbean. IMARES Report C020/14, 104 pp.

Southwell CJ, Pickles GS. 1993. Abundance, distribution, and rate of increase of feral goats in Western Australia. The Rangeland Journal 15: 334-338.

Southwell C, Weaver K, Sheppard N, Morris P. 1993. Distribution and relative abundance of feral goats in the rangelands of eastern Australia. The Rangeland Journal 15: 331-333.

Justification

Report C052/16
Project Number: 4315100004

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved:	Drs. J.T. van der Wal Researcher
Signature:	
Date:	3th of August 2016

Approved:	Drs. J. Asjes
Signature:	
Date:	3th of August 2016

To explore the potential of nature to improve the quality of life

IMARES Wageningen UR
T +31 (0)317 48 09 00
E imares@wur.nl
www.imares.nl

Visitorsadress
- Haringkade 1, 1976 CP IJmuiden
- Korringaweg 5, 4401 NT Yerseke
- Ambachtsweg 8A, 1785 AJ Den Helder
- Bevesierweg 4, Gebouw MML - Schiereiland Fort Harssens, 1781 CA Den Helder
- Landsdiep 4, 1797 SZ 't Horntje, Texel

IMARES (Institute for Marine Resources and Ecosystem Studies) is the Netherlands research institute established to provide the scientific support that is essential for developing policies and innovation in respect of the marine environment, fishery activities, aquaculture and the maritime sector.

The IMARES vision
'To explore the potential of marine nature to improve the quality of life'

The IMARES mission
- To conduct research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas.
- IMARES is an independent, leading scientific research institute

IMARES Wageningen UR is part of the international knowledge organisation Wageningen UR (University & Research centre). Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment.