Roaming livestock distribution, densities and population estimates for St. Eustatius, 2013

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Abstract

The problem of roaming livestock is a major impediment to agricultural development and nature conservation on St. Eustatius, as it also typically is on other islands in the region. In support of a government-led culling program, we here conducted a baseline study of livestock abundance and distribution on the island in the final quarter of 2013. Population density of cattle, goats, sheep and chickens were estimated along 33.5 km of permanent trails, representing six different habitat zones. Each of the 13 trails was assessed five times. The results show overall high densities of chickens, goats and cattle. Clear and statistically significant livestock density differences were found in different zones of the island. The two most ubiquitous species of feral farm animals were goats and chickens which were found in all habitat zones. Island population estimates (± 1 SE) based on habitat-specific detection curves for **goats is:** **N = 2470 ± 807**. For chickens, habitat-specific detection-curves were insufficiently distinct to affect population estimates and the island population size estimate for **chickens is: N = 2248 ± 668.**

Cattle and sheep were more restricted. Our estimate for sheep numbers is only crude 1300 ± 992 and only indicates a minimum count for the island of about 300 sheep. As cattle are large animals and dependent on man-made trails for their movement through the terrain, population size estimates for cattle extrapolated using the Distance approach were found to lead to an excessively high mean population estimate (N = 1012 ± 458). Our best estimate, based on tag-resighting rates **for cattle is: N = 600 animals**, which does fall within 1 SE for density estimation. So, while the established transects are a useful tool for monitoring livestock density, the counts for cattle should not be used to extrapolate population size.

The density of roaming small ruminants (ie, goats and sheep) are currently at levels considered excessive for sustainable range management in other semi-arid landscapes. Our estimates for goat density per km^2 and combined population size for the wooded habitats of the Northern Hills and the Quill where the terrestrial national parks are established are as follows: **d = 109 ± 27** and **n = (1323 ± 329)**. Such livestock densities cause soil degradation, loss of organic matter, reduced water retention and erosion in semi-arid rangelands. Therefore the results stress the need to cull, restrict and better manage the roaming livestock herds of the island. Of these, goats are the most problematic due to their habit of preferring steep terrain and cliffs. These are more vulnerable to erosion and harbour higher densities of rare species due to micro-habitat availability.

Complementary counts of cattle by LVV along the same network of trails show that over the last year cattle abundance has not appreciably declined, notwithstanding the ongoing removal efforts. Therefore cattle needs to be removed at a higher rate and/or longer period than achieved to date, to be able to effect a measurable population decline. As a final note we point to the high density of feral chickens on Statia. Chickens are aggressive omnivores capable of impacting small terrestrial animals and seedling regeneration. Their effect, particularly on the rainforest plants and animals of the upper Quill slopes and Quill crater deserves further assessment.

1. Introduction

Within the Caribbean Netherlands, overgrazing by feral livestock is one of the most serious threats to the biodiversity of these islands (MinEZ 2013, Smith et al. 2013). This is also the case on the island of St. Eustatius where in the past several attempts were made to address 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 (Esteban 2009). The roaming livestock issue is for instance a major impediment to agricultural development and has been indicated as a priority issue to address (DLG 2011). Neighbouring islands face very similar problems, where the roaming livestock also imparts damage to crops and wildlife (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).

For St. Eustatius severe consequences are self-evident and include, for instance, the lack of undergrowth in the Quill-slope woodlands, strong contrasts between grazer accessible areas and exclosed areas, and coppice formation with stunted bonsai-like growth for bushes due to chronic ungulate grazing pressure (Fig. 1). In their millennial review paper on the state of the seas in the Dutch Caribbean, Debrot and Sybesma (2000) identified erosion and overgrazing as two principal threats to the nearshore ecosystem for St. Eustatius.

Fig 1. Evidence of vegetation impacts by grazing on St. Eustatius: a) total lack of undergrowth in the Quill slope woodlands, b) large effects of grazing exclosure, c) coppice formation in *Melochia tomentosa*, due to chronic grazing pressure.

2. Objectives

At present the Agriculture, Husbandry and Fisheries Department of Statia is conducting a feral livestock culling program to address the roaming animal problem (DLG 2011). While animals are being removed by various means, they also reproduce and it is hence not clear to what extent current removal rates will actually help alieve overgrazing. To this end it is necessary to get a better estimate of livestock numbers, age, sex composition and distribution and to record removal rates. It is also not known which plants are being affected by livestock grazing and what capacity the vegetation has for regeneration. In this study we surveyed feral livestock abundance and distribution in different habitat areas of the island as a baseline assessment for management purposes. Our surveys were done from the established trail and road system to facilitate future monitoring.

3. Materials and Methods

Study area

St. Eustatius is a 21 km^2 island that lies in the north-eastern Caribbean between the islands of Saba (27 km to the northwest) and St. Kitts (12 km to the east). The island is volcanic in origin and it highest point is Mazinga at 600 m on the rim of the crater of the Quill volcano. The Quill is a dormant strato volcano that has not erupted in more than 1600 years (Roobol and Smith 2004). Rainfall in St. Eustatius averages 986 mm per year as measured in Oranjestad, but at altitudes above 400 m it likely averages more than 1500 mm per year (Veenenbos 1955). Most rainfall occurs during August-November, which accounts for an average of 47% of the annual rainfall. This is followed by a dry period from roughly January-April. The island lies in the zone of the trade winds and the predominant (80%) wind directions are northeast, east-northeast or east.

The island can be divided into three principal landscape areas: a) the Quill volcano, b) the central, formerly agricultural plains on which the town of Oranjestad is situated and 3) the north-western hills collectively named the "Northern Hills". The number of inhabitants of the island is about 3600. The total flora of the island amounts to 505 plant species representing 345 plant genera and 94 plant families, and based on these, Freitas et al. (2014) describe 13 semi-natural vegetation types for the island (Fig. 2). Agriculture has declined dramatically since the 1950s and this has led to notable vegetation recovery, particularly in the Northern Hills and on the lower slopes of the Quill where abandoned farmland has partially regenerated into thorny woodlands (Freitas et al. 2014). Nevertheless, the most sensitive elfin forest formerly found on the upper crater rim has been all but lost and all semi-natural areas today remain heavily subject to feral grazing by goats and cattle.

Field methods

Feral farm animal surveys were conducted from Oct 2013—Jan 2014 along 13 different established trails and roads distributed among 6 habitat sectors distinguished. These habitats amounted to the "Grasslands", "Urban Habitat", "Lower Quill Slopes", "Upper Quill Slopes", "Quill Crater", and the "Northern Hills". This categorisation clearly did not correspond to the finer plants species-based vegetation types described by Freitas et al. (2014) and were selected based on the rough distributional patterns of livestock evident after initial field orientation. It was evident that livestock distribution must be governed by several other factors aside from vegetation. Figure 3 shows the location of the different habitat zones distinguished and the location of the 13 trail sections, while Table 1 provides an overview of the basic sampling effort. Watering holes are a key determinant of distribution in large ungulates and were therefore also mapped for the island (Fig. 3). We did not choose to use randomly positioned transects due to the inaccessibility of many areas was such that reaching random locations through thick brush would not be possible without scaring away the livestock to be censussed (which would bias estimates down). Livestock numbers were surveyed by walking each transect five times during the study. All animals distinguished up to 100 m from the transect line were identified and counted. Surveys were done from 9 am to 3 pm by a single observer (J. Hazenbosch) during the period when farm animals were actively foraging. Sex (f/m/unknown), age class (young/adult), perpendicular distance from transect and GPS coordinates of the waypoint on the transect were recorded. The latter was done using a Garmin GPSmap 78 with an average accuracy of 3±1 meters. Perpendicular distance to the transect was estimated with the help of a Leica Rangemaster CRF 1000-R. GPS data was first transferred and controlled on irregularities in BaseCamp V4.2.5.0 (Garmin 2014) and thereafter transferred to ArcGIS V10.1 (ArcGIS 2014), by use of ArcGIS extension Data Interoperability, for analysis.

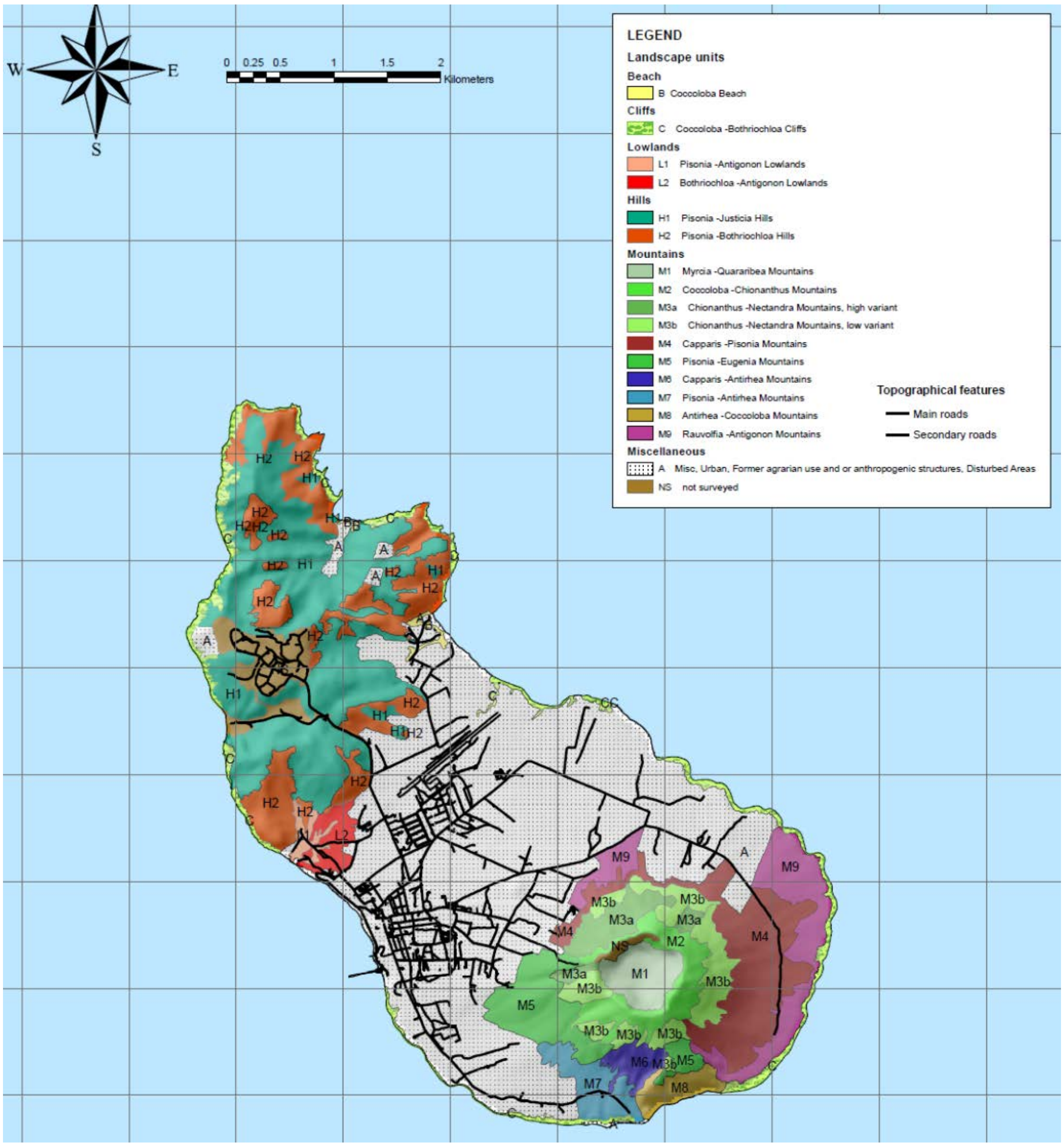

Fig 2. Vegetation map for St. Eustatius. From: Freitas et al. (2014).

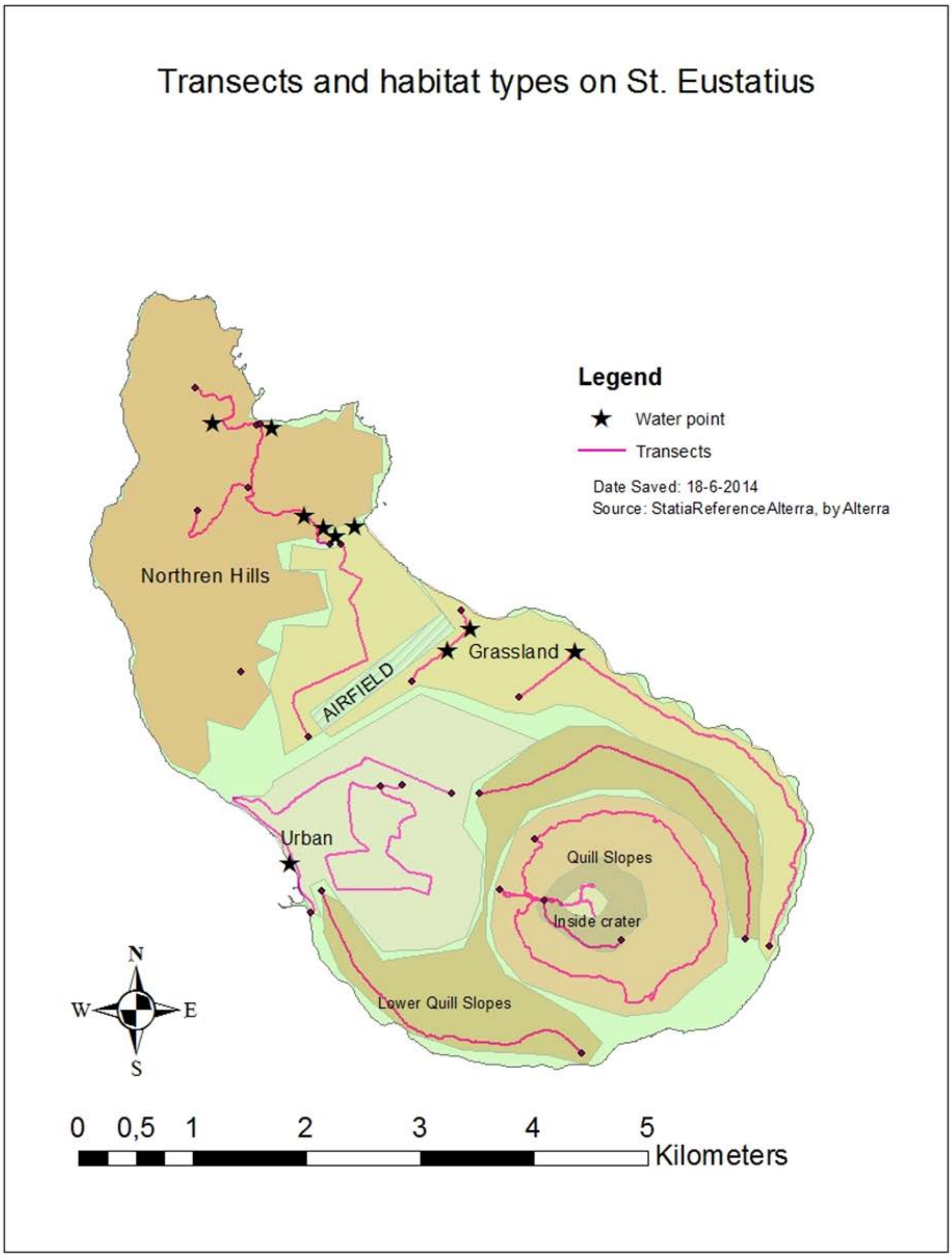

Fig. 3. Map of St. Eustatius showing the locations of the 13 transects used for surveying livestock. Known Watering points used by livestock shown as well.

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

Overall sampling	Upper Quill ***	Lower Quill Slopes	Grasslands	Urban Areas	Northern Hills	Inside Quill Crater	All Habitats
Sector surface area (km2)	2.78	3.23	3.66	3.35	5.95	0.08	19.14
# transects	2	2	3	2	3	1	13
# replicate surveys	5, 3	5	5	5	5	3	3-5
Combined transect lenth (m)	6100	6520	7705	7580	3994	1567	33466
Total Survey Effort (m)	32861	32600	38525	37900	19970	4701	166557
Mean cattle count	0	3.5	65.3	3.9	1.4	0.0	74.1
Mean goat count	8.6	14	32.9	14.8	6.1	0.6	77
Mean sheep count	0	0	186.8	2.5	0	0	189.3
Mean donkey count	0	0	5.6	0	0	0	5.6
Mean swine count	0	1.2	0.4	0	0	0	1.6
Mean chicken count	5.1	13.3	7.4	53	0.9	2.8	82.5

Even though farm animals were observed under a variety of conditions that made it difficult to determine age or sex (obscured by distance and brush, or fleeing), we recorded all observations possible regarding the age or sex status of the animals seen, so as to give a rough baseline for assessing population productivity features. We also collected extensive quadrat data on the nature of the vegetation along the transect and estimated such parameters such as vegetation composition and cover, dung densities, leaf litter densities, and percent herbivore damage to the vegetation. The vegetation results will be presented separately elsewhere.

Data analysis

To model density distribution curves, we used Distance 6.2 software package. In this method distances of objects to a line or point are recorded and from which density and abundance are estimated. Use of this method implies several assumptions about the quality of the data collected. The robustness of the method to violation of assumptions differs between assumptions but the many recent advances in the method and software allows partial relaxation of several assumptions (Thomas et al. 2010).

The key assumptions are:

- 1) objects on the line or point are detected with certainty. This certainly was not the case and causes detections to be biased to the low side;
- 2) objects do not move. Responsive movement before detection is problematic (implications of the violation of this assumption are discussed in Fewster et al. 2008). This was particularly problematic in the case of goats and chickens (as pointed out above), both which tend to flee upon hearing humans approach and which would cause detections to be biased to the low side;
- 3) locations of animals are independent of the position of lines/transects. Animals are differently influenced by the position and presence of trails, and this is fair to be seen from our results in which different species clearly responded differently to the presence of trails. Concentration on trails (as especially in the case of cattle) and near waterholes or avoidance of trails will clearly give unreliable extrapolation to a larger area. This assumption can almost only be met when locations are randomly chosen. Yet we did not randomly chose our transects. Due to the thick brush in most areas, the use of random locations would have made it impractical to reach most locations and also impossible to reach them quietly without spooking goats or chickens.

In Distance (Buckland et al. 2001) the four options for the key function were uniform, half-normal, hazard rate and negative exponential. The three options for the series expansion were cosine, simple polynomial and hermite polynomial. The options were studied for each livestock species as well as the possible need for truncation. The fitting criterium used was AIC (akaike information criterium). Based on this a best fit curve was determined for each species. The curves selected have been plotted together with their data in Figure 4, while other curve details are provided in Appendix 1. For goats and chickens we used individually fit curves for a number of habitats in which 60 – 80 or more observations were attained (Buckland et al. 2001). There was a clear distinction between on the one hand goats and chickens and other hand cattle and sheep with respect to the need for truncation. In contrast to the first two species, which are small and well-dispersed in the vegetation, the latter two species tended to be preferentially concentrated on or near trails.

All options for analysis of our dataset have not been exhausted. It would certainly seem possible to use the DSM analysis engine in conjunction with dividing transect lines into segment counts with covariates (habitat type, altitude, distance to water, land use, etc.) to yield a density surface model and predictions over a grid. Shorter lines yield more precise estimates of encounter rate variance (Thomas et al. 2010) and chopping our current long transects into shorter components could as yet improve precision.

For each species, population densities in different habitat zones were statistically compared using each conducted survey as an individual estimate for each transect. Individual counts were divided by the density-curve modelled effective transect width for each transect to give a density index. These were 4^{th} root transformed and compared between habitats by means of a 1-way ANOVA. Multiple comparisons were then done using the Tukey test to distinguish habitats differing significantly in mean density index.

4. Results

Density and distribution

Table 2 shows the density and population size estimates for all farm animals encountered on St. Eustatius. There may also have been a few domestic ducks and Guinea-hens but these were only found in the urban zone and were not assessed. For all species the halfnormal density curve was selected along with cosine expansion (Fig. 4). Whereas data for chickens and goats were right-truncated due to declining detection with distance (50 and 90 m, respectively), for cattle and sheep, fitting required left-truncation (5 and 2 m, respectively) as these two species showed evident concentration along trails and roads. For all species tested (cattle, goats, sheep and chickens) one-way ANOVA tests indicated significant habitat differences in density ($F > 6.8$; df: 5.55; $P < 0.001$), making further multiple pairwise comparisons between habitats by means of Tukey's test meaningful.

Table 2. Population density and size estimates (mean ± 1 SE) for the different livestock species in the different sectors of St. Eustatius. Significant multiple comparisons (p < 0.05) are indicated by a difference in letters.

Sector	Upper Quill slopes		Lower Quill Slopes		Grasslands		Urban Areas		Northern Hills		Inside Quill Crater		Investigated Area*	
Surface(km2)	2.78		3.23		3.66		3.35		5.95		0.08		19.14	
Species	Density	Pop. size	Density	Pop. size	Density	Pop. size	Density	Pop. size	Density	Pop. size	Density	Pop. size	Density	Pop. size
Cattle	0, a	0	N/A, a	N/A	276 ± 125, b	1012 ± 458	N/A, a	N/A	N/A, a	N/A	0, a	0	53 ± 24	1012 ± 458
Goats**	109 ± 27	303 ± 75	109 ± 27	352 ± 87	253 ± 140, a	928 ± 513	68 ± 79, b	230 ± 265	109 ± 27	648 ± 161	109 ± 27	9 ± 2	130 ± 42	2470 ±807
Sheep	0, a	0	N/A, a	N/A	356 ± 290, b	1303 ± 1060	16 ± 20, a	56 ± 67	0, a	0	0, a	0	68 ± 52	1300 ± 992
Donkeys	0	0	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	NApp	<90
Swine	0	0	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	NApp	<100
Chickens	55 ± 14, ac	154 ± 40	123 ± 60, ac	399 ± 194	72 ± 56, c	265 ± 207	278 ± 93, a	935 ± 314	24 ± 18, b	147 ± 110	305 ± 144, ac	27 ± 12	117 ± 35	2248 ± 668

N/A: actually seen or probably occur but too few to allow density curve estimation
Napp: not applicable as most donkeys and swine are currently simply held enclosed.
* Analysed separately as a whole
** goat densities based on 3 habitat-specific density curves

Water sources

Of the large grazing livestock species only the goat is known in exceptional cases to be able to survive on seawater (Burke 1990). Therefore, availability of water sources is a key determinant of livestock productivity and distribution (Bailey et al. 1996). Of the many types of natural or historical fresh water sources often found on Caribbean islands (Debrot, 2004a,b,c) Statia has only few. There are no streams, springs or karst waters. Due to the thick layer of highly permeable volcanic deposits, in most parts of the islands wells have to be dug very deep (30 and more m) to reach meaningful groundwater. Therefore, most historical well are close to the beach and near sea level (e.g King's Well). Even so, there are a variety of freshwater sources on Statia, ranging from seasonal puddles, and permanent natural ponds to wells specially built for horticulture but today used principally for watering livestock (Fig. 5). Many of these water sources have been mapped and appear concentrated in the central to northern sections of the island. We suggest that this is an important additional factor influencing the observed livestock distributions.

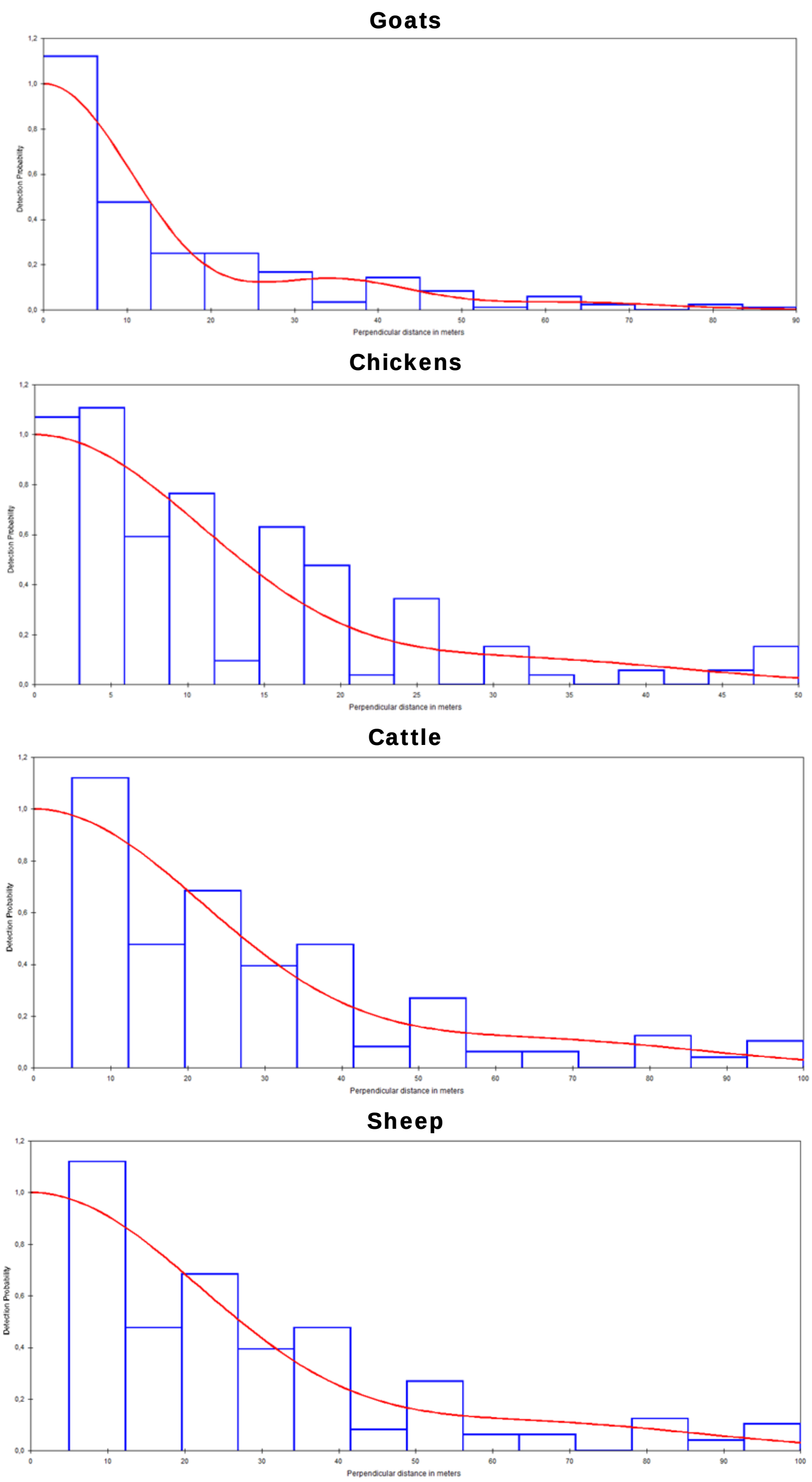

Fig. 4. Combined density curves for all livestock species for which sufficient counts were obtained for fitting purposes.

Fig. 5. Different freshwater sources on St. Eustatius as presently used by livestock: a) temporary rock pool in a road cut towards Venus Bay, b) the only semi-natural "Indian well" of the island, behind the beach at Venus Bay, c) goat using opportunistic domestic water source in Oranjestad.

Cattle (*Bos t. taurus* and *B. t. indicus*)

The cattle of St. Eustatius are a mix of breeds (incl. St. Croix Senepol, Holstein dairy cattle, Zebu and Jamaica Black) but the influence of the Red Poll breed appears dominant (R. Hensen, pers. comm.) This is a dual-purpose breed developed in England in the 19th century. During surveys, cattle was never encountered in steep areas of the higher Quill slopes and were mainly concentrated in the grasslands habitat of the central plains of the island (Fig. 5). Consequently, densities there differed significantly from densities in all other habitats (Table 2). For the lower Quill slopes towards White Wall, no cattle were ever seen during the 5 surveys conducted along the 3 km of transect, and from personal information provided by inhabitants they also did not occur there.

This is maybe not surprizing as the White Wall area is not only relatively isolated from the cattle's habitat of preference (Grasslands) but is also relatively far removed from the main wells and watering points currently in use (Fig. 3). Small numbers of animals were detected in the urban environment and the lower Quill slopes of the Botanical Garden road but in both these zones the animals were fully confined to the roads and roadsides. When the necessary truncation was done on the data the effect was that the density method could not be validly used for these habitat areas. Therefore, we used minimum estimates for both these areas based on maximum number of animals seen. Total animal counts for these areas are ± 45 heads of cattle for the lower Quill slopes of the Botanical Garden transect and ± roughly 12 animals straying the urban zone at any given time (mean: 4 animals detected per 4 km of road covering about 1/3d of the urban zone.

Fig. 6. Cattle and goats grazing on the invasive Indian couch grass, *Botriochloa pertusa*, on the coastal bluffs of Concordia.

As cattle are large animals and clearly dependent on manmade trails (Fig. 4c) for their movement through the terrain, population size estimates for cattle extrapolated using the Distance approach were found to lead to an excessively high mean population estimate (1012 ± 458), due to the violation of assumptions. Our best estimate, based on casual tag-registry and resighting rates and thanks to counts by LVV, is 600 animals, which does fall within 1 SE of the estimate from Density estimation. Of the 1039 cattle observed, 63% could be reliably sexed. The M:F sex ratio was 0.31 and the ratio of immature (< 1 yr) to adult cattle was 0.52.

Goats (*Capra hircus*)

The goats of St. Eustatius are largely creole goats interbred with imported Boer and Anglo-Nubian races many of which were imported from breeding stock in Curacao (A.O.Debrot, pers. obs). Goats were found in all habitat zones studied and showed high densities in wooded areas of steep terrain such as the Northern Hills and at the foot of the Quill. Goats are behaviourally known to be attracted to steep terrain and can therefore play an important negative role in erosion prone cliff areas such as on St. Eustatius (Fig. 7). Densities were highest in the grassland habitat and wooded areas of the Northern Hills and the Quill. These habitats contrasted significantly in terms of goat density with several other habitats (Table 2).

Fig. 7. Goat hooves and grazing contribute importantly to erosion on the unstable cliffs of Lower Town, St. Eustatius, and these animals often set off small avalanches.

Nevertheless, at the time of our survey, food availability for grazers in the wooded areas was low. Possibly due to this reason the goats were more than normally abundant in the lowland grassy areas. Using a combined density curve for all habitats, the population estimate for roaming goats was 2956. However, habitats were split into three principal categories according to vegetation density (woodland, grassland and urban habitat), and the difference in detectability between habitats became apparent

(Fig. 8). The Effective Strip Width (ESW) for sampling was highest in urban habitat (37 m) but varied between an average of 14 and 28 m in natural habitats (Lower Quill Slopes and Grasslands habitat). Using the more-detailed detection curves the corrected goat count for the island is 2470, which is appreciably lower than the estimate based on the global density curve (2956, Table 2). We therefore, choose the population estimate (± 1 SE) of 2470 ± 807 as the likely best goat population size estimate for the whole island. Our estimates for goat density per km^2 and combined population size for the wooded habitats of the Northern Hills and the Quill where the terrestrial national parks are established are as follows: density/km^2 = 109 ± 27; total population size for these habitats combined (n) = (1323 ± 329).

Of the 918 goats observed, 37% could be reliably sexed. The M:F sex ratio was 0.29 and the ratio of immature (< 1 yr) to adult goats was 0.34. The skewed sex ratio undoubtedly results from the selective culling of males during goat harvest. This means that the productive potential of such a population is much higher than to be expected in unharvest feral populations.

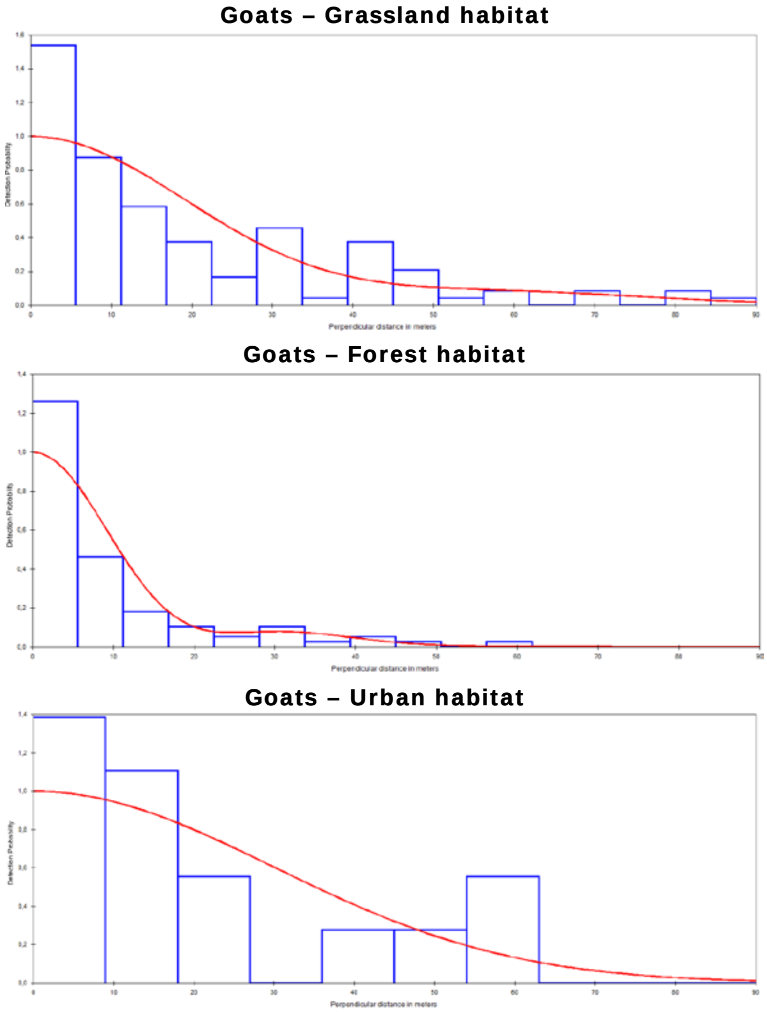

Fig. 8. Split density curves for goats in the three contrasting habitats in which they were encountered in large numbers.

Fig. 9. The largest group of sheep of St. Eustatius: English Quarter.

Sheep (*Ovis aries*)
The sheep of St. Eustatius are a mix but Barbados Black-belly blood dominates (Fig. 9). From our surveys it became evident that sheep absolutely avoid steep or excessively vegetated terrain None were ever observed in the steeper Quill slopes or in the Northern Hills (Table 2). Sheep were principally concentrated in the grassland areas of the central plain. Densities there differed significantly to densities in all other habitats (Table 2). However, our estimate for sheep numbers is only crude (1300 ± 992) and only indicates a minimum count for the island of about 300 sheep. The largest group of sheep observed (300+) was consistently found on the east side of the island in the English Quarter area (Fig. 9). Of the 1893 sheep observed during the multiple surveys, only 16% could be reliably sexed, making sheep the hardest species to sex at distance. The M:F sex ratio was 0.19 and the ratio of immature to adult sheep was 0.21.

Donkeys (*Equus asinus*)
In the last 3 years the Agriculture department has made a major effort to round up the donkeys on the island. At present there are two people who have a small number of donkeys on their own property (Laurence Duiveman: 21 donkeys and Ishmael Berkel: 1 donkey) and LVV who has enclosed the majority of formerly feral donkeys in a large enclosure (n = 53). At present there still may be at most 6-10 feral donkeys roaming loose (pers. obs. S. Piontek). Based on these results we estimate the total island donkey population at 90 donkeys or less.

Swine (*Sus scrofa*)
Mainly large white landrace swine were seen. Swine were encountered in low numbers loose in the vicinity of the urban landfill and in English Quarter along the road to the Botanical garden. Numbers were too low to allow density estimation but what can be said is that swine were not encountered at all in steep or rugged habitat zones (Table 2). We estimate a maximum of about fifty swine loose and about 50 swine kept in pens and distributed among about 5 small farmers. This yields a maximum current estimate for the whole island at 100 swine.

Chickens (*Gallus gallus domesticus*)

Chickens were ubiquitous on St. Eustatius but the two habitats with the highest densities were urban habitat the lower Quill slopes and the moist and protected Quill crater floor. Lowest chicken densities were observed in the Northern Hills area far from human habitation and the densities recorded there were significantly lower than most other habitats (Table 2). The ESW for chickens varied between 7 m in the Quill Crater and 20 m in Grassland habitat. The island estimate for chicken population size was 2248 ± 668 animals. As in the case of goats, the large number of sightings allowed calculation of separate density curves for the three principal habitat categories (woodland, grassland and urban habitat). However, in contrast to the case with goats an insufficient difference in detectability between habitats was found to greatly affect population density and size estimates (Fig. 10). Using the more-detailed detection curves the corrected feral chicken count for the island was 2234, which was not appreciably different from that using the combined global detection-curve for chickens (2348, Table 2).

Of the 747 chickens observed, 81% could be reliably sexed. The overall M:F sex ratio was 0.56 and the ratio of immature to adult plumage chickens was 0.15. There appeared to be a disparity in sex ratio in urban (0.52) and natural habitats (0.64). We suggest that this may reflect the tendency of people to favour female chickens around the house as a possible source of eggs or the possibility that excess young males are relegated to tougher or suboptimal habitat where females are less abundant. However, the difference in sex ratio was not statistically significant (X^2 = 1.38, df = 1, P > 0.05).

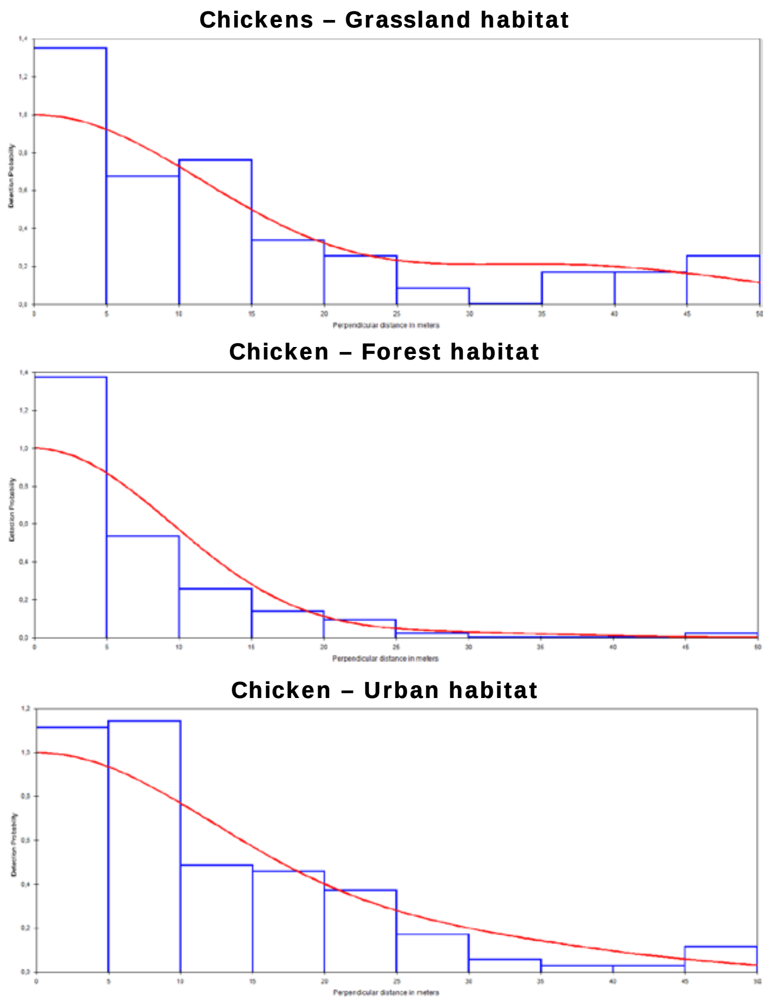

Fig. 10. Split density curves for chickens in the three contrasting habitats in which they were encountered in large numbers.

5. Discussion

In this study we provide a snapshot assessment of roaming feral farm animals on St. Eustatius during the end of the year 2013. All of these animals, possibly excluding chickens, can move long distances on a daily basis to find forage and water. Therefore, while this study shows some distributional patterns in livestock density between habitat zones, we expect actual distribution of livestock may possibly vary seasonally depending on rainfall and on how preferred vegetation is more intensively grazed and more rapidly depleted. In 2011 DLG made preliminary, expert-based, qualitative, livestock population estimates for St. Eustatius, as follows: cattle: ± 1700; goats: 1000-2000; sheep: ± 1000; donkeys ± 150; swine: unknown, chickens: unknown. Our island population estimates for the various species differ with these values and were as follows; cattle: 1012 ± 468; goats: 2470 ± 807; sheep: 1300 ± 992; donkeys: 50-75; swine < 100; chickens: 2248 ± 668. A comparison of estimates suggest that cattle and donkeys might have decreased in abundance in recent years in response to government control programs, that goat abundance may have increased and that sheep abundance likely has remained stable.

Our use of the existing trail system clearly biased our density estimation for cattle. This was much less so for chickens and goats but it must be kept in mind that our estimates should still be expected to be on the high side as when compared to using a grid of purely random transects. The nevertheless remaining bias of goats for trails (and which required truncation for analysis) certainly does not reflect attraction to the observer but likely reflect the goats' inherent tendency to use trails. We did not choose to use randomly positioned transects for two reasons. Due to the inaccessibility of many areas, reaching random locations through thick brush would not be possible without scaring away the livestock to be censussed (which would bias estimates down). A second reason for choosing the use of existing trail grid was for repeatability. Repeatability using a density index is more important for monitoring change than exact estimation. Habitat-specific detection curves were only of added-value in population density and size estimation for goats.

Notwithstanding our use of prescribed sampling methods, our dividing the landscape into semi-homogeneous sampling sectors, and our considerable sampling effort (33.4 km of trails) and replication (surveyed 5 times!), error margins for our estimates remain high. As more sampling effort will yield diminishing precision results, we can therefore not simply recommend more extensive sampling than we have already conducted. Management will likely need to accept the fact that estimating and monitoring feral livestock in diverse, accentuated and wooded landscapes will remain difficult and imprecise.
Most of St. Eustatius lies at elevations considerably lower than 400 m ASL and can be characterized as semi-arid tropical savannah landscape (Freitas et al. 2014). Worldwide such systems have been found to be very sensitive to overgrazing (Skarpe 1991). Removal of vegetation cover in semi-arid savannah systems leads to a rapid loss of organic contents in soils and in areas of severe and longstanding overgrazing, recovery of soils and vegetation may be very difficult due to the negative feedback cycles that get established (Albaladejo et al. 1998). In saline areas of Thailand Nemoto (1991) describes how overgrazing leads to soil salinification in the dry season and increased erosion during the rainy season. In the Dutch Caribbean livestock grazing promotes the growth of selected species, including several invasive and cosmopolitan weed species (Debrot and de Freitas 1993). A big problem is that in areas affected by overgrazing it is generally very difficult for the local inhabitants to understand the causal relationship between overgrazing and problems such as aridity, erosion and reduced soil fertility (Skarpe 1991).

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 Curacao 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.).

Tropical Livestock Units (TLUs) are a common way of comparing a wide range of different livestock types and sizes in a standardized manner (FAO 1999). The standard used in TLUs is once cattle of 250 kg. Metabolic exchange ratios show, for instance, that 5 goats or sheep of 30 kg will consume as much as one cow of 250 kg (FAO 1999). If we assume each head of cattle to be equivalent in terms of grazing pressure to 6 goats, and we combine all large herbivore counts, current combined amount to roughly 6 goats/sheep per hectare, but most grazing pressure is concentrated in the central plains Grasslands sector. While ecological damage due to overgrazing in this highly disturbed sector is debatable, for the rest of the 26% of the island surface designated as nature parks and conservation areas (McRae and Esteban 2009), clearly, current roaming livestock densities far exceed the ecological carrying capacity for island ecosystems. Median goat densities on the Lower Quill Slopes, Upper Quill Slopes and Northern Hills (more than 1 goat per ha which exceeds densities known elsewhere to cause unsustainable damage. The high density of goats in the more moist forest habitat which possesses some of the rarest and most vulnerable vegetation types of the island is worrisome (Freitas et al. 2014). Rare plant species for St. Eustatius include two endemics which are *Ipomoea sphenophylla* (Bush and Madden 2012) and *Gonolobus aloiensis* (Krings and Axelrod 2013), both of which have a very limited distribution on the island, as well as a long list of rare ground-growing orchids (Stenapa 2008).

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 current female-biased sex ratio, for St. Eustatius, goat population doubling time may be as short as 1-1.5 years. As a consequence, to effect population decline, 40-50% of the goat population might need to be culled annually to actually reduce the goat population measurably. Therefore, monitoring removal rates are important for assessing progress. This requires complete and accurate records of animals harvested from the population. However, the slaughterhouse records are poorly available and furthermore in reality only a small portion of animals is slaughtered in the slaughterhouse (DLG 2011). Most are slaughtered at home or “under a tree”.

The common chicken, or jungle fowl can have profound impacts on the flora and fauna of islands (Engbring 1983). The jungle fowl will prey on seeds, seedlings, endemic invertebrates and small reptiles(Collias and Collias 1967, Arshad et al. 2000). The consequences of this abundant and widespread introduced species on island floras and faunas in the Caribbean should be studied. This species is currently especially abundant at the bottom of the Quill crater. While eradication is probably impossible on the short-term, control is fully feasible and should be able to be accomplished easily by shooting and trapping. One incentive might be to market the trapped or shot chicken at a premium price as “Statia biological chicken”.

6. Conclusions and recommendations

There are many clear indicators of the deleterious impacts of grazing livestock on the flora, vegetation and erosional processes in St. Eustatius. Not surprisingly, this study also documents high grazing livestock densities for St. Eustatius. Based on comparative studies from arid ecosystems elsewhere, current livestock densities well-exceed the ecological carrying capacity of the semi-arid vegetation of the island. The need to continue with and expand the culling of feral livestock is indicated.

In this, goats are particularly problematic due to their habit of preferring steep terrain and cliffs which are more vulnerable to erosion and which will generally harbour higher densities of rare species due to micro-habitat availability (e.g. Sylvester et al. 2014). Goats are the most widely distributed and abundant ungulate grazer of St. Eustatius. Culling of goats is therefore of the highest priority.

The average counts we obtained for each species of livestock for the trails used (Table 1) can be used as a baseline index of abundance without any need for further calculation. Counts of cattle by LVV along the same network of trails show that over the last year cattle abundance has not appreciably declined, notwithstanding the ongoing removal efforts. Therefore, cattle will need to be removed at a higher rate and for a longer period than achieved to date to effect an actual population decline. On a longer time frame with 2011 as a reference point the results suggest that cattle populations might have indeed declined over the last 4 years. However, culling alone will not yield sustainable results if alternative husbandry practices (ie fencing, rotation-cropping etc) are not also successfully introduced as people will be tempted to revert to their old, extensive-husbandry ways if no viable alternatives are provided.

Feral chicken densities are estimated for the first time for different areas of St. Eustatius. The high density of these animals in protected areas of St. Eustatius are likely to be of deleterious effect on the flora and fauna of these protected areas.

Our main recommendations are:

- In order to stop habitat degradation higher removal rates are needed for all feral livestock. The culling of goats and chickens from the most ecologically vulnerable higher terrain around the Quill and the Northern Hills is particularly urgent.
- The probable current selective culling of male goats should make way for the unselective culling of female goats as well.
- The removal programme needs to be better supported by scientific information (data registration and analysis, calculation of removal effort and costs needed to reduce the intrinsic rate of increase).
- Limiting access to fresh water is a powerful tool in the management of feral livestock density and distribution (e.g. Russell et al. 2011). Cutting off livestock access to the only permanent freshwater pond at Venus Bay (Fig. 5b) could greatly restrict livestock abundance in this protected park area.
- Livestock kept in the lower “pasture habitat” of the central plains should be fenced in and likely also culled to reduce population densities.
- The possibility of marketing the caught, shot or slaughtered animals as “biological” specialty meat and poultry from St. Eustatius may serve as a financial incentive to this end. “Organic meat” is a growing trend and opportunity for the region to which the animal breeds and husbandry systems are quite suitable (e.g. Grenada Govt. 2007).
- Viable economic alternatives have to be developed for the current goat keepers to facilitate an efficient removal programme.
- By using the same grid of trails for monitoring and the same methods, our survey counts (Table 1) can serve as a baseline for monitoring livestock population size for management purposes.

- Additional studies are particularly needed on the recovery potential of the native vegetation under livestock exclusion to help set target densities for all species.
- Studies are also needed on the ecological impacts of chicken predation and how this affects forest seedling plants, invertebrates and reptiles.

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Author contributions: Conceived, and designed the project: AOD. Conducted the fieldwork: JH, CK, SP. Analysed the data: JH, SP, AS, JB. Produced the graphs: JH. Provided images: AOD, JH. Coordinated the project: AOD. Wrote the report: AOD, JH, SP, JB.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division 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.

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Justification

Report C088/15
Project Number: 4308701037 and 4308701029

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

Approved: Ing. Dennis Lammertsma
Researcher, ALTERRA-Wageningen

Signature:

Date: 26 June 2015

Approved: Drs. Floris Groenedijk
Head, Section Maritiem

Signature:

Date: 26 June 2015

Appendix A.

Sampling effort for each habitat zone and density curve characteristics for all feral farm animals except donkeys and swine.							
Overall sampling	Upper Quill ***	Lower Quill Slopes	Grasslands	Urban Areas	Northern Hills	Inside Quill Crater	All Habitats
# transects	2	2	3	2	3	1	13
# replicate surveys	5, 3	5	5	5	5	3	3-5
Combined transect lenth (m)	6100	6520	7705	7580	3994	1567	33466
Total Survey Effort (m)	32861	32600	38525	37900	19970	4701	166557
Chickens							
Detection probability (p)	0.25 ± 0.03	0.26 ± 0.02	0.41 ± 0.06	0.4 ± 0.04	0.20 ± 0.09	0.14 ± 0.05	0.33 ± 0.02
ESW (w*p)	13 ± 1.4	13 ± 1.1	20 ± 3.2	20 ± 2.0	10 ± 4.7	7 ± 2.4	16 ± 0.8
Truncation L	-	-	-	-	-	-	0
Truncation R	-	-	-	-	-	-	50
Clusters observed	38	53	50	140	7	7	295
Analysed clusters (n)	38	53	48	139	7	7	292
Key Function	-	-	-	-	-	-	Halfnormal
Series expansion	-	-	-	-	-	-	Cosine
Goats							
Detection probability (p)	0.26 ± 0.03	0.15 ± 0.01	0.31 ± 0.02	0.41 ± 0.07	0.19 ± 0.03	N/A	0.19 ± 0.01
ESW	23 ± 3.0	14 ± 0.8	28 ± 2.0	37 ± 6.6	17 ± 3.0	N/A	17 ± 1.0
Key Function	-	-	-	-	-	-	Halfnormal
Series expansion	-	-	-	-	-	-	Cosine
Truncation L	-	-	-	-	-	-	0
Truncation R	-	-	-	-	-	-	90
Clusters observed	21	50	120	17	21	1	230
Analysed clusters (n)	21	48	119	15	20	0	223
Cattle							
Detection probability (p)	N/A	N/A	0.28 ± 0.02	N/A	N/A	N/A	0.28 ± 0.02
ESW (m)	N/A	N/A	28 ± 2.1	N/A	N/A	N/A	28 ± 2.1
Key Function	-	-	-	-	-	-	Halfnormal
Series expansion	-	-	-	-	-	-	Cosine
Truncation L	-	-	-	-	-	-	5*
Truncation R	-	-	-	-	-	-	0
Clusters observed	0	14	239	12	2	0	263
Analysed clusters (n)	0	0	158	0	0	0	158
Sheep							
Detection probability (p)	N/A	N/A	0.3 ± 0.03	0.2 ± 0.14	N/A	N/A	0.3 ± 0.03
ESW	N/A	N/A	30 ± 3.0	22 ± 14	N/A	N/A	30 ± 3.0
Truncation L	-	-	-	-	-	-	2
Truncation R	-	-	-	-	-	-	0
Clusters observed	0	0	105	5	0	0	110
Analysed clusters (n)	0	0	89	3	0	0	92
Key Function	-	-	-	-	-	-	Halfnormal
Series expansion	-	-	-	-	-	-	Cosine