26 Roaming Livestock: A Threat to Caribbean Netherlands Climate Resilience and Biodiversity

Debrot, A. O., Bertuol, P., van Slobbe, F., Eckrich, C. and Francisca, R. 2025. From: State of Nature Report for the Caribbean Netherlands, 2024. WUR report C001/25.

Status

In the Caribbean Netherlands, overgrazing by introduced free-ranging livestock (especially goats but also donkeys, cattle, and increasingly pigs) is considered the most severe threat to terrestrial ecosystems (Min. LNV et al., 2020; Smith et al., 2014) and to climate adaptation. Some of the earliest authors to point this out and summarize the major negative impacts this has on vegetation, soil, and the nearshore ecosystem date from the middle of the last century (Duclos, 1954; Westermann and Zonneveld, 1956; Hoetink, 1969). For instance, Hoetink (1969, p. 397) comments on how uncontrolled grazing and extensive agriculture was accompanied by soil erosion, dust and heavy sedimentation of the inland bays and reefs (Figure 1). This process continues to this date and has been identified as the major reason for the loss of critical lagoonal seagrass habitat in Lac Bay (Debrot et al., 2019). Apart from being a direct threat to native vegetation and rare plants, overgrazing has many other adverse ecological, social and economic effects. In the past, several largely unsuccessful attempts were made on all three islands to address this problem. However, efforts remain ongoing, with recently much better success on both Saba and in the Washington-Slagbaai National Park (WSNP), Bonaire. The Nature and Environmental Policy Plan for the Caribbean Netherlands assigns a high priority to removing and controlling roaming livestock (Min. LNV et al., 2020).

Figure 1. *Muddy brown freshwater with eroded sediment flowing onto the coral reefs of the National Marine Park of Bonaire from Saliña di Vlijt during heavy rains in 2004. Photo: F. van Slobbe*

With the exception of Klein Bonaire, and recently Saba, and a section of Slagbaai (amounting to a total of 318 ha), where all invasive grazers have been removed, goat densities in all other natural areas of the Caribbean Netherlands have remained too high for sustainability (St. Eustatius: 5.9/ha; Bonaire, entire island: 1.4/ha; WSNP: 1.1/ha) and pose a very significant threat to ecosystem function on all islands of the former Netherlands Antilles (Coblentz, 1980). Due to centuries of overgrazing, the original groundcover of bromeliads and orchids has for the most part degraded to a vegetation now dominated by cacti and thorny plants (Debrot and de Freitas, 1993). This has significantly changed the structure, appearance, water retention, and even the insect fauna of the forests (Debrot et al., 1999). However, by reducing livestock densities to 1 goat or sheep per 10 hectares (as in Curaçao), it has been empirically demonstrated that reforestation and rare plants can recover quickly (Figure 2).

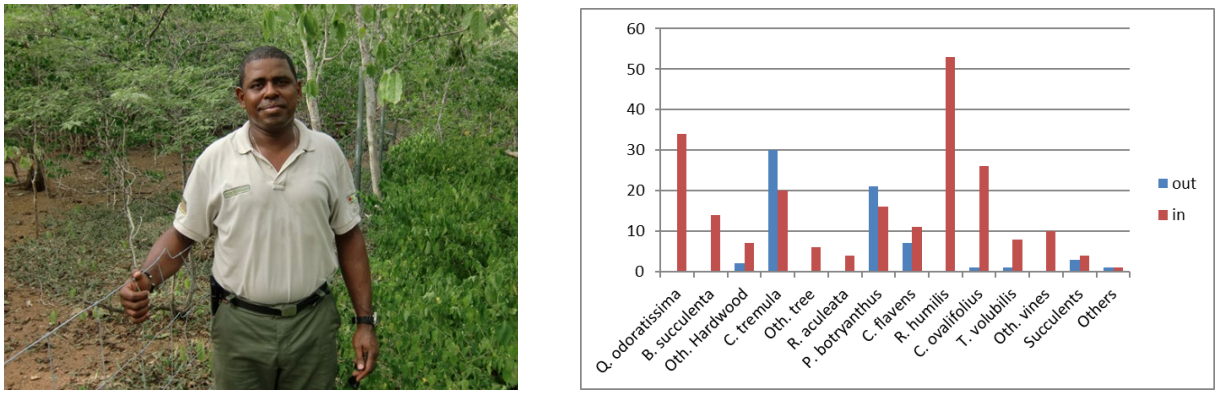

Figure 2. *Left: Park manager Juni Janga (2006) showing the sharp contrast between grazed and ungrazed habitat in the Washington-Slagbaai Park of Bonaire only three years after grazer exclusion; and right: the associated rapid increase in plant species composition. (Photo and data: A. O. Debrot). Full plant names from left to right: Quadarella odoratissima, Bourreria suculenta, other hardwood Casearia tremula, other trees, Randia aculeata, Phyllantus botryanthus, Croton flavens, Rivina humilis, Croton ovalifolius, Tournefortisa volubilis, other vines, Succulents, Others (plants).*

Description

Livestock farming in the Caribbean Netherlands has always been extensive. During the 18th and 19th centuries, various measures were enacted to protect forests and pastures from erosion and overgrazing (Van Grol, 1942; Westermann and Zonneveld, 1956), but these measures were never enforced and only applied to public domain areas (land owned by the island government), not to the large private plantations (De Freitas et al., 2005). The livestock roamed freely and reproduced in the wild. There was no pasture or herd management (Hoetink, 1969). Only a few larger plantations had some level of pasture management, with fenced livestock paddocks (Hoetink, 1969). According to Hoetink, small-scale farmers sent their goats onto public land, "where they must find their own food." This system of livestock farming continues to be largely maintained to this day. After arrival of oil refinery on Curaçao, growing economic prosperity heralded an end to the plantation era and small-scale agricultural fields became largely abandoned by the middle of the century (Hoetink, 1969, p. 525). With the declining interest in agriculture, and less need to maintain fencing, not only the public but also the private domain became fully accessible to uncontrolled feral livestock grazing. Further, with the advent of motorized transportation, donkeys, that once had been an integral part of domestic life, were abandoned to fend for themselves. This too became an important factor in further overgrazing, especially on Bonaire and St. Eustatius. However, the feral grazer with the highest impact remained the goats.

Goats are among the most adaptable livestock species and can thrive in almost any environment. Goat populations can grow very quickly. Without specific controls, a goat population can increase by 60-75% per year (GSA, 2005). Parkes (1984) calculated an annual natural population growth rate of 0.424 for a healthy hunted population on Raoul Island in the Pacific, indicating that such a population could double every 20 months, complicating population management. Under even the poorest conditions, goat populations can also slowly grow (e.g., Southwell and Pickles, 1993). The observed rate of population growth depends on age-

specific fertility and mortality, which are influenced by factors such as food availability, animal health, fertility, and sex ratios. Given the relatively good health and fertility and the suspected surplus of females in the Slagbaai area on Bonaire (Geurts, 2015), doubling times of 1-1.5 years are likely.

The consequence of this is that to achieve a real population reduction, perhaps 50% of all goats would need to be removed annually. For the average goat in Bonaire, we use the theoretical approach by Caughley and Krebs (1983) assuming a natural growth rate of 0.38, or 31% population growth per year. This would mean that to achieve a reduction in population growth, over 31% would need to be removed per year (Debrot, 2016; Figure 3).

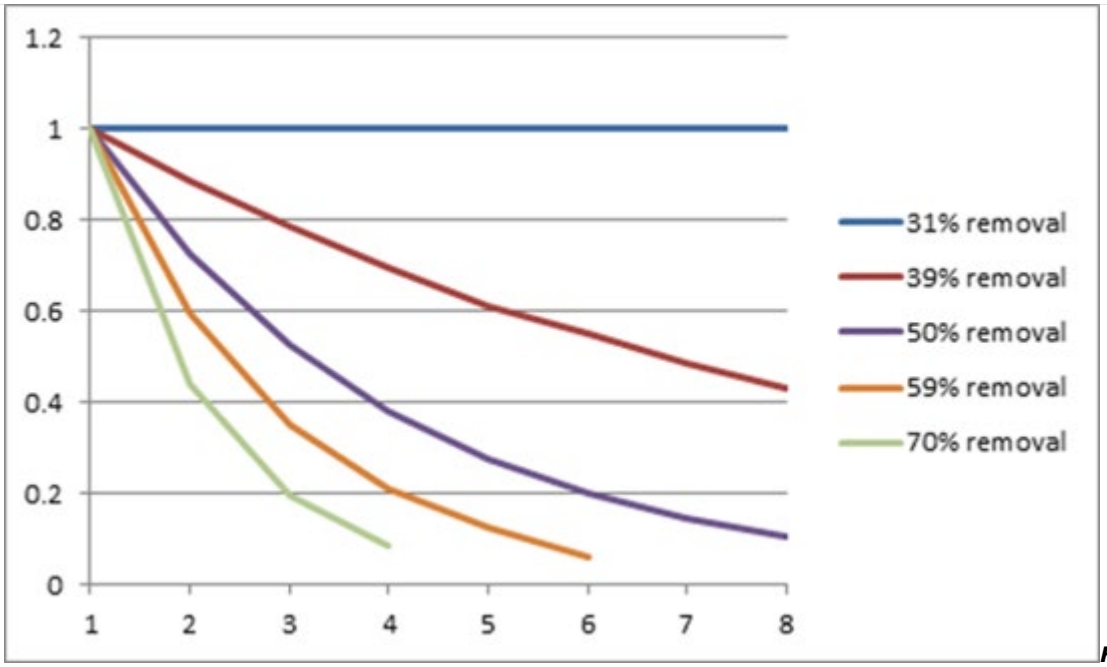

Figure 3. *Fractional population declines achieved year by year from the start of year 1 for different (discrete) removal rates. From: Debrot 2016.*

Effect of free-roaming livestock within the Caribbean region: massive

On the islands of the Caribbean Netherlands, the extensive form of livestock farming based on free-roaming livestock is a marginal source of income for a limited number of farmers (Neijenhuis et al., 2015). However, this form of livestock farming represents a major collective social cost (Neijenhuis et al., 2015), manifesting itself in:

- Uncontrolled erosion with loss of topsoil (Westermann and Zonneveld, 1956);
- Loss of biodiversity, lowering of groundwater levels, desertification, ambient temperature increase.
- Damage to coral reefs and fisheries (Fabricius, 2005);
- Damage to agriculture (the need for fencing);
- Dust damage and nuisance (Nolet and van de Meer, 2009);
- Traffic risks and damage (Bonaire Police Department, Division of Motor Safety); and
- Damage and plundering of vegetation by free-roaming livestock often poses a major obstacle to agricultural development (Neijenhuis et al., 2015).

This goat problem is shared with much of the Caribbean region, where free-roaming livestock not only causes loss of biodiversity but also damages commercial crops and public green spaces (Grenada Govt, 2007; Rijo, 2014). The argument is occasionally made that roaming goats at least form some kind of island self-sufficiency in food production. Nothing seems farther from the case. The combined damage of excessive densities of roaming goats to soil and vegetation is clearly a major detriment to island food self-sufficiency (Neijenhuis et al., 2015; Lotz et al., 2020). This is compounded by topsoil runoff, aridification, lowering of the groundwater

levels, resulting in poor soils that are leached out. Fencing and continuous maintenance is required to keep goats away from crops, which is relatively expensive.

To paraphrase Winston Churchill on the matter of goats:

"Seldom do so few benefit so little at the expense of so many"

Ecological Characteristics

Impacts

Since the early 1950s, the negative effects on ecosystems due to overgrazing by uncontrolled free-roaming livestock have been well-documented (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 authors to discuss the sensitivity of island ecosystems to exotic livestock. Since then, many others have demonstrated the extremely harmful effects of exotic grazers on island ecosystems (Gould and Swingland, 1980; Debrot and De Freitas, 1993; Fernández-Lugo et al., 2009; Carrion et al., 2011). In a recent global evaluation of 251 campaigns for removing invasive mammals on islands, it was concluded that such removals almost always led to rapid and effective ecosystem restoration (Jones et al., 2016).

On Bonaire, the driest of the three Caribbean Netherlands islands, the situation with regards to the free-roaming livestock remains the most acute. Many tree species can no longer regenerate because the seedlings do not survive the grazing pressure (Debrot et al., 2018). For this, the Bonaire government has published a list of trees that are protected by law (OLB 2008). It is likely that numerous native species on Bonaire have already gone extinct, and others will follow in the coming decades if no effective measures are taken (Lo Fo Wong and de Jongh, 1994; Proosdij, 2012; Freitas et al., 2005; Debrot et al., 2018). While the problem has long been recognized (Anonymous, 1985, 1989, 2006, 2009), few actual measures have been implemented so far. Of concern is how free-roaming goats and donkeys strip the bark from the columnar cacti, which leads to the death of these critically important trees. Columnar cacti flower and bear fruit during the dry season, when most deciduous trees are bare, providing an essential food source for fauna ranging from birds, and bats to reptiles during the dry season (Petit, 1997).

Maximum permissible population densities

Various studies provide insights into the carrying capacity of semi-arid ecosystems for livestock. For semi-arid regions of Australia, densities of 0.1 goat per hectare are already considered a severe threat to the environment and agricultural productivity (Southwell et al., 1993; Southwell and Pickles, 1993). On the semi-arid island of St. Catalina, off the coast of California, the island's natural vegetation was already heavily depleted and overgrazed at densities of 0.25 goats/ha (Coblentz, 1977). On Pinta Island, in the Galapagos, a density of 1.69 goats/ha was considered excessive, and the vegetation and unique flora quickly recovered after the goats were removed (Hamann, 1993). In arid parts of Australia, Pople et al. (1996) indicated that average grazer densities of 0.25 goats/ha already posed a severe threat to agricultural production. Lastly, Brennan et al. (1993) described the need to cull goats at a density of 0.16 goats/ha. On Curaçao, the removal of goats from the Christoffel Park to densities of approximately 0.1 goats/ha was sufficient to lead to rapid ecological recovery (Debrot and de Freitas, pers. obs.). In the Labra/Brasiel area on Bonaire, where average densities of 0.45 goats/ha were measured, ecological recovery and regeneration of vulnerable species are not evident, indicating that goat density must be reduced below 0.45 goats/ha before ecological recovery is possible. Based on results from the nearby and comparable island of Curaçao, it appears that livestock densities of 1 goat per 10 hectares should be sufficiently low to enable rapid ecological recovery, including the recovery of many rare species (Debrot, 2015). Of course, complete eradication (i.e., density is zero) is the best possible scenario. However, even where people no longer keep goats, total eradication is difficult at best and if goats are allowed to be legally kept on an island, eventual strays are practically impossible to prevent. Aside from islands like Klein Bonaire and Klein Curaçao where eradication has been complete, and the keeping of goats is not allowed, in

practice this means that removing goats becomes a long-term structural activity for nature management (e.g., Christoffel Park, Curaçao).

Present Distribution and Reference Values

To date, there have been very few quantitative studies on livestock density and distribution on the islands of the Caribbean Netherlands. Only recently have quantitative livestock counts been conducted on St. Eustatius (Debrot et al., 2015, Madden, 2020) and Bonaire (Lagerveld et al., 2015; Geurts, 2015). For Saba, there have as yet only been expert estimates, with no formal livestock counts.

Bonaire: Lagerveld et al. (2015) conducted livestock counts for Bonaire in 2014. Based on 75 line transects of 500 meters, the first quantitative estimates of the island's goat population were made. They used the so-called "Distance method," a modern, widely recommended, and accepted method to estimate animal density in natural areas. About 50% of the animals were found in agricultural areas, 12% in coastal areas, 37% in areas with thorny vegetation, and 1% in urban areas. In the forest, the density of goats was highest in the WSNP, where the lowest density would be expected based on its designation and management as a natural area.

For the entire island, a total of about 32,200 goats was estimated, with the number of animals in forested areas (about 12,000) possibly underestimated. The goat counts align with expectations based on previous professional qualitative estimates. However, despite considerable research effort (75 transects), there remained a relatively large margin in the estimated minimum and maximum numbers. The estimates yield densities averaging 1.41/ha (minimum 0.86 and maximum 2.30). This is much higher than what is sustainable for extensive livestock farming. A new form of sustainable livestock farming is therefore recommended, not only to provide real opportunities for the sector but also to reduce the negative ecological and economic consequences of the current situation.

For the Slagbaai plantation, located within the WSNP, the density of goats was estimated at 2.69 goats/ha in 2014 (Geurts, 2015). This density is far above what is sustainable in unmanaged semi-arid natural areas (Geurts, 2015; Debrot, 2016). As a result of a prolonged lack of livestock management in this nature reserve, the vegetation of Slagbaai is among the sparsest and most impoverished of all natural areas on Bonaire, with many tree species threatened with extinction (Freitas and Rojer, 2013). Individual plants produce leaves, flowers and fruits in different periods of the year. Therefore, to maintain food supplies year-round for the many birds, bats reptiles and insects that depend on such plant foods, maintaining vegetation diversity is essential (Restrepo et al., 2022). However, STINAPA data, as collected by Rivera-Milán et al. (2018, 2020, 2021, 2023) show that current efforts are making considerable headway in reducing livestock densities inside the park.

The management authority (STINAPA) of WSNP started in 2014 with active measures to remove all goats from the park. After different approaches did not achieve the objectives, a combination of measures was adopted. This includes trapping and shooting whilst fencing-off discrete parts of the area. The has led to fenced-off sections of Slagbaai being currently completely goat free. In goat-free areas, an increase in seedling densities has been documented (Figure 5). STINAPA has recently bought out the remaining grazing rights for the Washington section of the WSNP.

Feral pigs

Feral pigs (*Sus scrofa*) are a major scourge to nature conservation worldwide (Risch et al., 2021). As habitat and food generalists they are extremely adaptable and because of their extreme fecundity they can overpopulate very quickly (Echo, 2019). The damage they inflict to fauna, flora and ecosystems can be summarized as follows: they damage soil and vegetation by consuming seedlings and digging up tree roots, and have a major impact on small soil and ground-inhabiting fauna such as lizards, geckos (including their eggs), soil arthropods and ground-nesting birds like the endangered endemic White-tailed nightjar (*Caprimulgus cayenensis insularis*), endangered terns and gulls and iguana and sea turtle nests.

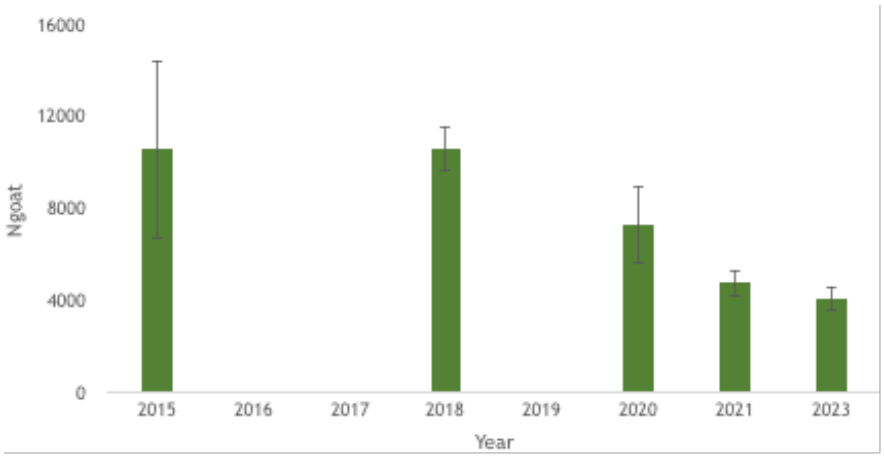

Figure 4. *Recent trends in estimated goat numbers inside the Washington-Slagbaai National Park. Based on counts by Rivera-Milán et al. 2018, 2020, 2021, 2023.*

In the WSNP, feral pigs have uprooted and destroyed most of the formerly extensive historical aloë (*Aloë barbadensis*) fields (A. Debrot, pers. obs.). Due to their compact strength, they destroy even the best fencing, and it is near impossible to fence them off crops or out of unguarded gardens. In addition, they also constitute a traffic hazard and if with piglets and cornered, can be hazardous to approach. The only proper way to keep pigs is enclosed behind special fencing. Between 2016 and 2019, a government sponsored culling project resulted in the capture and euthanization of 175 swine.

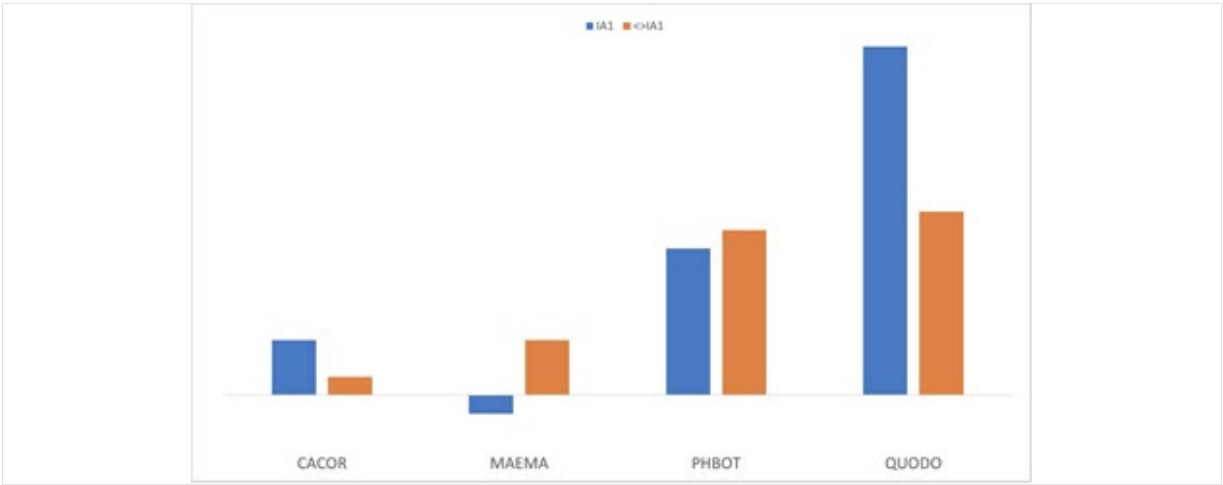

Figure 5. *A comparison of seedling densities before (brown) and after (blue) inside goat exclosure "Area 1" in the Slagbaai plantation (end 2024). CACOR = Caecalpinia coriaria, MAEMA = Malpighia emarginata, PHBOT = Phyllanthus botryanthus, QUODO = Quadarella odorata.*

Feral Donkeys

Feral donkeys (*Equus asinus*) are not native to the island of Bonaire but can have massive impacts on island ecosystems and biodiversity particularly in arid ecosystems (Malo et al., 2011; Symanski, 1996). During the colonial epoch and up to the mid-20th century, they were a key form of transportation but were subsequently abandoned to the wild ("set free") to fend for their own (Hartog, 1954) and population densities have since grown unchecked.

"The donkey (and mules) had an important place in the economy and transportation, was part of the family, had its own technology and jargon, its own folklore (Figure 6). Most donkeys belonged to people. The large plantation owners also always had some stray feral donkeys, but they were not [so abundant] like they are now" (Bòi Antoin, in interview with Dòlfi Debrot, 2014).

Figure 6. *"How it used to be". Plantation owner Shon Willem Schotborgh on his favourite mule at Sabaneta in the 1950s, Curaçao (A. Debrot, family photos). Equines (mostly donkeys, some mules) were an integral part of the family household but after WWII and the surge in motorized transportation, they were mostly abandoned ("set free") to fend for themselves.*

For biodiversity and resilience against climate change, population control actions for feral donkeys in Bonaire are highly needed. Recognizing this, the island government, in collaboration with various local parties, initiated a program in 2012 to remove free-roaming female donkeys from the wild and sterilize male donkeys. A total of 204 males were sterilized, earmarked and returned to the wild, 97 were euthanized as they were sick and suffering, and 326 female donkeys and foals were adopted into the donkey sanctuary. This program was discontinued in 2014.

In 2020, Simal et al. (2020) estimated donkey density for the whole of Bonaire at 0.043 donkeys ha-1 and population size at 1,084 donkeys. Donkeys graze differently than goats but are highly damaging (Malo et al., 2011) so control of donkeys and preferably limiting donkeys to (as formerly) a controlled, captive and properly cared-for registered population is to be preferred. Aside from a donkey capture program for the island as executed by the local government (2012-2014), the only area where donkeys remain being removed is in the WSNP where the density of donkeys decreased from 0.119 to 0.018 individuals per hectare between 2018 and 2023. (Rivera-Milan et al., 2023).

St. Eustatius: In 2013, counts were conducted on St. Eustatius (Debrot et al., 2015). The densities of goats, cattle, sheep, and chickens were estimated over a total transect length of 33.5 km, along existing nature trails in six different habitat zones. Each of the 13 different trails was visited and counted five times. The results indicated that the density of especially chickens, cattle, and goats was high. Statistically significant differences in density between the different habitat zones were demonstrated. Based on the counts and species-specific detection curves, the island's population estimate (± standard deviation) for goats was 2,470 ± 807. More recently, Madden repeated livestock density estimations using the same distance method and concluded a much higher goat population (7,602 ± 1,555) for the island as a whole, indicating a more than fourfold increase in goat densities in the island's protected areas between 2015 and 2020 (Madden 2020). Recognizing that the situation seems to be spiralling out of hand, STENAPA has started to try to fence off some of the most critical vegetation areas around the Quill.

The estimated densities are far too high for the sustainable management of vulnerable semi-arid grasslands. At these densities, there is a loss of organic matter in the soil, reduced water retention capacity, and increased erosion. It is crucial that the livestock population is limited and better managed. Of all livestock species, goats are the most problematic because they have a strong preference for rough and steep terrain. Such areas are much more vulnerable to erosion and house higher densities of rare species dependent on scarce microhabitats.

Saba: So far no livestock counts have ever been conducted on Saba. Many short-lasting removal efforts have been attempted in the past, but these generally met with strong local resistance. Fortunately, following a long history of start-up difficulties, serious removal has been taking place since 2020 with an estimated 90% reduction in the feral goat population (Public Entity Saba, pers. comm.). Due to the high fecundity of goats, and practical impossibility of total eradication (as sometimes possible on uninhabited islands), goats can bounce back in numbers very quickly and removal needs to be seen as a structural conservation measure that needs to continue steadily and in the long term. Until recently, average densities on Saba seemed to have been above 1 goat per hectare, but densities are said to have dropped by around 90% since 2020 (PES, pers. comm.). A quantitative assessment would be very good to conduct. On this island, to an untrained eye, the damage is less noticeable because it is generally much greener than St. Eustatius and Bonaire. However, based on the most recent assessment (Janssen and Proosdij, in this collection of reports) the vegetations of Saba are in unfavourable-bad CS and all show declining species richness since the last assessment. The gross impact of overgrazing is still strongly observable on the lowest slopes of the island, where these animals have been especially numerous and significantly contribute to erosion (Debrot and Sybesma, 2000). The former lowland forests have been unable to recover since the *Tabebuia* die-off that took place in the 1980s (Freitas et al., 2016) and it seems certain that the high goat densities in the island's drier coastal areas have been a major culprit in preventing forest regeneration.

Key Threats and Management Implications

Trends

Quantitative livestock counts have only recently become available for St. Eustatius (Debrot et al., 2015) and Bonaire (Lagerveld et al., 2015; Geurts, 2015). No livestock counts have been conducted for Saba, so it is impossible to say with certainty how livestock densities have changed on these islands in recent years. However, it can be assumed that the current livestock densities are indicative of structurally excessive densities on all three islands, something that older, often non-quantitative sources have already warned about (Duclos, 1954; Westermann and Zonneveld, 1956; Debrot and Sybesma, 2000).

Recent Developments

Several key recent developments can be listed as follows:

- On Bonaire, STINAPA, in collaboration with the island government and with funding from the Dutch Green Fund (currently the Nature and Environment Policy Plan – NEPP 2020), has been working on a project since 2014 to reduce the goat population within the WSNP (OLB/STINAPA 2014).
- On Bonaire, the island government, in collaboration with various local stakeholders and Wageningen Livestock Research, had been working to develop sustainable livestock farming options but this initiative has been discontinued.
- On Bonaire, the island government, in collaboration with various local stakeholders and Wageningen Livestock Research, is assessing plans to fence off and remove goats from biological hotspots and sensitive areas such as Lac.
- On Bonaire, the island government, in collaboration with various local parties, initiated a program in 2012 to remove free-roaming female donkeys from the wild and sterilize male donkeys. This program was discontinued in 2014.
- On Bonaire, the Island government, in collaboration with local foundations, initiated a program in 2016 to eradicate feral pigs and prevent owners to allow them roam freely. Over 175 feral pigs were captured and euthanized. The program terminated in 2019.
- On St. Eustatius, the LVV department is implementing a structural program to enclose free-roaming donkeys and capture and slaughter free-roaming cattle.
- On Saba, thorough removal of goats has been taking place since 2020 with an estimated 90% reduction in the feral goat population, as per 2024. (Public Entity Saba, pers. comm.).

Assessment of the Effect of Distribution on Biodiversity: Unfavourable-bad
Apart from the island of Klein Bonaire and a section of Slagbaai, goats are found everywhere in the nature areas of the Caribbean Netherlands. Notwithstanding some (short-lasting) initiatives as indicated previously, for Bonaire feral donkey densities contribute significantly to feral grazer densities (Simal et al., 2020) and highly fecund feral pigs are no longer being controlled (Echo 2019). On Bonaire, only in the WSNP are donkeys still being removed but they remain abundant in the Brasiel-Labra part of the park (F. van Slobbe, pers. obs.). Fortunately, neither on St. Eustatius nor Saba are feral pigs or donkeys a major problem (K. Wulf, pers. obs., Madden, 2020). Goats are found from sea level to the top of Mt. Scenery on Saba (880 m) and even in the crater of the Quill on St. Eustatius (600 m). They can be seen on the steepest mountain slopes on all islands, where climbing seems to be a sport for them. The only exceptions are a few small experimental plots on the slope of the Quill and a few long-term fenced vegetation plots in the WSNP on Bonaire.

Assessment of the Effect of Population Size on Biodiversity: Unfavourable-bad
As mentioned above, assessed livestock densities have been, on average, ten times or more than what is required to allow the recovery of rare species (Debrot et al., 2015; Lagerveld et al., 2015; Geurts, 2015; Debrot, 2016).

Assessment of Habitat: Unfavourable-bad
The negative effects are diverse and severe and have been extensively discussed in various studies (Debrot and De Freitas, 1993; Debrot and Sybesma, 2000; Debrot et al., 2014; de Freitas and Rojer, 2013; Freitas et al., 2005, 2014, 2016; Debrot et al., 2019; Lotz et al., 2020; Van Proosdij et al. and Janssen and van Proosdij in this collection of reports).

Assessment of Future Prospects: Unfavourable-bad
Control of free-roaming livestock in the Dutch Caribbean has only been successful in one park on Curaçao for more than 30 years, and since recently partially successful in WSPN on Bonaire. Eradication has however been fully successful on the small satellite islands of Klein Curaçao and Klein Bonaire. Although various efforts continue, it is unlikely that, in the short term, radical change for vaster natural areas in goat control and eradication will occur (in the case of Bonaire and St. Eustatius). This could result in several plant species going extinct within 10 years and is especially acute on Bonaire. One exception appears to be the WSNP where efforts to remove livestock have been ongoing for several years now with some success. Another exception is Saba on which thorough removal has been taking place since 2020 with an estimated 90% reduction in the feral goat population as of 2024 (Public Entity Saba, pers. comm.). Only if removal efforts can be sustained in the long-term, can it lead to sustainable results and long-term improvements for biodiversity. This is especially so because both goats and pigs are extremely fecund and can quickly regain population size even if only temporarily left unchecked. On all islands the parks remain surrounded by goat keepers and the chance of goats escaping to the wild and re-entering park areas cleared of goats is high. Also, the temptation of goat keepers to make holes in the park fence so that their animals can enter unnoticed, will also remain as long as they feel they can get away with it. So even if areas have been fully eradicated of goats, the need for vigilance and removal of accidental entries will remain a priority so long as goats are kept on Bonaire.

Good news is that several recent reforestation experiments indicate that recovery can be rapid and extensive once free-roaming livestock is excluded from an area (Debrot, 2013, 2015). Additionally, based on successful eradication campaigns and long-term control on Curaçao (Oostpunt and Christoffelpark) and based on cost-benefit analyses for Slagbaai on Bonaire (Debrot, 2016), if effectively implemented, this critically important conservation measure can be achieved at minimum cost as in neighbouring Curaçao (simply because the market value of a goat caught is still less than the costs and effort required for catching it).

It is important to keep in mind that before slow-growing seedling trees grow to a size beyond which they are vulnerable to grazers will take more than 20 years for most tree species (E. Houtepen, Carmabi, unpublished data). Hence, continuity needs to be guaranteed, and this is very difficult considering the less-than-solid public support and scanty and unstable attention to the feral grazer matter. The culling, removal or eradication of

roaming livestock is about the most important nature protection role for any park management organization to fulfil. This activity needs to be elevated to top priority.

Table 1. *Summary overview of the threat of roaming livestock to biodiversity in the Caribbean Netherlands in terms of different criteria.*

Threat level	**2024**
Impact on biodiversity	Unfavourable-bad
Population size	Unfavourable-bad
Habitat impacts	Unfavourable-bad
Future prospects	Unfavourable-bad
Overall Assessment of Threat Status	**Unfavourable-bad**

Comparison to the 2018 State of Nature Report

On St. Eustatius the situation seems to have gotten much worse with roaming goats. On the positive side is that all the local park organizations remain more or less active in this area, however, on Saba the lead has been decidedly by the PES. There is especially hope for positive change for the WSNP of Bonaire in the near future so long as removal efforts can be sustained. On Saba too, major removal has been achieved since 2020 and if this can be sustained into the future, vegetation recovery will certainly get underway.

Recommendations for National Conservation Objectives

For protected natural areas, livestock densities should be reduced to the equivalent of 0.1 goat/ha or less. First focus on goat control and eradication in areas which hold the largest biodiversity. Ascertain that goat keepers in, or adjacent to, nature areas keep their goats fenced-in.

Conservation Sub-Goals

- Implement an information campaign to educate the public on the large societal costs exacted by excess feral roaming livestock.
- Introduce flexible but structured control of livestock densities as an integral component of nature conservation.
- Establish monitoring programs to evaluate and adjust control and recovery measures.

Apart from Klein Bonaire and a section of Slagbaai, where complete removal of goats has been achieved, total eradication of goats and other livestock in the other terrestrial nature areas of the Caribbean Netherlands is currently very difficult to achieve. Reducing populations to a maximum of 1 animal (goat) per 10 ha is currently the next best alternative to total eradication. For other livestock (donkeys and cattle), it is suggested to consider an equivalence of four goats for each donkey and six goats for each cow.

Key Threats and Management Implications

The core threats caused by free-roaming livestock and the main management implications are shown in the table below:

Table 2. *Overview of key threats to biodiversity caused by roaming livestock in the Caribbean Netherlands and implications for biodiversity management.*

Core threats		**Management implications**
Extinction of rare plants:	High grazing pressure prevents many plants from reproducing and regenerating.	- Reduce livestock densities - Exclude livestock from critical areas through fencing and control - Ban livestock from protected natural areas

Core threats		Management implications
Erosion:	- Overgrazing and trampling by livestock cause large-scale erosion - Lowers groundwater levels, and dries out the soil - This leads to loss of topsoil, freshwater, and soil nutrients - Limits agricultural potential and ecosystem resilience – Causes siltation of important aquatic habitats - Sediment kills coral reefs by smothering - Creates dust that causes nuisance and damage to mechanical and electrical devices	- Reduce livestock densities - Exclude livestock from critical areas through fencing and control - Ban livestock from protected natural areas
Traffic hazard:	Collisions caused by free-roaming livestock are a significant cause of traffic accidents and fatalities.	- Reduce livestock densities - Exclude livestock from critical areas through fencing and control - Raise awareness - Develop and introduce sustainable forms of livestock farming
Infrastructural costs:	Free-roaming livestock damages plants and property and requires costly fencing to protect green infrastructure.	- Reduce livestock densities - Exclude livestock from critical areas through fencing and control - Raise awareness - Develop and introduce sustainable forms of livestock farming

Data Quality and Completeness

A few quantitative livestock counts have become available for St. Eustatius (Debrot et al., 2015) and Bonaire (Lagerveld et al., 2015; Geurts, 2015, Rivera-Milán et al., 2018, 2020, 2021, 2023). For St. Eustatius, the last five years have seen an explosive increase in the total livestock herd and a more than fourfold increase in livestock densities in protected conservation areas (Madden, 2020). No livestock counts have been conducted for Saba, however according to the PES roughly 90% of all goats are believed to have been removed between 2020 and 2024. Generally speaking, the available data is insufficient to properly evaluate ongoing initiatives and to provide a basis for adjusting the approaches to removal, even should any adjustments be needed. Now that removal has started in earnest, it is critical to start collecting data on vegetation recovery by means of permanent monitoring quadrats as has been started in 2023 in the WSNP.

The exact number of livestock to capture and cull is difficult to determine in advance. Reference numbers for natural birth and mortality rates are uncertain and influenced by local conditions, so predetermined capture and removal targets are likely not to achieve the intended goal. The effects of capturing and removing free-roaming livestock can only be determined if total livestock numbers are monitored. These periodic counts should define the targets for the next period.

The "Distance" method used in all three studies for livestock counts yielded wide margins of uncertainty in estimated densities, despite extensive sampling (Debrot et al., 2015; Geurts, 2015; Lagerveld et al., 2015). Thus, the ”Distance method” is not recommended as a method for estimating densities. Instead, we suggest using a simplified and standardized method as an index for population density (Debrot, 2016). The possible use of drones for livestock counts should be investigated. With the removal of feral livestock, it is not so much about livestock counts but about key vegetation metrics like vegetation cover, height and species composition.

As vegetation change resulting from goat removal seems much easier and less costly to reliably monitor, at present WMR and Stinapa are switching to vegetation plots as a proxy of grazer impact as a preferred way to verify grazer reductions.

Many plant species on all the islands are critically threatened in their existence due to free-roaming livestock. For such species, it is not feasible to wait until the livestock is removed. Mature trees of rare species should be fenced off to protect the last surviving seed sources and seedlings. The effectiveness of current reforestation initiatives should be monitored and evaluated.

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Keywords: biodiversity, conservation state, climate resilience, environmental threats, drivers of decline, active intervention, cascading benefits.

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This report can be downloaded for free from https://doi.org/10.18174/684783
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Photo cover: An extreme example from St. Eustatius of how uncontrolled livestock husbandry can overgraze vulnerable slopes to the point at which even infrastructure at the top of the cliff comes in danger from erosion.

Photo: J. Hazenbosch

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