Free-roaming livestock distribution, densities and population estimates on St. Eustatius: a 2020 update

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Economy, Nature and Infrastructure

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Contents

Abstract

Free-roaming livestock constitute a major threat to the terrestrial and marine ecosystems of St. Eustatius. In anticipation of a government-led culling program, we repeated population surveys of feral livestock from November 2019 to February 2020. Our goal was to compare current population estimates with those presented from 2013 by Debrot et al. (2015). Population densities of goats, sheep and chickens were estimated along 33.5 km of permanent roads and trails, representing six different habitats. Each of the 13 transects was surveyed twice. The results show that densities of goats and sheep have increased significantly compared with 2013, and chickens have increased slightly. The island population estimate (± SE) based on habitat-specific detection curves for goats is **7,602 ± 1,555**; for chickens the island population estimate is **2,668 ± 417**.

Detections of cows were too low to be included in the analysis, however these were present in town, lower Quill and grasslands. Given that sheep were primarily restricted to grasslands, the island population estimate is less exact at **4,316 ± 2,140**. Nevertheless, the densities of free-roaming goats and sheep rose significantly between 2013 and 2020, and are now at levels considered extremely unsustainable considering the island's size. Our estimates for goat densities per hectare and combined population size in the terrestrial protected areas are **D = 5.93 ± 1.35** and **N = 5,171 ± 1,182**, compared with D = 1.09 ± 0.27 and N = 1,323 ± 329 in 2013. This suggests that the numbers of goats have increased fourfold in the parks over the past seven years, especially the northern hills. Such excessive densities of feral goats increase soil erosion and degradation, reduce organic matter, and reduce water retention in vulnerable landscapes.

Feral chickens were present in all habitats but especially prevalent in urban areas. In addition to being aggressive omnivores, chickens can transmit diseases and therefore constitute a public health risk. Our results suggest that there is an urgent need to drastically reduce numbers and implement effective management of free-roaming livestock on St. Eustatius.

Introduction

The impacts of free-roaming livestock on terrestrial ecosystems are well documented (e.g., Bayne et al. 2005; Pisanu et al. 2005; Bakker et al. 2010; van der Geest and Slijkerman 2019). When native vegetation is consumed faster than it can regenerate, vegetation cover, water retention and root biomass decrease (Roberts et al. 2017). Inclement growing conditions for plants result in a reduction in food availability for livestock, which in turn increases grazing pressure on remaining vegetation and subsequent erosion rates. Such impacts result in a sub-optimal yield from animal husbandry whilst simultaneously exacerbating erosion, with subsequent environmental impacts on both terrestrial and marine ecosystems (Roberts et al. 2017). The climax vegetation on most Caribbean islands is dry forest, one of the most endangered tropical ecosystems on earth (Janzen 1988). In the former Netherlands Antilles, grazing by feral goats has been a significant problem for decades. Of all free-roaming livestock, goats are the most destructive due to their ability to graze native vegetation in virtually all habitat types (Polman et al. 2016). On Bonaire, an estimated 32,200 goats roam freely, of which approximately 40% are unregistered (Lagerveld et al. 2015). Other livestock such as sheep, donkeys and pigs also graze freely (van der Geest and Slijkerman 2019). Soil erosion caused by feral livestock negatively affects both the terrestrial and marine ecosystems of St. Eustatius (Fig. 1), which are a prime resource for tourism.

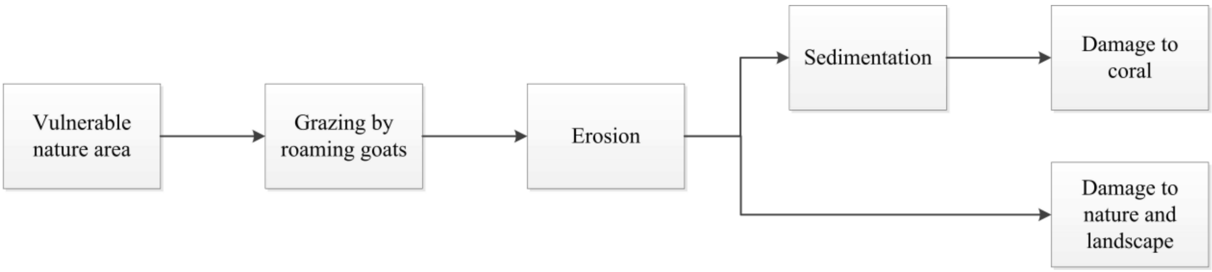

Figure 1: Stylized model of the impacts of free-roaming goats on marine and terrestrial ecosystems (taken from Polman et al. 2016).

In addition to environmental costs, free-roaming livestock incur economic costs to businesses and residents of St. Eustatius, who must fence off their properties, and cause hazardous traffic situations (Neijenhuis et al. 2015). Consequently, for island residents, any income gained from animal husbandry in its current state is comparably lower than the financial costs incurred from grazing-induced ecological and other damage (van der Geest and Slijkerman 2019). Nevertheless, the benefits of unregulated and unmanaged livestock-keeping for owners include minimal labor, feeding and fencing costs (Polman et al. 2016). Whereas the financial gains are very low, owning livestock is still considered attractive, despite the fact that many famers do not possess land on which to adequately support their animals (DLG 2011). Feral livestock pose a significant impediment to agricultural development and this has been highlighted as a priority issue by the Dutch government (DLG 2011).

Free-roaming livestock also constitute a public health risk to the inhabitants of St. Eustatius (DLG 2011). Domestic animals have been identified as relay species in the transmission of zoonotic pathogens from wildlife species to humans (Webster and Hulse 2004). Because of close contact with both humans and wildlife species, and increasing populations worldwide, domestic animals are likely to be major stepping-stone species favoring the emergence of infectious diseases in humans. *Toxoplasma gondii* is a global protozoan parasite of cats which can infect almost all warm-blooded animals, including humans (Hamilton et al. 2017). Free-roaming chickens are good indicators of environmental contamination with *T. gondii* due to their habit of feeding from the ground. In St. Kitts, 41% of chickens tested positive for *T. gondii*. This highlights the greater genetic diversity of *T. gondii* circulating in the Caribbean region, with potentially different degrees of virulence to humans (Hamilton et al. 2017).

In Debrot et al.'s 2018 report on the state of nature in the Dutch Caribbean, the authors concluded that the outlook for dry tropical forests was extremely unfavorable. Free-roaming livestock were cited as one of the main threats. Overall, the threats caused by feral animals to biodiversity and natural habitats were classified as extremely unfavorable (Fig. 2). Population sizes and predictions for the future were also considered extremely unfavorable if current conditions remain the same (Fig. 2).

Bedreiging door Loslopende hoefdieren	2017
Verspreiding op biodiversiteit	Zeer ongunstig
Populatiegrootte	Zeer ongunstig
Habitat	Zeer ongunstig
Toekomstperspectief	Zeer ongunstig

Figure 2: Threats posed by free-roaming livestock in the Dutch Caribbean by Debrot et al. (2018). (Impacts on biodiversity; population size; habitat; prediction for the future. Assessment: extremely unfavorable)

Various studies have estimated the carrying capacity of semi-arid ecosystems in relation to free-roaming livestock. In Australia, goat densities of 0.1/ha are considered a serious threat to the environment and to agricultural productivity (Southwell et al. 1993; Southwell and Pickles 1993). On the semi-arid island of St. Catalina, California, natural vegetation growth was strongly impacted by goat densities of 0.25/ha (Coblentz 1977). On Pinta island, Galapagos, goat densities of 1.69/ha were considered excessive and, following their removal, the island's unique flora recovered quickly (Hamann 1993). On Curacao, the removal of goats from Christoffelpark at a density of 0.1/ha gave rise to rapid ecological recovery (Debrot and de Freitas, pers. comm.). On Bonaire, goat densities of 0.45/ha prevent the recovery of vulnerable species. This suggests that for ecological recovery to occur, the density of goats must be reduced to less than 0.45/ha (Debrot et al. 2018). On Redonda (Antigua) following the removal of goats and black rats, land bird populations increased tenfold, rare endemic species rebounded, and plant diversity increased from 17 species in 2012 to 88 in 2019 (Fig. 3; Island Conservation).

Figure 3: Recovery of native vegetation following goat and rat removal on Redonda.

Objectives

The aim of our study was to provide an update to the 2013 population estimate of free-roaming livestock on St. Eustatius by Debrot et al. (2015) and compare the results with those presented from 2013. The government of St. Eustatius, together with Rijksdienst voor Ondernemend Nederland (RVO) and the Dutch government, have given high priority to the removal of free-roaming animals. The current removal rate is not known but is not thought to have any impact on grazing. Slaughterhouse data had been requested but were not available at the time of writing. Our surveys were conducted along established trails and roads to repeat those conducted by Debrot et al. (2015) and to facilitate repeat future monitoring.

Materials and methods

Study area

St. Eustatius (21 km^2) (17^o 28' – 17^o 32' N, 62^o 59 – 63^o W) has a human population of around 3,900 (Statistics Netherlands 2018). The island comprises two volcanic areas separated by lowlands (Van Andel et al., 2016). Boven (289 m) to the north consists of five extinct volcanic centers, whereas the Quill (600 m) to the south is a dormant stratovolcano (Roobol and Smith 2004). The Quill (~220 ha) and Boven (~320 ha) are terrestrial protected areas (TPA) that are actively managed by St. Eustatius National Parks Foundation (Collier and Brown 2008). Both areas are covered in secondary dry forest (Van Andel et al. 2016).

The island can be divided into three principal landscapes: 1) the Quill volcano, 2) the central plains and urban areas, and 3) the northern hills. Axelrod (2016) described 617 vascular plant species, excluding strictly ornamental plants. The decline of agriculture combined with conservation efforts resulted in the regeneration of dry forests between the 1950s and 2015, however natural habitats are subject to grazing by free roaming livestock (van Andel et al. 2016).

Field surveys

We followed the same methodology described by Debrot et al. (2015), namely walking transects along established roads and trails in six habitats: 1) Grasslands; 2) Urban; 3) Lower Quill Slopes; 4) Upper Quill Slopes; 5) Quill Crater; and 6) Northern Hills (Fig. 4). Livestock numbers were surveyed by walking each transect twice during the 2020 study rather than five times in the 2013 study. All animals distinguished up to 200 m from the transect were identified and counted. The perpendicular distance of the animal from the center of the transect was measured using a rangefinder. Surveys were conducted between 7am and 12pm by a single observer (H. Madden), with the exception of one survey in the urban habitat which was conducted between 1 and 4pm. Sex (m/f/unknown) and age class (young/adult) were recorded. An overview of sampling effort is provided in Table 1.

In 2013, nine goat exclusion and non-exclusion plots were established in different areas of the Quill National Park to measure the effects of exclusion on plant growth (Madden 2014, 2015). We used data collected in 2015 to make a preliminary analysis, and these will be revisited in 2020 to gather additional data.

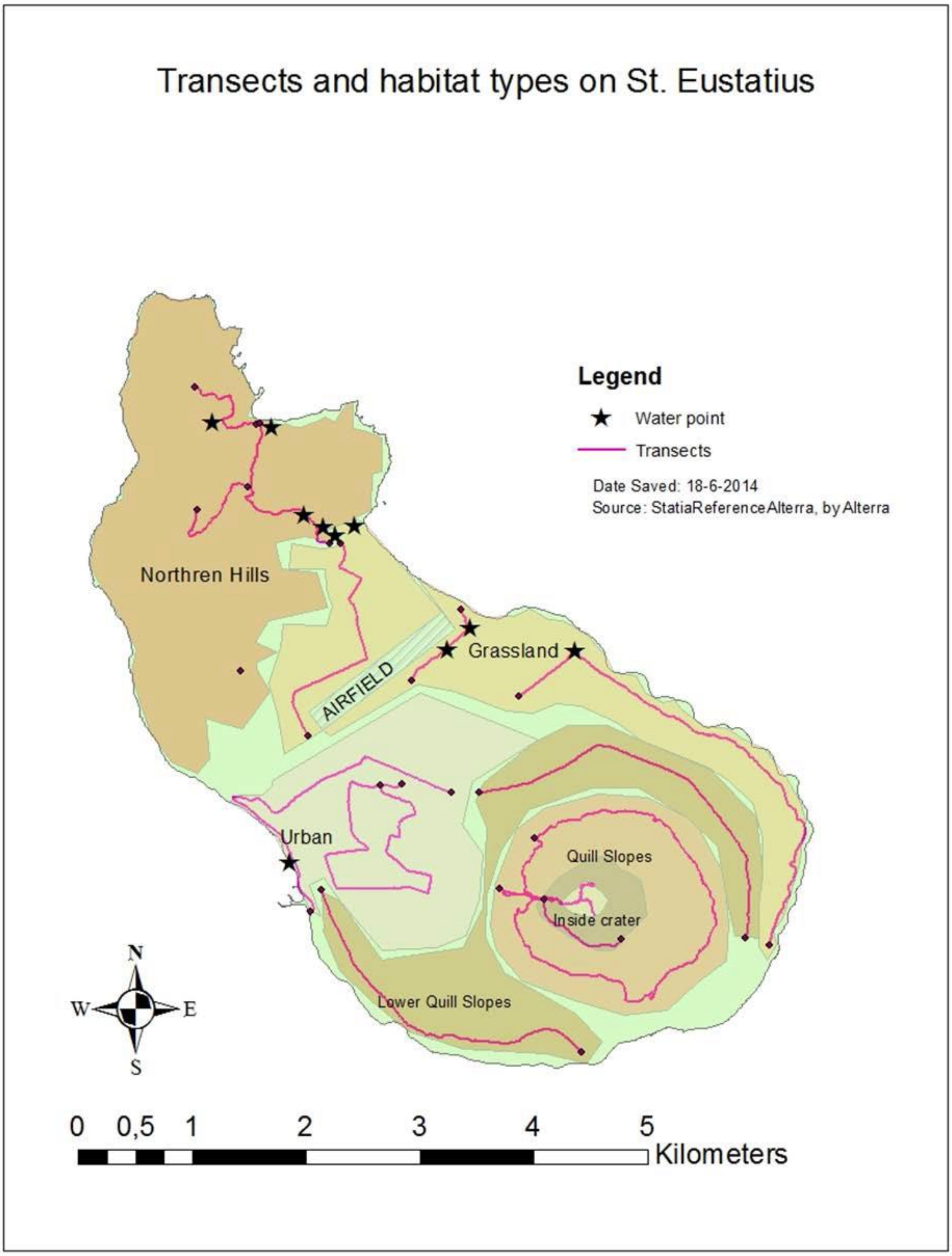

Figure 4: Map of St. Eustatius showing locations of the 13 transects used for surveying free-roaming livestock (taken from Debrot et al. 2015). Known watering points used by livestock shown as well.

Table 1: Surface area, sampling effort and mean transect livestock counts per habitat

Overall sampling	**Upper Quill slopes**	**Lower Quill slopes**	**Quill crater**	**Grasslands**	**Urban areas**	**Northern hills**	**All habitats**
Sector surface area (ha)	*278*	*323*	*8*	*366*	*335*	*595*	*1914*
# transects	*2*	*2*	*1*	*3*	*2*	*3*	*13*
# replicate surveys	*2*	*2*	*2*	*2*	*2*	*2*	*2*
Combined transect length (m)	*6100*	*6520*	*1567*	*7705*	*7580*	*3994*	*33466*
Total survey effort (m)	*12200*	*13040*	*3134*	*15410*	*15160*	*7988*	*66932*
Mean cattle count	0	3.67	0	2.5	2.5	0	8.67
Mean goat count	2.16	2.27	1.77	5.56	3.94	3.23	18.93
Mean sheep count	0.94	0	0.40	17.77	4.4	2.86	26.37
Mean chicken count	1.28	1.59	0.19	1.23	1.69	1.41	7.39

Data analysis

To model density distribution curves, we used Distance 7.3 software package (Thomas et al. 2010). We made the same assumptions and performed the same analyses described by Debrot et al. (2015). We compared our results with those presented by Debrot et al. (2015) using a paired *t*-test. We compared population densities of goats and chickens in the different habitats using each survey conducted as an individual estimate for each transect. Individual counts were divided by the density-curve modeled effective strip width for each transect to give a density index. These were 4^{th} root transformed and compared between habitats using a one-way ANOVA. We performed a paired *t*-test on vegetation data from 2015 to compare plant height, number of species and number of plants in the goat exclusion and non-exclusion plots in the Quill National Park.

Results

We present an overview of the density/ha and population size estimates for all feral animals detected during surveys in six habitats on St. Eustatius in Table 2. We did not include cattle in the analysis since the number of detections was too small for Distance sampling analysis. We did not encounter any swine or donkeys during surveys. For all species, the half normal density curve was selected along with cosine expansion. We also present Debrot et al.'s 2013 results for comparison (Table 3).

Table 2: Population density and size estimates (mean ± SE) for free-roaming goats, sheep and chickens in the different habitats of St. Eustatius (2019-2020 surveys).

Sector	*Upper Quill slopes*		*Lower Quill slopes*		*Quill crater*		*Grasslands*		*Urban*		*Northern hills*		*Total*	
Area (ha)	278		323		8		366		335		595		**1,914**	
Species	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***
Goats	2.84 ± 0.93	790 ± 258	3.29 ± 0.82	1063 ± 263	N/A	N/A	7.61 ± 2.17	2753 ± 784	3.46 ± 0.71	1158 ± 239	10.04 ± 2.34	5976 ± 1391	3.97 ± 0.81	**7602 ± 1555**
Sheep	N/A	N/A	N/A	N/A	N/A	N/A	17.60 ± 8.30	6441 ± 3040	N/A	N/A	N/A	N/A	2.25 ± 1.12	**4316 ± 2140**
Chickens	0.72 ± 0.24	200 ± 67	1.21 ± 0.40	391 ± 128	N/A	N/A	N/A	N/A	9.02 ± 0.76	3021 ± 255	N/A	N/A	1.39 ± 0.22	**2668 ± 417**

D/ha: Density per hectare
N: Population estimate (± SE)
N/A: Detected but too few to allow density curve estimation

Table 3: Population density and size estimates (mean ± SE) for free-roaming goats, sheep and chickens in the different habitats of St. Eustatius (2013 surveys; Debrot et al. 2015).

Sector	*Upper Quill slopes*		*Lower Quill slopes*		*Quill crater*		*Grasslands*		*Urban*		*Northern hills*		*Total*	
Area (ha)	278		323		8		366		335		595		**1,914**	
Species	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***	**D/ha**	***N***
Goats	1.09 ± 0.27	303 ± 75	1.09 ± 0.27	352 ± 87	1.09 ± 0.27	9 ± 2	2.53 ± 1.40	928 ± 513	0.68 ± 0.79	230 ± 265	1.09 ± 0.27	648 ± 161	1.30 ± 0.42	**2470 ± 807**
Sheep	0	0	N/A	N/A	0	0	3.56 ± 2.90	1303 ± 1060	0.02 ± 0.20	56 ± 67	0	0	0.68 ± 0.52	**1300 ± 992**
Chickens	0.55 ± 0.14	154 ± 40	1.23 ± 0.60	399 ± 194	3.05 ± 1.44	27 ± 12	0.72 ± 0.56	265 ± 207	2.78 ± 0.93	935 ± 314	0.24 ± 0.18	147 ± 110	1.17 ± 0.35	**2248 ± 668**

D/ha: Density per hectare
N: Population estimate (± SE)
N/A: Detected but too few to allow density curve estimation

Comparison of all species in all habitats between 2013 and 2020 revealed a significant difference in population densities/ha (paired *t*-test: $t = -2.85$, df = 11, $p = 0.02$). There were no significant differences in goat or chicken population densities between the different habitats (ANOVA: $p > 0.05$). Comparison of data from nine goat exclusion plots in the Quill from 2015 revealed significant differences in the number of species (paired *t*-test: $t = -3.82$, df = 8, $p = 0.01$; Fig. 5), number of plants (paired *t*-test: $t = -3.19$, df = 8, $p = 0.01$), and average plant height (paired *t*-test: $t = -2.62$, df = 8, $p = 0.03$).

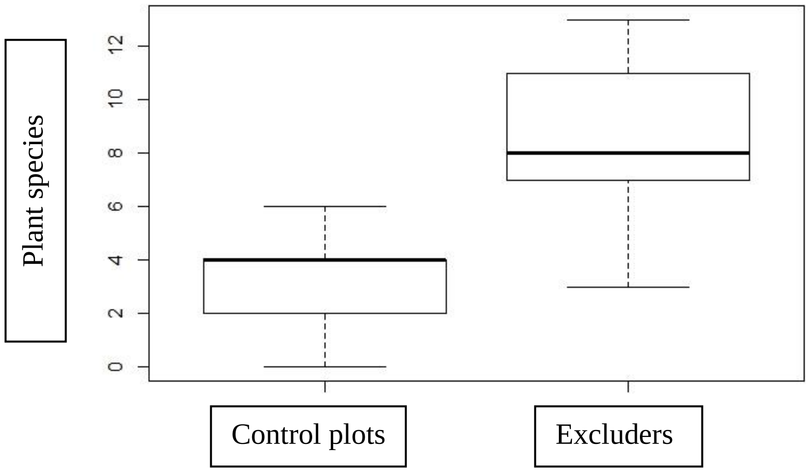

Figure 5: Number of plant species growing inside goat excluders compared with non-excluded control plots in the Quill National Park from 2015 (Madden, 2015).

Goats

In total we detected 481 goats during surveys. Goats were observed in all habitats except the Quill crater. Whilst goats were present inside the crater, there were too few detections to perform a Distance analysis. The highest recorded density of goats was in the northern hills (10.04/ha) and lowest in the upper Quill slopes (2.84/ha; Table 2). Food availability for goats in the forested areas was low, most likely due to excessive grazing within these habitats, which could explain the high densities of goats in other areas. The effective strip width (ESW) for sampling was highest in grasslands (58 ± 7 m) and lowest in the lower Quill slopes (33 ± 8 m). Using the more detailed detection curves, the corrected goat count for the island is 7,602 (minimum 5,063 – maximum 11,414; Table 2). Estimates for goat density/ha and combined population size in the wooded habitats of the upper Quill slopes and northern hills, which overlap with the TPAs, are D/ha = 5.93 ± 1.35 and $N = 5{,}171 \pm 1{,}182$. Estimates for goat density/ha and combined population size in all areas of the Quill (upper and lower slopes plus crater) are D/ha = 3.25 ± 0.59 and $N = 1{,}982 \pm 361$. Of the goats detected, 41% could be reliably sexed. The overall M:F sex ratio was 0.35 and the ratio of immature (<1 year) to adult goats was 0.40.

Chickens

In total we detected 409 chickens during surveys. Chickens were detected in high densities in urban areas, and upper and lower Quill slopes. Whilst chickens were present in all habitats surveyed, there were too few detections in the Quill crater, grasslands and northern hills to perform a Distance analysis. The highest recorded density of chickens was in urban areas (9.02/ha) and lowest in the upper Quill slopes (0.72/ha; Table 2). However, there was no significant difference in chicken density between habitats. Food availability for chickens is highest in urban areas, where food scraps and water are often available among private residences and restaurants. The ESW for sampling was highest in the lower Quill slopes (49 ± 11 m) and lowest in urban areas (28 ± 7 m). Using the more detailed detection curves, the corrected chicken count for the island is 2,668 (minimum 1,954 – maximum 3,643; Table 2). Of the chickens detected, 76% could be reliably sexed. The overall M:F sex ratio was 0.59 and the ratio of immature to adult plumage chickens was 0.21.

Sheep

In total we detected 1,433 sheep during surveys. Although sheep were detected in all areas surveyed, there were too few observations in all but one habitat (grasslands) to perform Distance analyses. The density of sheep in grasslands was 17.60/ha (Table 2). The ESW for sampling in grasslands was 62 ± 8 m. Using the more detailed detection curves, the corrected sheep count for the island is 4,316 (minimum 1,653 – maximum 11,271; Table 2). This is a much coarser estimation with higher margins of error than those given for goats and chickens but nevertheless gives an indication of the population size. Our results were similar to Debrot et al. (2015) in that of the sheep detected, only 18% could be reliably sexed. The overall M:F sex ratio was 0.22 and the ratio of immature to adult sheep was 0.25.

Discussion

We present an update to the 2013 snapshot assessment by Debrot et al. (2015) of free-roaming goats, sheep and chickens on St. Eustatius. In the seven years since the initial assessment, population estimates of all species have increased, some significantly. In particular, island-wide goat densities have tripled from 1.30/ha in 2013 to 3.97/ha in 2020. The low metabolism, efficient digestive system and low water requirements of goats allows them to persist in conditions unsuitable for other herbivores (Campbell and Donlan 2005). Grazing by goats changes natural habitats by altering soil properties, removing vegetation, and decreasing the abundance of palatable herbaceous species. It also causes degradation of the forest understory, reducing tree regeneration (Schofield 1989). In the upper Quill slopes, goat densities have increased from 1.09/ha to 2.84/ha. Extensive grazing in the Quill National Park is evident in the form of large sections of bare slopes, especially along the Around the Mountain (south) trail and the trail to the crater rim (Figs. 6 and 7). In the northern hills, which overlap with Boven National Park, goat densities increased significantly from 1.09/ha in 2013 to 10.04/ha in 2020. Such densities far exceed ecological carrying capacity rates, including those quoted in the introduction (page 6). As predicted by Debrot et al. (2015), the general good health of the island’s goat population allowed it to more than double in just seven years.

Just two years following the establishment of nine goat excluders in the Quill, there were significant differences in the number of species, number of plants and average plant height between the exclusion and non-exclusion plots. This is a clear indication of the negative effects of goat grazing on vegetation and suggests that, following the removal of roaming animals from the TPAs, flora should recover quickly. Goats have also been documented feeding on native orchids in both parks and are cited as a primary threat to the overall population health of *Brassavola cucullata* (Ackerman et al. in press).


Figures 6 and 7: Lack of undergrowth on the Upper Quill slopes due to overgrazing by goats.

Island-wide sheep densities have tripled from 0.68/ha in 2013 to 2.25/ha in 2020. In grassland habitats, the population density of sheep has increased almost fivefold from 3.56/ha in 2013 to 17.60/ha in 2020. Although sheep were observed in other habitats, including the upper Quill slopes and crater, the majority of populations appear to be concentrated in grasslands. On Santa Cruz Island, California, long-term overgrazing by feral sheep resulted in moderate to severe ecological impacts (Van Vuren and Coblentz 1987). Feral sheep are generalist herbivores, consuming a variety of plants according to availability and phenology. Effects of sheep in grasslands include reduced herbaceous cover, increased bare ground, altered community structure, decreased litter, and increased erosion. Sheep browsing impacts shrubs by altering growth form and preventing regeneration, and by completely defoliating lower-growing shrubs (Van Vuren and Coblentz 1987).

Island-wide population densities of feral chickens have increased from 1.17/ha in 2013 to 1.39/ha in 2020. Chicken densities in the upper Quill slopes increased from 0.55/ha to 0.72/ha, but remained fairly constant in the lower Quill slopes. Chickens were present inside the crater but not in sufficient numbers to allow analysis. In urban areas, however, population densities have tripled from 2.78/ha to 9.02/ha. Chickens have an omnivorous diet and are known to feed on small reptiles (Arshad et al. 2000). A feral chicken was observed attacking/eating an iguana hatchling on St. Eustatius (van Wagensveld, pers. comm.), which could have further implications for an already critically endangered species. As mentioned earlier, free-roaming chickens may pose a public health risk as relay species in the transmissions of diseases to humans (Hamilton et al. 2017). Additionally, there is a risk of disease transmission from chickens to native bird species that may have little resistance to introduced pathogens (Gottdenker et al. 2005). Besides disease transmission, the omnivorous diet and aggressive nature of chickens enables them to compete with native species for food and other resources (Lowney et al. 2005). This is particularly relevant in the upper slopes and crater of the Quill where vulnerable, restricted-range species exist. As recommended by Debrot et al. (2015), studies into the impacts of feral chickens on native flora and fauna are required.

Conclusion and recommendations

Sustainable development based on environmental criteria is high on the agenda of most European governments. In order to succeed, a removal program requires political support, appropriate methods, sufficient effort, and the ability to detect remaining animals at low densities (Campbell and Donlan 2005). Implementing large-scale measures to reduce the negative effects of grazers for the wider community will be more successful than small-scale measures. For example, the current project to reinforce parts of the cliff on Orange Bay, combined with excluding goats from the area and the ongoing reforestation project, will help minimize the rates of erosion that threaten properties and infrastructure. In order to prevent reintroduction, a long-term plan combined with removal campaigns and the integration of locally based education programs will be necessary (Campbell and Donlan 2005). On other Caribbean islands, initiatives such as buying out grazing rights or developing alternatives for livestock keepers have been successful (Polman et al. 2016).

In the Quill and Boven National Parks, excessive grazing has resulted in habitat degradation. Recovery of native vegetation and ecosystems on islands following eradication is often swift and dramatic (Campbell and Donlan 2005), but will require monitoring. In some cases, vegetation will recover but species composition might differ from the original (Schofield 1989). The availability of local products (e.g., goat burgers, meat sale) makes the island more attractive for residents and tourists (Polman et al. 2016). However, productivity is limited by the carrying capacity of the land, nutritive quality of vegetation and sustainability, environmental protection, and animal health (Dýrmundsson 2006). Nevertheless, new niche markets for cheese, yogurt, goat-milk soap, and high quality textile fiber may contribute to the local economy whilst simultaneously combining sustainable farming practices with habitat conservation (Boyazoglu and Morand-Fehr 2001; Lu et al. 2010).

Main recommendations:

- Removal of all free-roaming livestock, especially from vulnerable ecosystems such as Quill and Boven National Parks.
- Support the removal project with extensive data collection and analysis.
- Create fenced off areas in the central plains for livestock. Ensure the carrying capacity of these areas is not exceeded.
- Provide training for livestock owners, as well as subsidized fencing and feed, to encourage better management of animals.
- Consider a buyback program.

- Develop alternative sources of income for livestock owners.
- Repeat surveys every five years to monitor feral livestock population sizes and compare changes pre-/post-removal.
- Monitor the effects of livestock removal on vegetation and ecosystems.
- Research the impacts of feral chickens on native flora and fauna in the TPAs.

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