Predation threats to the Red-billed Tropicbird breeding colony of Saba: focus on cats

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Summary

Feral domestic cats (*Felis catus*) are recognized as one of the most devastating alien predator species in the world and are a major threat to nesting colonies of the Red-billed Tropicbird (*Phaethon aethereus)*, on Saba island, Dutch Caribbean. Cats and rats are both known to impact nesting seabirds and hence are both potential threats to the tropicbird on Saba. However, whereas the tropicbird has coexisted with rats for centuries, cats have only recently become a problem (since about 2000). Several studies from the region suggest that the tropicbird may be less-vulnerable to rats but cats have been unequivocally implicated in the depredation of tropicbird nests on Saba (unpublished data, Michiel Boeken). In this study we collected baseline data on cat and rat distribution, and cat diet and health. We also conducted 83 questionnaire interviews with Saba residents to assess their views on cats, rats, tropicbirds and the acceptability of different management options.

Two methods were used to assess cat density distribution. We used baited camera traps (73 successful 2-night deployments divided among 4 habitat categories) as an index of relative density. We also used scat densities (collected from 15,474 meters of transect from eleven trails) from which to extrapolate and compare relative cat densities in different habitats. For the study of diet we collected and analysed a total of 94 cat scats and studied the intestinal contents of 13 sacrificed feral cats.

Both scat densities and camera trap recordings showed large and statistically significant differences in cat density on trails between habitat zones. Cat densities were lowest in the lush forest habitat found at higher elevations (mean: 4 cats/km^2) on the island and highest at lower coastal elevations. Densities were particularly high (mean: 286 cats/km^2) in the small area surrounding the island landfill where food, consisting of human refuse and garbage was abundant. These densities are for areas along hiking- and goat-trails. These are actively selected by cats. Therefore, densities along trails cannot be simply extrapolated to the rest of the island.

While at the landfill daily incineration of garbage takes place, un-incinerated garbage is left open overnight almost every day. This provides feral cats with an ample food source. Construction of a vermin-proof, concrete overnight storage pen could greatly reduce food availability to cats and rats. Dry woodland and coastal scrub trail habitat had intermediate cat densities (respectively, 107 and 166, cat/km^2). Rat density as documented using camera traps was highest in the forest habitat where food, water and shelter for rats was particularly abundant. Rat and cat density were markedly inversely related. Cats were concentrated at lower elevations and in more open areas where tropicbirds principally nest.

Diet analysis showed the feral cats on Saba are an opportunistic predator-scavenger consuming various categories of prey (mammals, birds, reptiles, and insects) as well as anthropogenic waste. Food composition of the feral cats of Saba differed significantly between habitats. Overall, rats were the most important food species of the cat, followed by reptiles and birds. However at the landfill where cat population densities were highest, birds and rats were strongly reduced in the diet, while garbage and reptiles were of greatly increased importance. Scats collected in the forest zone suggested a lower importance of rats in the diet of cats than at lower arid elevations. The cat scats collected in the urban environment had no prey species represented and were apparently all from well-fed house cats. The

opportunistic and flexible food habits documented for cats in this study allows them to easily switch to seasonally abundant prey (for instance during the seabird breeding seasons).

Preliminary veterinary assessments on cats removed from the landfill showed the animals to be in overall poor health. This suggest that releasing neutered cats back into the wild without any further supporting care may be much less humane than typically assumed. Based on these results and taking into account the welfare concerns of the tropicbirds preyed upon by cats, the Saba Foundation for Prevention of Cruelty to Animals (SFPCA) has decided to discontinue its practice of releasing neutered unwanted cats into the wild (Trap-Neuter-Release, or TNR).

Public views regarding cats, tropicbirds and management options as assessed using a simple questionnaire and 83 questionnaire returns were obtained. Around 30% of the participants owned cats of which only about 5% were not neutered. A significant majority of respondents (66%) believed feral cats on Saba are an environmental problem. In this there was no difference between natives and expat residents. Most (44%) believed that cats were principally a problem in being a threat to wildlife. Diseases and parasites was quoted as the second-most perceived problem with feral cats (30%). Feral cats and rats scored as the two most important perceived threats to the tropicbird (respectively, 65% and 70%). When asked “how many saved tropicbirds do you think justifies the death of one cat”, 38% of Sabans and 22% of expats did not answer the question. Of those that did answer, 36% of Sabans and 48% of expats, valued the life of a tropicbird more than that of a single cat. The remainder considered cats somewhat more important than one tropicbirds but only few (5% natives, 18% expats) considered feral cats more important than the combined sum of all their tropicbird prey. Between 70-80% of respondents thought registration, neutering and removal of cats from breeding colonies was a good idea. When asked if euthanization would be acceptable to them, a significant majority (80%) found it to be an acceptable method for use in cat control. Finally, 43% even thought that total eradication of all cats (domestic and feral) from the island would be a good idea. Of the participants upwards of 80% stated that rats were also an environmental problem and more measures to control rats are supported by 75% of those interviewed. Awareness and willingness of the Saban resident population towards measures against cats and rats are clearly high. This means that there exists a wide management scope to implement measures with which to address these problems.

For more than 15 years government rat control has used brodifacoum as the main rodenticide, but rats remain a widespread and unrelenting problem on Saba. This suggests that the rats might well have become partly resistant to this anticoagulant toxin and that the time has come to alternate to a different rodenticide. Alternating use of rodenticides is the internationally recommended practice for rat control. It is already being practiced on nearby St. Eustatius where rat problems are much less acute than on Saba (but where feral fruit trees are also less abundant and landfill practices are also less favourable to vermin).

Key management recommendations:

- Upgrade the 2004 Saba "**Island Ordinance on Identification and Registration of Livestock and Domestic Animals"** to prohibit the importation and keeping of unneutered cats.
- Capacitate the SFPCA to enforce the mandatory registration of domestic animals.
- Construct a vermin-proof concrete overnight pen at the Saba landfill (for secure storage of the garbage that might not be incinerated the same day).
- From now on euthanize all unwanted and uncared-for stray and feral nuisance cats.
- Judiciously use humane euthanization to address the acute overpopulation of cats in particularly sensitive areas (such as the mapped seabird colonies) as this is quite acceptable to Saban residents.
- Start use of a new alternative rodenticide, following the example from St. Eustatius.
- Management measures need to be accompanied by an (inter)active and effective communication plan to keep public support levels high.

Key recommendations for research:

- Investigate the role of rats as predators, not only with respect to seabirds but also in the forested zone where they are most abundant and may seriously impact native forest species.
- Assess the effect of cat removal on tropicbird breeding success and on rat population density, as well as the broader predator-prey relationships on the island.

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Contents

1 Introduction

Insular ecosystems often are relatively susceptible to invasive species (Reaser et al. 2007, Caut et al. 2008). Not only are island communities likely easier to be invaded by non-native species (Simberloff 1995, Sol 2000) but introduced species also have a high probability to develop and alter the natural ecosystems (Coblentz 1978, Mack, Simberloff et al. 2000). The occurrence of relatively few species on insular ecosystems results in empty niches in the system which can easily be occupied by intruders. In ecosystems where natural predators are absent, native animals are also generally inexperienced with anti-predator behaviours so they will also be relatively vulnerable to the advent of predators (Salo et al. 2007, Kovacs et al. 2012).

Feral cats (Felis domesticus L., 1758) can have devastating effects on island faunas and are responsible for extinctions and declines of many island species (Bonnaud et al. 2011, Nogales et al. 2004, Loss et al. 2013), particularly on islands where they have neither natural predators nor competitors (Courchamp and Sugihara 1999, Jones 1977, van Aarde 1980, Iverson 1978, Peck et al. 2008, Paltridge et al. 1997, Horsup and Evans 1993, Campbell et al. 2011).

On Saba island in the eastern Caribbean, cats are a major threat to the internationally important breeding colonies of Red-billed tropic birds (*Phaethon aethereus*), which represent about 13% of the global population and 40% of the Caribbean population (Lee and Walsh-McGehee 2000, Lee and Mackin 2009, Walsh-McGehee 2000). The tropicbird breeds scattered along all cliffs on the islands perimeter. Walsh-McGehee (2000) estimated the population size to number 750-1000 breeding pairs. Recent research suggests this estimate is likely conservative. Based on densities in two study plots and the birds' distribution an estimate of 1200-1500 pairs was obtained in the 2010-2012 breeding seasons (Michiel Boeken & Adrian Delnevo, pers. comm.).While very little research has so far been done on the species, the key threats to the species are the high level of predation by two introduced invasive predators, feral cats and rats. In recent years, research by DCNA and Dr. Adrian Delnevo has shown that breeding success has been brought back to zero (Delnevo, unpublished data) due to the combined effect of cats and rats that now are a critical menace to the future of these important breeding colonies. Basic knowledge and understanding of the effects of predators and ways to remediate these are needed for effective management.

Objectives

This project reports principal findings and conclusions from fieldwork conducted from September 2012 through January 2013, to address four objectives. Firstly, a study of feral cat scats was conducted to gain insight into the prey species of the cats as well as to provide a measure of cat population density in different habitats. Secondly, baited camera traps were deployed in different habitats to measure relative densities of cats and rats in different areas of the island. Thirdly, cats were trapped for removal and for preliminary veterinary analysis of cat health status. Fourthly, a survey was also conducted under various groups of inhabitants to assess the awareness level and willingness of the island population to cooperate with a range of control and eradication measures.

We here review the principal findings in light of recent advances in the science and management of invasive predator control as extensively available in the published literature. Based on this, key strategic management options and knowledge needs for both short-term and long-term solutions are identified and recommended.

Acknowledgments

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Study location

Saba is a small 13 km^2 island in the Caribbean. The island is situated at 17°36'59'N latitude and 63°15'09''W longitude and is part of the younger island arc in the Lesser Antilles also known as the inner curve. The island of Saba was formed by a currently dormant oceanic volcano which emerges from the sea surface up to 887 meter above sea level. The island arises from the sea floor at 600 m depth (Defant et al. 2001). As a typical of a volcano island, the topography of Saba is dominated by steep and mountainous gradients. Around the coastal areas the average slopes are more than 45^o and there are several steep cliffs. At the higher elevations, volcanic activities have influenced the shape of the mountainous landscapes. The highest peak is Mt. Scenery, altitude 887 meter above sea level (m) bounded by some other lower hills. Only small sections of the island have relatively flat terrains: The Bottom, Windward Side and St. Johns. These are mostly urbanized areas.

In spite of its small area of about 13 km^2, and thanks to its accentuated topography, Saba has many different vegetation communities. According to (Augustinus et al. 1985) vegetation of Saba is divided into several principal formations. Montane formation (elfin woodland and tree-fernbrake) and rainforest at the higher elevations followed by evergreen and seasonal formations in the middle altitudes. The bottom part of the island is dominated by croton thicket communities. Natural vegetation on Saba has been influenced by anthropogenic activities. Agriculture activities and livestock have become the major factors of vegetation alteration on Saba, particularly the original, virgin rainforest and the seasonal woodland have been transformed into secondary forest and shrubland (Westermann and Kiel 1961).

This study was conducted across different vegetation types and habitats. Four different habitats were defined: Rainforest, Dry woodland, Shrubland and Dump area. Existing trails in each habitat type were used as survey transects and served as entry points for the camera traps used for comparative density assessment (Fig. 1).

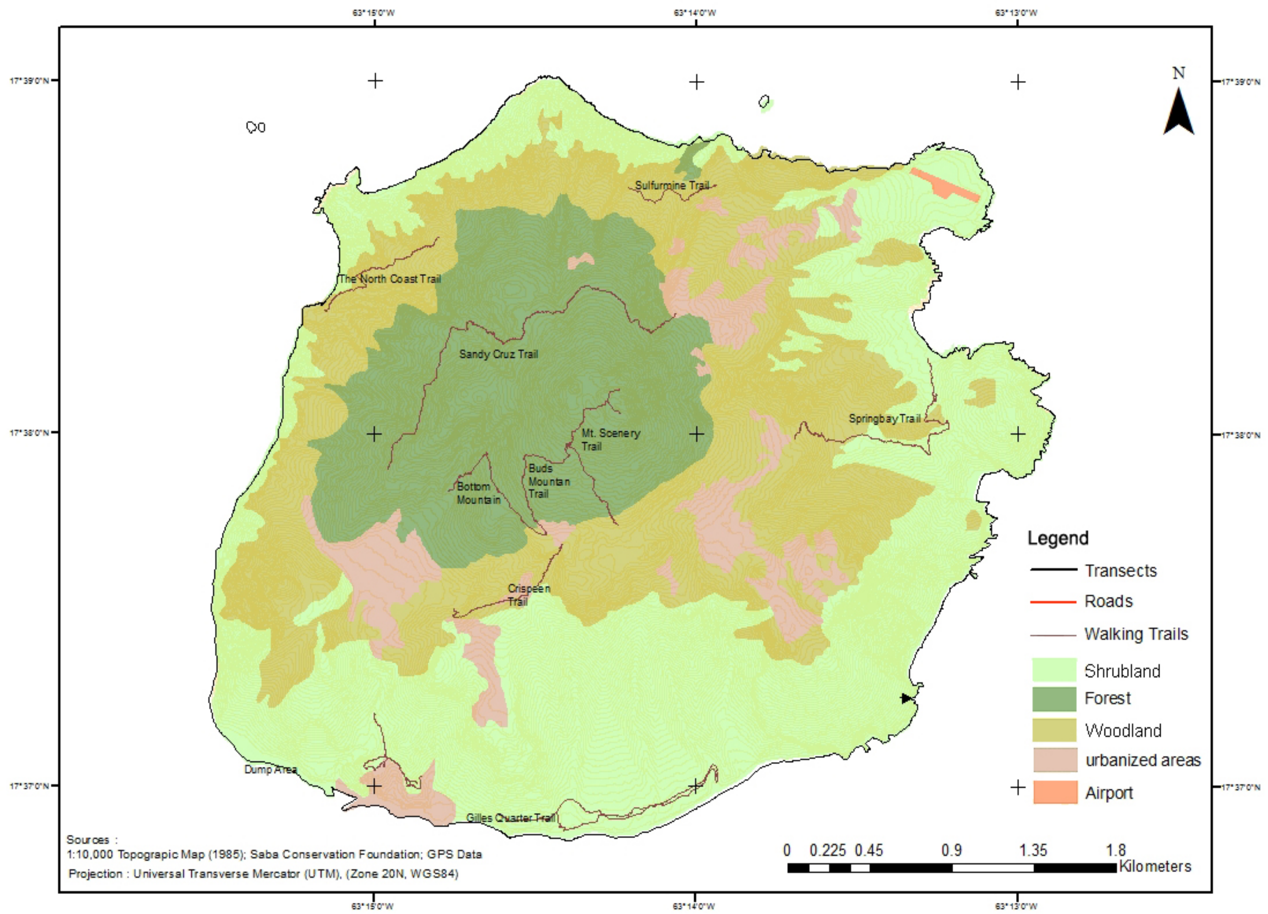

Figure 1. Map of Saba showing the principal trail areas used. (map by Saba Conservation Foundation).

Rainforest

Rainforest habitat consists of montane forest (elfin woodland and tree fern) and secondary rainforest (Fig. 2). Some typical montane forest vegetation are Palm brake (*Euterpe spp*); *Freziera undulata* and *Rapanea ferruginea* (Augustinus et al, 1985). In the lower elevations, secondary rainforest vegetation is found. Some prominent species in this area are *Hirtella triandra Psychotria undata, Chionanthus compactus, Cordia sulcata, Tabernaemontana citrifolia* and *Myrcia citrifolia*. Four rainforest trails were used for the surveys: Mt Scenery (550-850 m asl); Buds Mountain (500-710 m); Bottom Mountain (320-500 m) and Sandy Cruz (380-600 m). No distinction was made between the two rainforest types for the purposes of this study.

Figure 2. Wempy Endarwin on a rainforest trail on Mt. Scenery, Saba, during field data collection (Photo: A. Debrot).

Dry Woodland

Dry woodland habitat is located mainly in the middle elevations between the rainforest and the shrubland habitats. According to Augustinus et al. (1985) and Prins et al. (1985) this habitat derived from the evergreen forest and seasonal forest. Several prominent vegetation species in the dry woodland habitat are *Eugenia spp, Myrcia spp, Pithecellobium spp, Malpighia spp, Chicocca spp, Trema spp, Tabebuia spp* and some remains of former anthropogenic activities such as *Tamarindus, Delonix* and *Annona* (Augustinus et al.,1985; Prins et al., 1985). Four dry woodland trails were used for the surveys: The North Coast (30-280 m AMSL, height above mean sea level); Spring bay 1 and Paris Hill (220-350 m AMSL); Sulfur mine (220-350 m AMSL) and Crispeen trail (200-500 m AMSL).

Shrubland

In Augustinus et al. (1985) shrubland habitat (Fig. 3), named Croton thickets, was defined as shrubby vegetation of *Croton flavens*stands combined with other plant species e.g. *Lantana camara*, *L involucrata*, *Jatrophagossypifolia*, *Urechites lutes*, *Opuntia dillenii* and *O. triacantha*. Some scattered small tree species, *Capparis spp, Citharexylum spinosum and Bursera simaruba, Caseria decandra Pisonia subcordata,* cactus (Cephalocereus) and herbs are also commonly found within the shrubland habitat. Two transects were used in this habitat type: Giles Quarter (5-40 m),Spring Bay 2 and Paris Hill (10-220 m).

Figure 3. Open coastal shrublands on Saba (Photo: A. Debrot).

Dump area

The dump area is located in the southern part of the island close to the harbour area. This area is surrounded by shrubby vegetation and urban area. According to Hutchings (2003) the presence of rubbish dump in a particular area will provide a food source for the feral cats and consequently influence its density. Therefore, for the purpose of this study, the dump area is considered as a separate habitat. The dump area trail has a length of approximately 1500 m at an elevation of 60 to 110 m ASML.

2 Methods

2.1 Relative feral cat habitat-densities

Scat density counts

For this study the geographical characteristics of the island o.a. steep gradients and rocky terrains debilitated direct survey methods. Therefore an indirect survey method through scat counts was used to determine the relative density of the feral cats on Saba.. Scat densities are in any case at the minimum useful as an index of abundance. The values obtained here, can be compared to future values of scat surveys when conducted using the same methods to assess possible developments in cat population densities. Scat counts were carried out along the existing trails on the island.

Feral cats are known to utilize anthropogenic and wildlife trails for inter- and extra- territorial movement, defecation and hunting (Bonnaud, pers. comm.). Therefore these trails were used to obtain a higher probability to find cat scats. Two observers walked along the trails, whose width varied between two and four meters, and collected the cat scats manually. Different trail widths were applied due to different habitat conditions. In the rainforest and dry woodland areas, which are mostly located at higher elevations, paths are narrow while the grassland and dump areas at lower elevations have wider trails. Trail lengths also differed between areas, ranging from 680 to 3100 meters. Three times repeated surveys were applied for each transects with different interval days ranging from 6 to 26 days.

A total of 15,474 meters of transect from eleven trails were surveyed, divided into forest (6231 meters); woodland (3563 m); shrubland (4380 m) and dump area (1300 m). Detailed information on surveyed transects are provided in Table 1.

Table 1. Transect characteristics of the surveyed area.

Trail Name	Elevation (m)	Length (m)	width (m)
Forest			
Mt.Scenery	550-850	1290	2
Buds Mountain	500-710	928	2
Bottom Mountain	320-500	1088	2
Sandy Cruz	380-600	2925	2
Woodland			
Crispeen	260-480	925	2
The Northcoast	40-270	1088	2
Springbay 1	220-350	680	2
Sulfurmine	190-240	870	2
Shrubland			
Gillesquarter	10-40	3180	4
Springbay 2	10-220	1200	2
Dump area			
Dumptrail	60-110	1300	4

Data from scat or nest counts can be converted to estimate the animal density of a particular species. Two factors are essential to estimate the animal density based on the scat counts: the production (defecation) rate and the disappearance (decay) rate (Laing et al. 2003; Rivero et al. 2004). Animal density can be obtained by calculating the number of scats found per unit area in a given time interval, divided by the number of defecations produced by one individual during that time (Rivero et al. 2004). If the time interval is no longer than the decay period then estimating the decay rate is not needed (Laing et al. 2003).

The following formula was adopted from (Rivero et al. 2004) to estimate the cat density as:

$$D = \frac{\textbf{No. scats encountered per area}}{\textbf{No. of deposition days x daily defecation rate}}$$

According to Fitzgerald and Karl (1979), Howard (1957) and (Liberg, 1984) feral house cats are assumed to defecate once a day. The decay rate of the feral cats can vary across different habitats affected by environment factors (Lozano et al. 2003). A few studies suggest that the median persistence for a cat scat is 30 days (Sanchez et al. 2004; Peck et al. 2008). In this study the decay period is assumed to be at least 30 days, so for an interval day period less than 30 days the decay rate can be ignored.

As neither production or disappearance rates for scats were actually measured in this study but assumed from values published in the literature, our estimates of density should only be used for comparative purposes (ie. as an index of density and not as actual measures of density). An additional caveat is that the indicative density estimates only refer to densities in the preferred “trail habitat” and not to densities within the habitat categories proper.

Data collection

Field work was conducted on the island from 11 October 2012 to 6 January 2013 and continued in the laboratory from 21 January until 6 February 2013. Scat collection began on 17 October 2012, after a week of torrential rains from the hurricane Rafael. It can be assumed that all scats found during the surveys were produced within this period.

During the surveys, all cat scats were removed from the trails (Fig. 4). Trail and scat positions were tracked and recorded using a Garmin GPSMAP 78®. Scat counts were carried out at four different habitats based on the vegetation types: forest, woodland, shrubland and dump area. The dump area was categorized as one particular habitat type because this area has a relatively high cat density compared to other areas on the island because of the higher (anthropogenic) food availability. Scats of other animals were also found in the fields but feral cat scats were relatively easily identified based on length, width, shape, colour, prey contents and sites deposited. Sometimes iguana faeces and raptor pellets resembled that of cat scats, but they could be distinguished by analysing the contents. In particular, feral cat scats generally contained animal remains (bone fragments, feathers or reptile scales) and organic matters. A cat scat normally consists of several segments, thus all segments found in a particular location were counted as one sample unless they can precisely be distinguished as two different scats (i.e. old and new scats which have different appearance). To avoid overlap with domestic cats, scat counts were only conducted on trails away from inhabited areas. Nevertheless, we also collected scats from the villages of Windward side and The Bottom as a control to compare the diet compositions between the feral house cats and the domestic cats.

Figure 4. A fresh cat scat deposited along Crispeen trail, Saba (Photo: A. Debrot)

Baited camera traps for relative density estimation of cats and rats

In the four habitat categories studied we deployed camera traps with motion detectors at a minimum of 15 replicates for a period of two consecutive camera days each. A total of eleven Reconyx HC500 Hyperfire Semi-Covert IR® cameras were deployed between 20 November 2012 till 10 January 2013. The cameras were programmed to make a picture every 5 minutes and with the infra-red motion sensor trigger set to make 3 pictures in a row with a 1 second delay if movement was detected. To lure cats and rats, bait bags made of wire mesh (5mm) were baited with ±160gr of cut-up raw sardines. Cameras where placed ±100 cm away from bait bags and replicate locations were a minimum of 100 m apart. Bait, batteries and memory cards generally lasted at least 2 days. We counted the total number of different cats observed at each camera trap and used that as an index of cat abundance. Rats could not be individually recognized and required use of a different abundance index. Therefore the maximum number of rats seen simultaneously in one image was used as an index of rat abundance. Camera traps were rotated between habitats during the course of the study to reduce temporal side-effects and days with unusual weather were discounted to reduce potential weather effects from our habitat comparison. The results are based on a combined total of 140 camera nights (73 placements, 2 fails = 71. 71 x 2 = 142, minus two single days = 140 camera nights). Differences between habitats were tested for using a Chi-square Goodness of Fit test on combined counts of all camera traps.

2.2 Feral cat diets

Cat diets were studied through scat analysis and some additional stomach content analysis. Feral cat scats were collected from different habitats during the scat counts and some additional scats were obtained opportunistically. In addition to the feral cat scats, scats from domestic cats were obtained from urban areas to check for diet differences between the domestic and the feral cats. It should be noted that in the case of the urban scats, where prey was scarce in the scats (because household pets were fed commercial cat food at home), we cannot exclude the possibility that some scats of small dogs may have accidentally been included.

Scats collected from the field were placed in individual plastic bags with data on location, date and scat ID. Each individual scat was soaked in water for 1-2 days to segregate the contents. After that, scats were sieved using a 1 mm mesh test sieve and flushed with water to separate all distinguishable prey remains. All identifiable prey items from each scat were collected and stored in vials with 10% preservative fluid, (90% Propylene glycol and 10% Ethylphenylglycol ether).

For identification purposes, some reference materials such as lizards, birds and rodent were collected from the field. Reference materials were obtained from dead animals found during surveys. Only the skeleton (and feathers for birds) of the animals were used as a reference. Therefore, those dead animals were buried in the ground for several days after which the remaining bones where cleaned from left-over debris using boiling water and forceps. All reference materials were stored in 10 % preservative fluid. Identifications were carried out in the laboratory at Wageningen University. Individual prey items were compared with the reference materials and other identification guide sources.

Prey items were categorized as either; Mammals: rats (*Rattus spp*) and house mice (*Mus musculus*); Birds: Tropic bird (*Phaethon aethereus*) and unidentified birds; Reptiles: Anole Lizard (*Anolis sabanus*), Green iguana (*Iguana iguana*), Red-bellied racer snake (*Alsophis rufiventris*) and unidentified lizards; Insects; Garbage and/or “no identifiable contents” (e.g. often domestic village cats). The individual numbers of each prey item found in the scats were counted conservatively. For example, a pair of jaws found in a scat was calculated as one individual. Non-countable prey items (e.g. garbage) were registered as either present (1) or absent (0). Overall diet composition was analysed by percentage of occurrence. Frequency of occurrence was calculated as the number of scats containing a particular prey category expressed as percentage of all scats, following Nogales et al. 1988 and Paltridge et al. 1997:

$$\boldsymbol{Fi} = \frac{n_i}{\boldsymbol{N}} \times 100$$

$$Fi = Frequency\ of\ occurrence\ prey\ i$$

$$n_i = number\ of\ scats\ contained\ prey\ i$$

$$N = total\ number\ of\ scats$$

The feral cat is known as an opportunistic predator thus its diet is supposed to be influenced by the surrounding habitats. To test the habitat influence on diet compositions, a multivariate analysis using canonical correspondence analysis was performed. Diet compositions in each habitat type were analysed separately with a Goodness-of-Fit Test, by means of a Chi-square test. Statistical analysis was conducted by using IBM SPSS statistics 19 and Canoco 5.

2.3 Feral cat health

To prepare for a study on the effect of cat removal on tropic bird survival, the SCF removed thirteen cats by trapping them in baited box traps overnight from in and around the island garbage tip where cat concentrations were particularly high. Trapped cats were put down early the next morning with a single shot to the skull with a .22-caliber rifle by Saba Conservation Foundation park rangers. We used this opportunity to conduct preliminary gross external and internal visual post-mortem examinations at the veterinary station housed at the Agricultural Station of Saba. The necropsy examinations were based on guidelines by Israel Ministry of Agriculture and Rural Development (http://www.vetserveng.moag.gov.il/). Specimens were first examined externally for evidence of wounds, for coat colour and condition, external parasites, tooth condition and sex. Specimens were then weighed to the nearest gram on a calibrated electric balance (± 1 g) and measured (after rigor mortis) from the tip of the snout to the base of the tail (± 1 mm). The thoracic and abdominal cavities were then opened to examine all contents, first without disarranging the viscera to look for signs of hemorrage and lesions with emphasis on lungs and liver. The heart was externally inspected and dissected to examine for parasites (heartworm). The viscera of the abdominal cavity were all examined individually and then dissected for internal examination. Finally, the intestinal tracts from stomach to anus were opened and the ingesta was removed. A search was done for signs of hemorrage, normal and abnormal content and parasites. In course of the internal inspection the different fat deposits were logged e.g. subcutaneous, omentum majus, pubis and abdominal cavity. Voucher specimens of parasites were preserved on alcohol for preliminary identification (Novartis 2010).

2.4 Public views regarding cats, tropicbirds and management options

One of the most important factors contributing to the success or failure of implemention of nature management measures is the degree of public support and awareness (Bremner and Park 2007, Lloyd and Miller 2010). Therefore, prior to introducing any program for predator control it is necessary to measure public awareness and support. The information gathered provides a baseline of public sentiment and awareness, helps define the scope of management measures that can be used and helps identify any gaps in awareness that may need to be addressed through public awareness campaigns. Involvement of the local community in implementation and decision making also works beneficial for the success of the project (Phillip and MacMillan 2005).

Therefore, public views regarding cats, tropicbirds and management options were assessed using a simple questionnaire with twelve multiple choice questions (Appendix 1). We limited our questionnaire to legal-aged residents and did not query tourists or foreign students of the Saba medical school.

The specific goals were to:

- Obtain insight into the companion cat population of Saba
- Assess the attitudes of Saban residents towards feral cats and black rats
- Assess the awareness of Saban residents concerning the environmental impact of feral cats and black rats on Saba
- Obtain insight into public readiness on Saba for invasive predator control measures

A total of 83 questionnaires were completed, 34 by native Sabans, and 49 by expatriate residents. Initially we tried individually approaching people on the street. However, this was very laborious. Therefore, questionnaires were handed over to the heads of companies which then distributed questionnaires to their employees. This method proved more effective and provided 79 filled questionnaires. Results from the questionnaires basically came down to proportions of respondents choosing or rejecting certain propositions, and all results were expressed as percentages. Testing for differences in proportions was done using the Chi-square Goodness-of-Fit Test (e.g. Debrot and Nagelkerken 2000).

3 Results

3.1 Relative feral cat habitat-densities

Only scats from the second and third observations were included for cat density estimation to be able to count the deposition days of the survey. Repeated surveys of total 15,674 metres of transects were conducted and 56 scat were encountered within the fixed (2 and 4 meters) width transects during the surveys. The density value for each observation was obtained by counting the number of scats found in one particular transect divided by the area of the transect. The average density value from all observations in a particular habitat was counted as the cat density index for each habitat. Average densities were varied between habitats, ranging from the lowest at the forest habitat (3.631 km^{-2}) to the highest density at the dump area (285.88 km^{-2}) (Table 2).

Table 2. Feral cat relative* density estimation of different trail habitat types on Saba.

	Forest	Woodland	Shrubland	Dump area
Number of trails	4	4	2	1
total surveyed area (km^2)	0.025	0.014	0.030	0.012
day Intervals	9-26	6-22	5-9	7-8
total scats	2	11	18	25
cat density ($/km^2$)*	3.631	107.151	165.968	285.886

- **As deposition and disappearance rates were not separately calculated in this study and as habitat sampling was not random but done along trails, these densities can only be used as indicative. Actual habitat densities will likely be lower than the obtained estimates.**

3.2 Relative camera-trap density index

Table 3 provides an overview of the camera trap results. Both cat and rat densities differed greatly and significantly between habitats studied). Cat densities were highest near the island dump where an average of about 2 cats were seen at each trap per night. Moving up to habitats of higher elevations on the island average cat densities went way down. The exact opposite was observed in rats. Rat densities were highest in the forest habitat and lowest at lower elevations and in and around the island dump (Table 3).

Table 3. Number (N) of 2-day baited camera trap sessions and total number of cats and rats documented, in four different habitats on Saba.

Habitat	(N)	Total cats	Total rats
-	-	-	-
Dump	15	64	2
Scrubland	19	25	4
Drywoodl.	18	11	36
Forest	19	2	74
	X^2 (df = 3)	115.9	104.3
	P	(<< 0.01)	(<< 0.01)

3.3 Feral cat diet composition

A total of 94 scat groups from different habitats on the island and 11 additional stomach contents from the dump area were obtained for diet analysis. Natural food substances from animals and plants and artificial food from anthropogenic refuse were found in both cat scats and stomachs. However, plant material was excluded from the diet analysis as plants were only utilized by cats to help the ingestion process and not as a food source.

Based on the scat and stomach analysis, two species of mammals were found, rats (*Rattus spp*) and mice (probably *Mus musculus*). One bird species, the Red-billed tropicbird (*Phaethon aethereus*) and three species of reptiles, Saban Anole (*Anolis sabanus*), Red-belied racer (*Alsophis rufiventris*) and Iguana (*Iguana* spp) were identified. Remaining bird and reptile samples where pooled respectively as unidentifiable birds and unidentified reptiles. Some insects were also found in the cat scats, however only large insects, mostly from the order Orthoptera (Grasshoppers) and Blattodea (Cockroaches), were considered as cat preys. All non-natural food found in cat scats and intestines were categorized as garbage. Frequency of occurrence of each prey category can be seen in Table 4. There was a large difference in prey composition scats and stomachs. Insects, which are relatively perishable were found predominantly in stomachs but not in scats, whereas mammalian remains were more common in scats than in stomachs (Table 4).

Table 4. Frequencies of occurrence of each food item type based on scat (n=94) and stomach (n=11) analyses.

prey items	Scat analysis		Stomach analysis	
	no. scats	Frequency of occurrence (%)	no. stomachs	Frequency of occurrence (%)
Mus sp	4	4.3	0	0
Rattus spp	42	44.7	1	9.1
total mammals	**44**	**46.8**	**1**	**9.1**
Phaethon aethereus	4	4.3	0	0
Unidentified_bird	10	10.6	0	0
total birds	**14**	**14.9**	**0**	**0**
Anolis sabanus	25	26.6	5	45.4
Iguana spp	8	8.5	0	0
Alsophis rufiventris	1	1.1	0	0
Unidentified lizard	3	3.2	0	0
total reptiles	**37**	**39.4**	**5**	**45.4**
Insect	**11**	**11.7**	**7**	**63.6**
Garbage	**38**	**40.4**	**6**	**54.5**
No identifiable items	**3**	**3.2**	**2**	**18.2**

In general, feral cat diets consisted of natural prey (animals) and artificial (anthropogenic) food items. A distinction between natural and artificial (anthropogenic) prey was made to see the frequency of each natural prey category. A total of 111 natural prey items from four different categories (mammals; birds, reptiles and insects) was found in the 94 scat samples. The frequency of each prey category was expected to be different from each other and therefore tested for significant deviation from the null hypothesis of equal representation. The frequency of each prey category differed amongst each other, X^2 (df=3, n=111)= 36.28, p<0.001. Mammals and reptiles had higher frequencies while the frequencies of the birds and insects were significantly lower than expected assuming equal representation (Figure 5). This may be caused by differential availability of the different prey categories and/or different selection. Probably both factors contribute to the observed results.

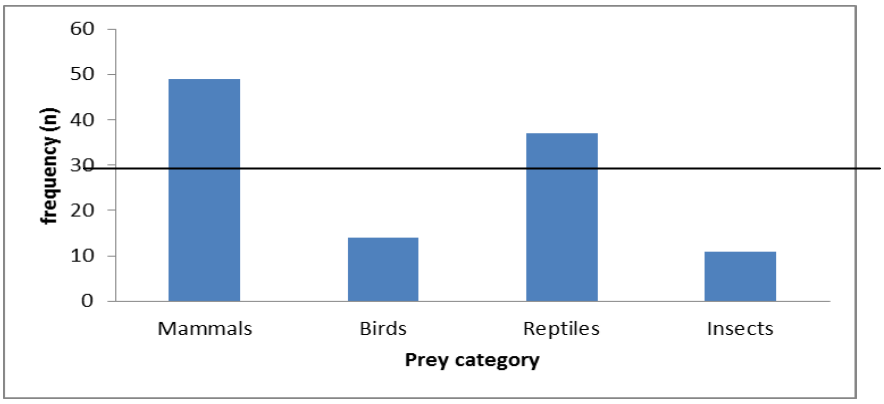

Figure 5. Four categories of the natural prey of the feral cats. The frequency of the mammals and reptiles are higher than the average frequency (horizontal line) while the birds and insects are lower.

A multivariate analysis showed the influence of the habitat types to the diet composition of the feral cats. Figure 6 shows a canonical correspondence analysis ordination of the habitats (forest, woodland, shrubland, urban and dump area) as the environmental factors with the prey species.

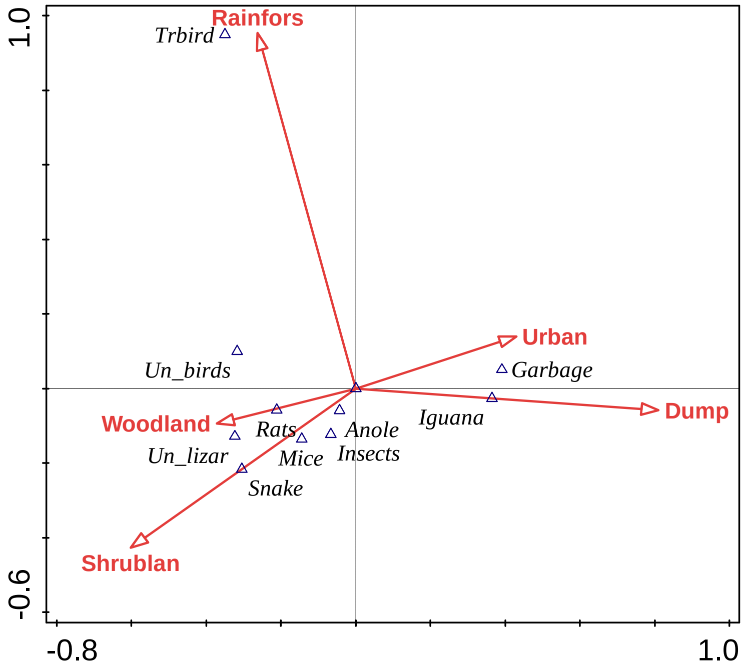

Figure 6. Canonical Correspondence Analysis (CCA) ordination analysis of the habitat factors (forest, woodland, shrubland, urban and dump area) with the prey species of the feral cats.

The eigenvalues of the first two axes (axis 1 and axis 2) are 0.28 and 0.11 respectively, explaining 39% of the total variance of the data. A significance test of all axes shows that the environmental factors (habitats) have a significant role to play in the ordination (F = 3.6, P = 0.002).

Cats at the urban and dump area had relatively similar diet compositions. Garbage was strongly related to these two habitats. At the opposite direction to the urban and dump area were the woodland and shrubland where prey species diversity appeared higher. Due to too small sample size, diet data from urban and forest had to be excluded from the analysis and only three main food categories (mammals; reptiles and garbage) from three different habitats: woodland, shrubland and dump area could be validly compared (between habitats) by means of a Chi-square test. The test showed that there was a statistically significant difference in diet compositions of feral cats between these three different habitats on Saba (X^2 =26.2, df=4, p=0.001). In this section we plotted scat prey composition for all habitats, including forest and urban habitats, even though low sample sizes for these two habitats precluded statistical comparisons.

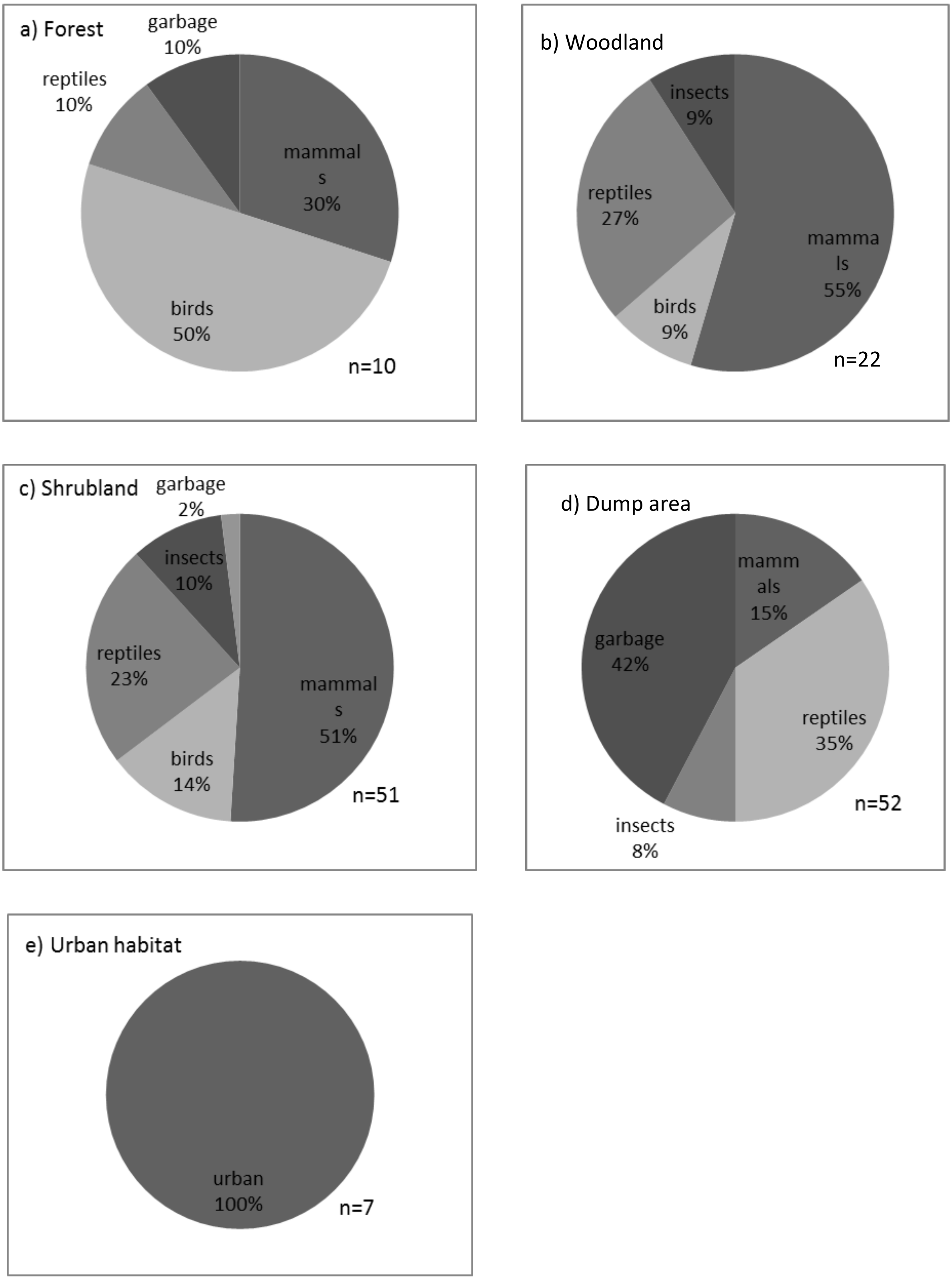

Figure 7. Diet composition of feral cats in five contrasting habitat situations.

Only 10 food items from 4 classes were found in the scats from the forest habitat where birds accounted for half of the observed food items (Fig. 7a). Twenty-two food items were found in the scats from the woodland habitats. Mammals and reptiles appeared to be the most frequent prey (Fig. 7b) but the small sample size precluded within-habitat statistical comparison. Fifty-one identifiable food items were found in the scats from the shrubland. Mammals and reptiles were two most frequent prey species encountered (Fig. 7c). A chi square test showed that the relative frequency of different prey category differed significantly from a null-hypothesis of equal representation of prey categories within this habitat (X^2 = 36.74, df=4, $p < 0.001$). Fifty-two identifiable food items were found in the scats from the dump area. Garbage and reptiles were the most abundant food items (Fig. 7d) and the overall relative frequency of different food categories differed significantly from a null-hypothesis of equal representation of prey categories (X^2= 16.30, df=3, $p < 0.001$). Finally, seven food items were found in scats from urban area, all of which were classified as urban garbage (Fig. 7e).

3.4 Feral cat health

Twelve of the 13 animals caught by SCF were female, one was male and only 2 of the 13 were juveniles (less than 1 year of age). Ten of the cats had been neutered. Mean length (snout to base of tail) of the adult cats (± 1 SD) was 48 ± 2.7 cm and mean weight was 2853 ± 420 grams. The animals were underweight as normal weight for healthy lean female domestic European shorthair cats typically averages 3.5 kg or higher (Hoenig et al. 2010, Kienzle and Miok 2011, Bermingham et al. 2013). Five animals had normal body fat. Four had practically no body fat while four had none at all. Four suffered poor dental health, one of which had a necrotic jaw. Aside from 11 of the animals having ear mites, only two animals had other external parasites (mange). Seven of the cats had intestinal abscesses while eleven had blackened or reddish and enflamed lungs of which three with partial necrosis and one with heavy lesions. Nine cats had abnormal diseased livers with discoloration or blackened areas. One liver displayed hepatomegaly to double the normal size and one was spongy (due to a massive trematode infestation). Seven cats had discolorations on the large intestines, and two had defective heart ventricles. While most cats had multiple helminth infections, four had heavy infestations with one or more kinds of parasitic helminths. The number of animals carrying worms was as follows: tapeworms (taenids) (4), roundworms (*Toxocara* spp.) (2), whipworms (*Trichurus* spp.) (7), hookworms (*Ancylostoma* spp. or *Uncinaria stenocephala*) (7), stomach worms (*Physaloptera* spp.) (2) and trematodes (3). Six animals had potentially dangerous amounts of inanimate anthropogenic garbage in their intestines: plastic wrapping (6), polystyrene foam (1), glass (1), steel clip (1). Two animals had small amounts of paper in the intestines.

3.5 Public views regarding cats, tropicbirds and management options

Of the approximate total island population of around 1824 residents, the target population from which responses were obtained (age 18-70 yr) amount to about 1310 people. This means that about 6% of the sample population had been queried. The proportion of male vs. female respondents was equal. The majority of respondents were in the 30-50 year age category. The majority of respondents were from the two principal villages of the island (42% from The Bottom, 20% from Windward Side). Around 30% of the participants owned cats. A total of 23 male and 15 female cats were owned by the participants. Of these, only one male was not neutered and for one male and one female it remained unclear whether they were neutered or not. The average number of cats per household was 1.2 for natives and 1.4 for expats. Unfortunately our estimates of pet ownership and relative feral cat population densities in different habitats do not allow a reliable extrapolation to an estimate of total number of cats for the island.

Cat versus tropicbird

A significant majority (66%) believed feral cats on Saba are an environmental problem while 21% believed they are not (Fig. 8). In this there was no difference between natives and expat residents. When then asked in what way cats are a problem on Saba, cats were more often (44%) perceived as a threat to wildlife, and second-most as a reservoir of disease and parasites.(Fig 16) and there was no difference between native Saban and expat residents. Diseases and parasites was quoted as the second-most perceived problem with feral cats (31%, Fig. 9).

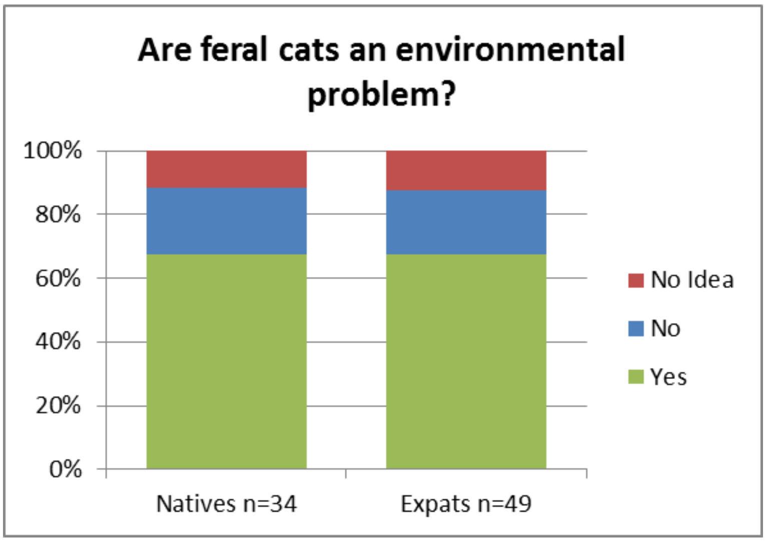

Figure 8. Public perception on cats as a potential environmental problem.

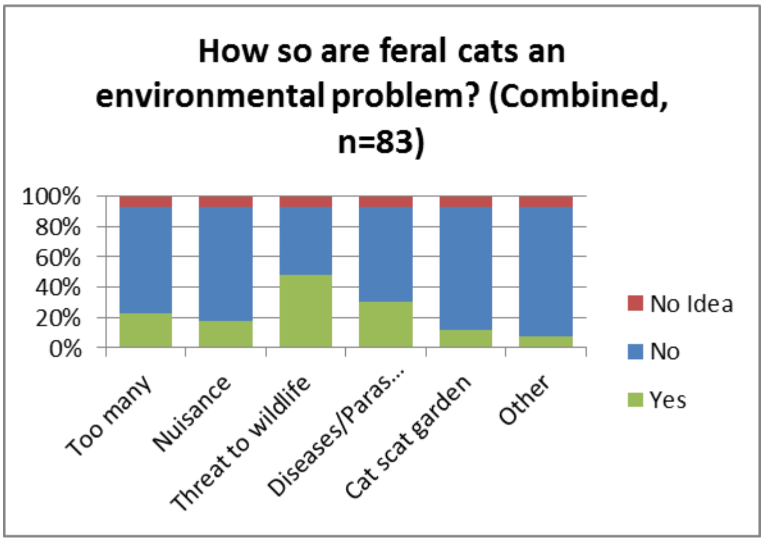

Figure 9. Public opinion on the way in which cats form an environmental problem.

When asked to further specify how cats principally affected Saba nature, most people were of the opinion that the biggest effect was on tropicbirds (48%), followed by the Green Iguana (39%) and the Shearwater, *Puffinus lherminieri* (28%) (Fig 10). The Saba population of the Green Iguana, is a unique melanistic native population of the species and is limited in numbers on this small island (Powell 2006). The Shearwater is endangered locally (Geelhoed et al. 2013) as well as regionally (Schreibner 2000). An average of 47% of respondents indicated not to know for sure about any specific threat.

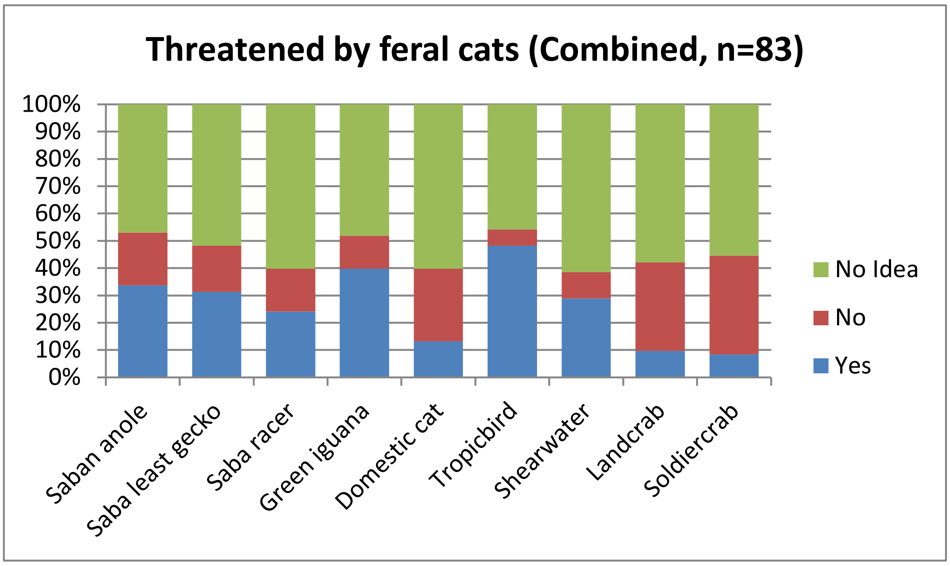

Figure 10. Public perception of which animals are threatened by cat presence.

Significantly more natives than expat residents believe that medical students pet regulations need to be more strictly enforced (Fig. 11). Surprisingly many residents believe that the medical students are an apparent problem in regard to the feral cat problem, notwithstanding the fact that none of the students we spoke to indicated actually keeping any cats.

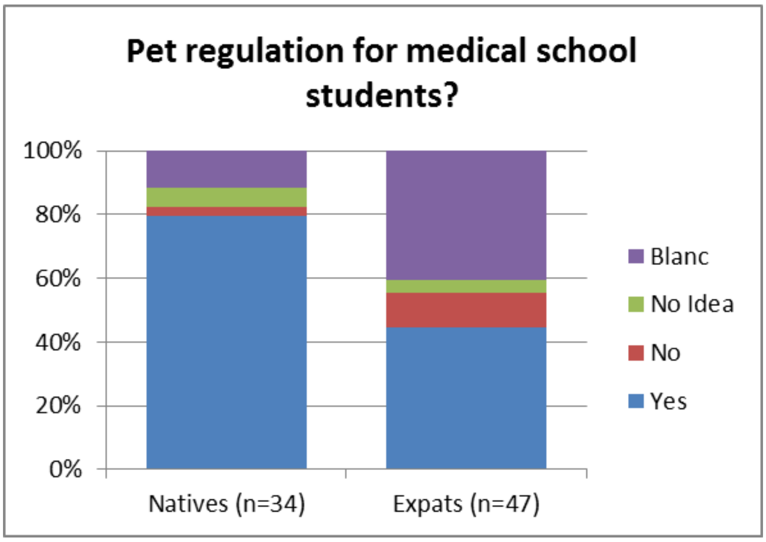

Figure 11. Resident Saban perception on the need for more stringent regulation of Saba Medical School students pet prohibition.

We asked the respondents to rank according to their perception the various sources of perceived threat to the tropicbird. Here cats, but also rats scored as the two most important threats (respectively, 65% and 70%) to the tropicbird (Fig. 12).

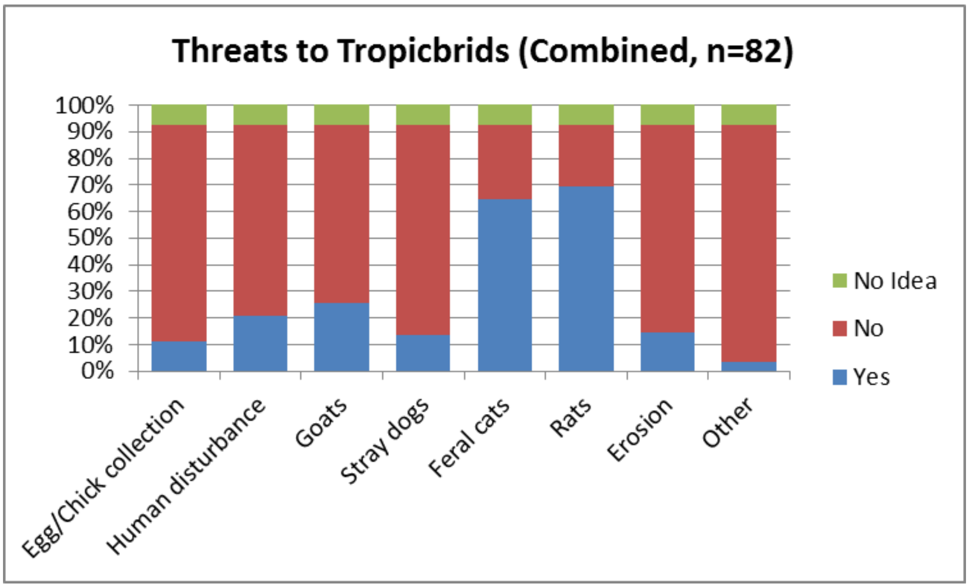

Figure 12. Public perception on the relative importance of different potential threats to the breeding tropicbird colonies.

When asked "how many saved tropicbirds do you think justifies the death of one cat", 38% of Sabans and 22% of expats did not answer the question. Of those that did answer, 36% of Sabans and 48% of expats, valued the life of a single tropicbird more highly as that of a cat (Fig. 13). The remainder considered cats somewhat more important than one tropicbirds but only few (5% natives, 18% expats) considered feral cats more important than the combined sum of all their lifetime tropicbird victims. Public acceptance and willingness to cooperate with a diversity of measures to help solve the cat problem is high (Fig 14). Between 70-80% of respondents thought registration, neutering and removal of cats from breeding colonies was a good idea. Sixty percent (60%) thought that a limit on the allowable number of cats per residence would be helpful, 34% thought that mandatory use of a collar with warning bell would be useful, while 43% thought that total eradication of all cats from the island (ie. no cats feral or pets) would be a good idea. Finally, when asked if euthanization would be acceptable to them, a significant majority of native Sabans and expats found it to be an acceptable method for use in cat control (Fig. 15).

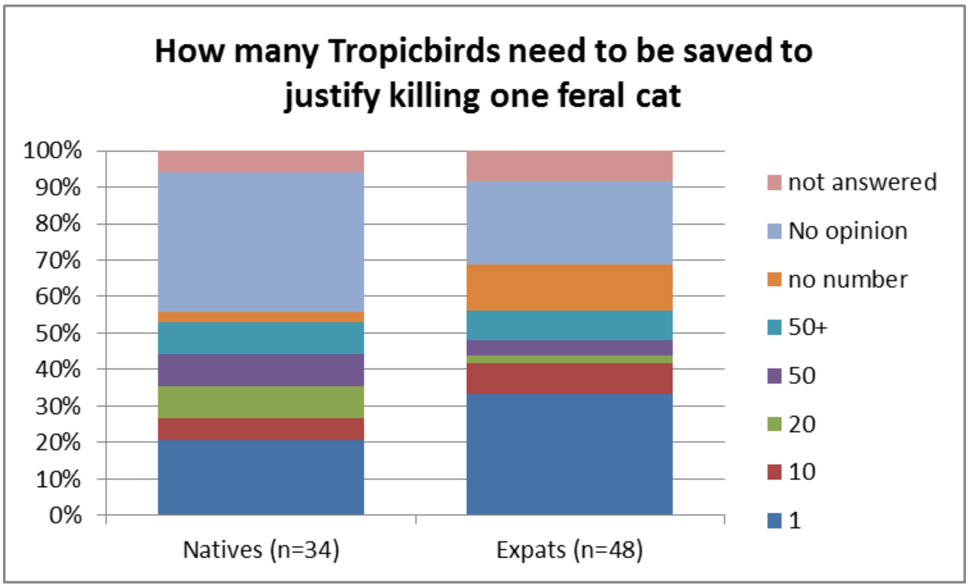

Figure 13. Public opinion on the value of the life of a cat relative to the lives of its tropicbird prey.

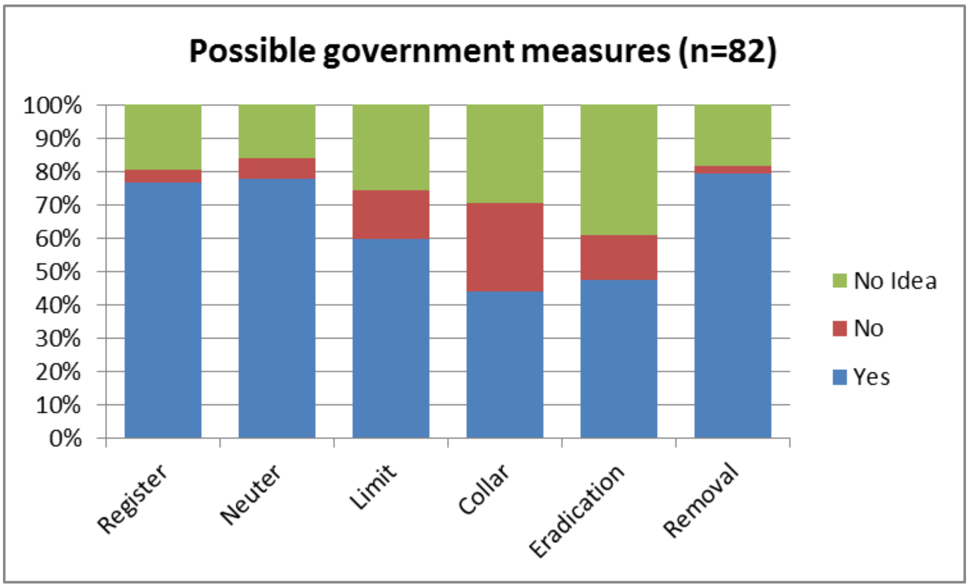

Figure 14. Public willingness to cooperate with a number of potential government measures to help solve the Saba feral cat problem.

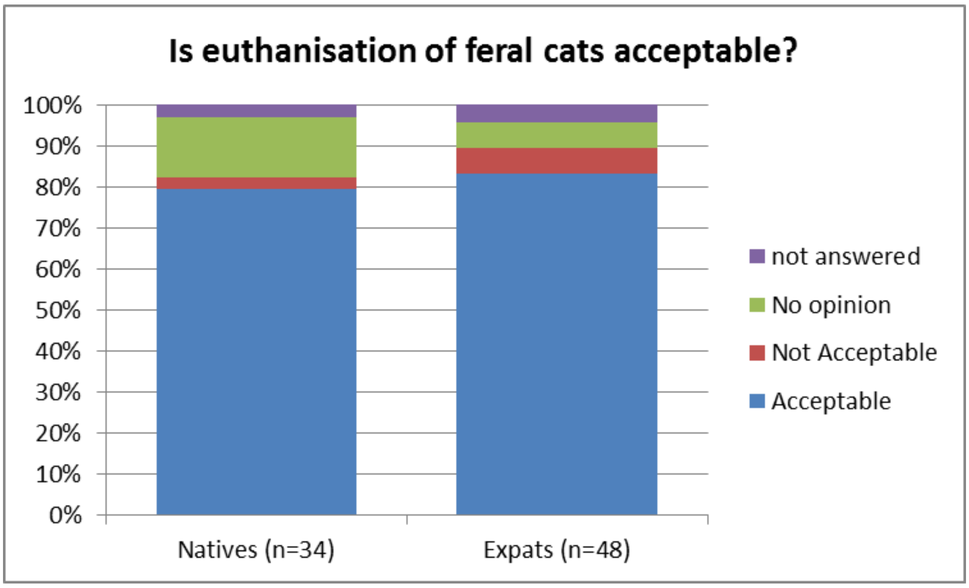

Figure 15. Public opinion on the acceptability or inacceptibility of euthanization as a method for cat control.

Rats

We also queried the public on their perceptions of various aspects of the rat problem on Saba. Both natives and expat residents experienced rats as a major problem on Saba (Fig. 16) and most respondents identified several issues which contribute to the rat problem (Fig. 17). As in the case of cats, the problems with rats are considered of sufficient priority that public willingness to cooperate with government measures is high (Fig. 18).

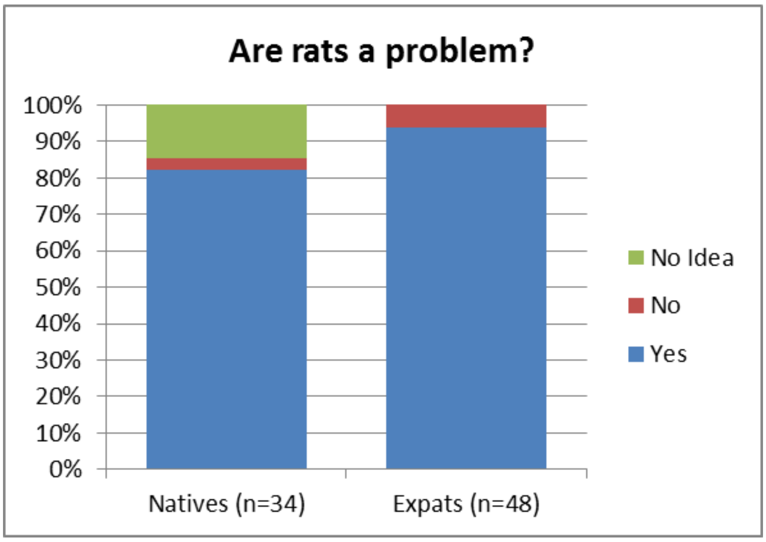

Figure 16. Public perception of rats as a possible environmental problem on Saba.

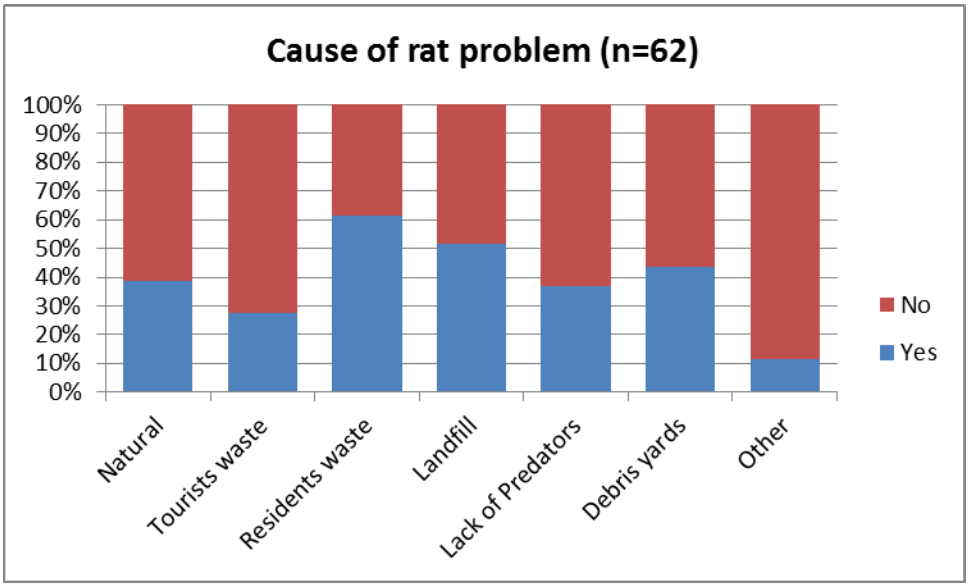

Figure 17. Public perception of the most important likely causes of rat problems on Saba.

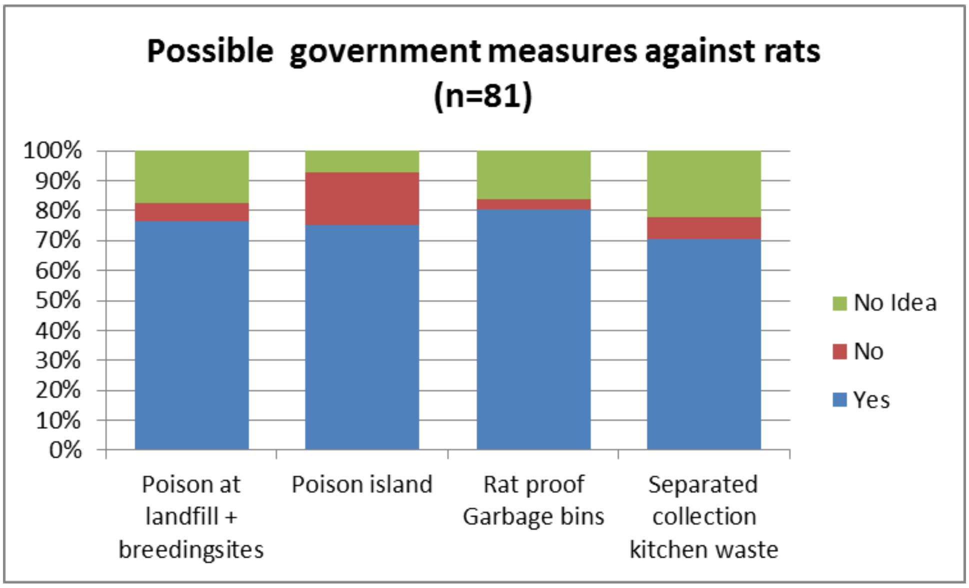

Figure 18. The level of public agreement with a number of potential government measures that might be useful to help address the rat problem on Saba.

Discussion

3.6 Relative density distributions

Cats

Based on scat presence, feral house cats were found to be present across the island and in all areas and habitats studied. Feral cat scats were found from the dry shrubland in the lower elevation (10-220 m asl) to the humid montane forest in the higher elevation (320-850 m asl). Nevertheless, scat densities were much lower at higher elevations in part corroborating the findings from tropical Marion island (in the Indian Ocean) that cats appeared absent from the lusher montane habitats at elevations above 450 m asl (van Aarde 1979). Watanabe et al. (2003) found feral cat scats to be more abundant in cultivated and bare lands compared to forested habitat. Hence our findings corroborate the findings of others that cats select more open vegetation as their preferred habitat.

According to Fitzgerald and Karl (1979), Howard (1957) and (Liberg, 1984) feral house cats are assumed to defecate once a day. However if defecation rate is affected by food intake, then cats in the forest where food capture may be less, may also defecate less and could contribute to lower scat collections. The decay rate of the feral cats can vary across different habitats affected by environment factors (Lozano et al. 2003). Feral cat scats can persist under normal conditions during a long period and they may even persist after heavy rainfall. Some scats can easily remain for three months before decaying (Lozano et al. 2003). Another study suggested that the median persistence for a cat scat is 30 days (Sanchez et al. 2004; Peck et al. 2008). In this study the decay period is assumed to be at least 30 days, so for an interval day period less than 30 days the decay rate can be ignored. As neither production or disappearance rates for scats were actually measured in this study, our estimates of density should only be used for comparative purposes (ie. as an index of density and not as actual measures of density). An additional caveat is that the indicative density estimates only refer to densities in the preferred "trail habitat" and not to densities within the habitat categories proper.

Keeping these limitations in mind, the highest scat (and extrapolated cat) "density" was found in dump area and was significantly higher than three other habitats (forest, woodland and shrubland habitat). The relatively high food-availability around the dump area (food scraps and garbage) was the probable cause of the high feral cat density in this area and this category of food item was also abundant in cat scats and intestines. Hutchings (2003) and Watanabe et al. (2003) likewise documented a significant association between garbage as a food source and feral cat abundance. The feral cat densities extrapolated from scat densities on the surveyed trails ranged from 3.63 km^{-2} (on forest trails) to 285.88 km^{-2} (in coastal lowland trail in the landfill area). The feral cat densities on the shrubland and woodland trails were 196.96 km^{-2} and 107.15 km^{-2}, respectively. (These densities can only be considered as indicative and should not be extrapolated to larger "habitat" areas as they relate specifically to trails.)

The results from the baited camera traps corroborated the scat density findings and showed cat densities to be highest in and around the dump area and lowest in the lush and humid upland forested zone. Domestic cats are principally terrestrial ambush hunters and it is therefore not surprising that they would prefer to hunt in the open areas where prey distribution is more concentrated towards ground levels within their preferred hunting and stalking zone. Even though cats are mobile animals and certainly demonstrate some dynamism in terms of density and distribution with their most important prey species, we believe that the pronounced differences in density between habitats most importantly reflect stable effects of habitat selection.

Rats

The inverse relationship between cat (predator) and rat (principal prey) density as found here is interesting. Karyakin (2010) describes a similarly inverse habitat segregation between large avian raptors and their lagomorph prey in the Transvolga region of Russia. Non-random cat and rat distributions in a heterogeneous environment such as the island of Saba may be the consequences of both habitat selection and biotic interactions between the predator and its prey (Birkhofer et al. 2010). Hence the observed distribution can potentially have a combination of different causes. One possibility is that both cats and rats are distributed simply randomly according to habitat suitability. A second possibility is that cats are distributed according to habitat suitability but that that rats are depleted in those areas with higher cat density. A third possibility is that prey is distributed according to habitat suitability and that predators concentrate in those areas of high prey abundance.

In simple predator prey situations, predator and prey population size may vary cyclically through time. In the case of Saba, cats take a variety of prey and hence the temporally cyclical patterns in density can be expected to be less pronounced. Nevertheless, it cannot be excluded that the observed density distribution may also be affected by temporal population cycles, whereby when rats are depleted in one area, cats may move to other areas which would allow rat population densities to recover.
In reality animals have been found to choose habitat patches based on a series of factors (Hosseini 2006), both biotic and abiotic. Whereas most theoretical models greatly simplify scenarios and until recently even could not allow for the free movement of either prey or predators (Sih 2005), determining which factors weigh most is and remains a complex task (Holt and Barfield 2003).

If temporal cyclicity is not an important factor on Saba and the observed inverse distribution patterns largely reflect stable difference in habitat preference between cats and rats, then two important conclusions can be made. First is that cat and rat predation are likely to be (most) problematic in different areas of the island and second that while cats may exert a controlling influence on rats at lower elevations they cannot actively control them control them in the forest zone of the island where rats are most problematic (Fig. 19).

Figure 19. Rat damage to planted crops in the forest zone of Saba. (Photo: A. Debrot).

Cats and rats have been present on Saba for centuries along with the endangered seabirds without causing acute crises (otherwise the tropicbirds would no longer be present). However, in recent years the problem of mortalities among the seabird colonies has been revealed as a significant problem. Mortalities due to predation now largely exceed the reproductive capacity of the species. This can be directly traced to a TNR program in which, instead of putting unwanted and stray cats down, more than 1000 cats were neutered and released into the wild (E. Peterson, pers. comm.). Van Halewein and Norton (1984) and Campbell (1991) have suggested that the reason the tropicbird can persist on islands elsewhere that are infested by rats is that they are relatively aggressive towards rats. In contrast, the smaller and less aggressive tern species may suffer massively from rat predation (Dewey and Nellis 1980). Based on research elsewhere, the main problem for the tropic bird, therefore, appears to be the cat and not the rat. In their study of cats feeding on a small Mediterranean island important to an endemic shearwater species, Bonnaud et al. (2007) concluded that because rats provide the main food source of cats, they increased the year-round carrying capacity of cats as rats serve as a fall-back food source in 'naturally' scarce times. This was to the great disadvantage of the shearwater, which become the favourite cat menu-item during the breeding season. In essence they suggest that as a dependable but less-favoured food source for cats, the presence of rats makes cats ever so more devastating.

3.7 Cat diets

The result of this study is consistent with other references asserting that feral cats are generalist predators and generally have wide ranging prey categories (Bonnaud et al., 2007). Nevertheless, they typically only focus on a few prey species (typically rodents first and ground nesting birds second). Feral cats on Saba however feed on both natural prey and anthropogenic waste. Mammals, as represented principally by rats (*Rattus rattus*), were the most common prey for feral cats on Saba (in 47% of scats). Other studies also find that cats on islands prey mostly on introduced mammals (Jones 1977, Nogales 1981, Fitzgerald et al. 1991, Pontier et al. 2002, Bonnaud et al. 2007). We found only one other study on feral cat diet for the Caribbean (Garcia et al. 1991). Of 33 cats collected on Mona Island by trapping and shooting, 22 stomachs contained food, and arthropods (40%) and reptiles (33%) were the most common prey items found. This corresponds to our findings.

There was also a notable difference in prey composition between scats and stomachs. Therefore, scat and stomach contents cannot easily be compared. Insects, which are relatively perishable are typically more prevalent in stomachs than in scats, whereas mammalian remains are typically more prevalent in scats than in stomachs. Reptiles were found in about 39% of the scats. Three species of reptiles were found and all of these species were native to Saba. Anole lizard (*Anolis sabanus*) was the most frequent reptile on the cats diet with 26.6% frequency of occurrence. This endemic lizard is commonly found on Saba from the sea level up to 870 m, across different habitats with exception of the driest areas (Rojer 1997). The native green iguana (*Iguana iguana*) occurred in about 8.5% of the total scats. The only snake species on Saba, the endangered red-belied racer (*Alsophis rufiventris*), was found in 1.1% of the scats. The rest (3.2%) was categorized as unidentified species of reptiles.

Birds were found in 14.9% of the scats. Most of the birds remains found were unidentified (71% of scats). The only species identified was the red-billed tropicbird, which occurred in 4.26% of the scats. In addition insects were also found in 11.70% of the scats. In many studies birds have been found as the second most important food source for feral cats (Bonnaud et al. 2007; Fitzgerald et al. 1991), but on Saba reptiles were clearly more important that birds. In addition to natural prey items, anthropogenic waste was also an important part of the feral cat diet. Bone fragments and kitchen paper were the most common garbage found in the scats from dump area. 40.4% of the scats contained man-made waste.

Birds and insects each occurred in 9% of the total prey items from the woodland. Three out of five bird remains found in the scats from the forest were identified as the Red-billed tropicbird (*Phaethon aethereus*). This species is known to nest in scarcely vegetated areas (Snow 1965) at lower elevations whereas forest occurs at higher elevations.

Diet composition of feral cats from the dump area showed a different pattern to other habitats. Food items from dump area were dominated by garbage (42%; n=52). This finding corresponds with other studies on feral cat diet around dump area from other regions. According to Hutchings (2003) in Victoria, Australia cats around the rubbish tip consumed garbage significantly more than other dietary categories. Another study from Oklahoma, US also suggested that feral cats from residential regions consumed more garbage and less prey (McMurry and Sperry, 1941). In addition to the garbage, reptiles (36%) were also important food source for the cats in the dump area. Two reptile species, anole and iguana were found in scats from dump area, with iguana being exclusively found in scats from the dump area. Predation on iguana species by feral cats was also reported by Iverson (1978) who stated that the rock iguana population in the Caicos Islands decreased significantly due to primarily predation by feral dogs and cats. Mammals amounted to only 15% and insects to 8% of the food items. Scats from the urban area suggest that cats in the urban area did not prey on natural prey. Only anthropogenic waste was found in scats from the urban area. These cats were likely fed with pet food or human food scraps.

Food preference of the feral cats is influenced by the availability and accessibility of each food source in a particular environment (Hutchings 2003). Several factors that could alter the diet composition of feral cats are seasonal variation (Bonnaud et al. 2007; Paltridge et al. 1997) and habitat differentiations (Coman and Brunner 1972; Watanabe et al. 2003). This study indicates that the difference in availability and accessibility to certain prey categories between habitats leads to different diet compositions in different habitats on Saba.

3.8 Cat health

The development of effective and humane eradication and control methods has recently received considerable interest (Hildreth et al. 2010, Campbell et al. 2011). One approach often advocated as an effective and humane option for cat control is the capturing of feral cats to neuter them and subsequently release them back into the feral state, typically referred to as trap-neuter-return (TNR) is. There are many problems with the TNR approach to cat management (Jessup 2004, Hildreth et al. 2010) but an underlying, and mostly untested, assumption of TNR programs is that the animals released back into the wild will lead “healthy lives outdoors” (Alley Cat Allies 2011). Whereas many TNR programs in urban settings provide longer term medical care to feral cats, after release on Saba, animals received no form of care. Our preliminary assessment shows that feral cats of the garbage tip of Saba are predominantly underweight and in poor health, with multiple parasitic infestations, abscesses, and diseased or necrotic vital internal organs, and that they consume potentially life threatening human debris. The gross symptoms observed can be caused by any of a number of feline diseases such as parasite infections or feline immunodeficiency virus but further veterinary study is required. Recent research on feline health shows that feral cats may carry heavy parasite loads that can infect wildlife, or pets, and may even be of public health concern (Mendes-de-Almeida and others 2004, Cantó et al. 2013, Gerhold and Jessup 2013). This also appears to be the case with the Saba feral cats we studied. Many parasitic helminths have been isolated from cats in the Dutch Caribbean (Rep 1975) or adjacent islands (Moura et al. 2007, Dubey et al. 2009, Krecek et al. 2010, Kelly et al. 2011) many of which are also of health concern to man. Very few studies on abandoned pet (cat) health focus on or even acknowledge the issue of animal welfare (Jessup 2004, Levy and Crawford 2004) or go on to attempt to address the “quality of life” of abandoned pets (Stafford and Mellor 2008) even though feral cats are known to suffer much higher mortality rates than owned cats (Van Aarde and Skinner 1981, Ogan and Jurek 1997, Schmidt et al. 2007, Krecek et al. 2010). Unfortunately, assessments of TNR effectiveness in cat management are typically only in terms of their effectiveness in the curbing overpopulation (Longcore et al. 2009, Gerhold and Jessup 2013).

At the lower coastal elevations on Saba where this study was conducted, the climate is semi-arid and there semi-permanent freshwater spring available at Fort Bay. The cats survive largely on discarded garbage, insects and the occasional lizard. The anticoagulant poison brodifacoum has long been and still is widely used on the island as the principal rodenticide. Consumption of poisoned rats might also contribute the poor health of the cats studied. Finally, our observations of apparently poor cat health suggest TNR, as done on Saba, without any further health care or support, may be less humane than commonly assumed.

3.9 Public views regarding cats, tropicbirds and management options

Our assessment of public views on cat issues is based on 83 questionnaires answered by 34 native and 49 expatriate legal-aged residents of the island. This amounts to more than 5% of the resident population. We did not conduct a non-response analysis. Therefore we can say nothing about any possible difference in opinion between respondents and those who chose not to cooperate with the study. Self-selection of respondents is also a potential problem in opinion studies as those to whom the issue matters most are more likely to respond to a questionnaire (Sapsford 1999). In that, people strongly against and strongly in favour are possibly equally likely to respond. Policy decisions in democracies are typically made based on those who do respond and not on those who do not respond. Around 30% of the queried inhabitants owned cats, but about 95% of cats were already neutered. A significant majority of respondents (66%) believed feral cats on Saba are an environmental problem. Awareness and willingness of the Saban resident population towards measures against cats and rats are clearly high. When asked "how many saved tropicbirds do you think justifies the death of one cat", 38% of Sabans and 22% of expats did not answer the question. Of those that did answer, 36% of Sabans and 48% of expats, valued the life of a single tropicbird more highly as that of a cat (Fig. 20). The remainder considered cats somewhat more important than one tropicbirds but only few (5% natives, 18% expats) considered feral cats more important than the combined sum of all their lifetime tropicbird victims. Between 70-80% of respondents thought registration, neutering and removal of cats from breeding colonies was a good idea. When asked if euthanization would be acceptable to them, a significant majority (80%) found it to be an acceptable method for use in cat control. While in the past cat extermination campaigns by the Saba Conservation Foundation were met with negative publicity, our results show that Saba residents support stringent measures that may be less popular to certain groups of visitors. Lloyd and Miller (2010) have found that especially wildlife value orientations and negative experiences with feral cats are strong predictors for the preference for lethal management and use of euthanasia in cats. The popularity of the native tropic bird is high and the general awareness and pro-environmental stance of Saba residents is no doubt an indication of high visibility and effective communication by the Saba Conservation Foundation. However, due to stringent limits of capacity and funding, the continuity of this and all other programs of the SCF remain very vulnerable to interruptions.

Figure 20. Feral cat about to kill and remove a Red-billed Tropicbird fledgling from its nest burrow, Saba, December 2013 (*M. Terpstra*).

4 Strategic options

Prior to exploring the strategic choices available, we briefly recap our most significant conclusions. These are:

1) Cats are flexible and adaptive in their diet choice. This makes them especially lethal as a predator since they can easily switch to target preferred 'easy' prey when these become available such as in the case of 'naïve' ground-nesting seabirds during the breeding season.
2) Cat density is inversely related to the density of their main prey the rat. In the colonial past most of the forested areas of Saba were used for fruit trees and small seasonal crops, whereas the lower vegetation zones of the island were principally used for wood harvest and grazing. Whereas rats are by choice arboreal and concentrated in upland moist habitats where the food supply from feral fruit trees is abundant, cats prefer the sparsely vegetated coastal habitats where they function best as a terrestrial predator. Domestic cats in the villages seem to eat mostly cat food and probably have less impact on wildlife than feral cats.
3) Rat control is more than likely not optimal due to year-long use of the same anticoagulant rodenticide brodifacoum.
4) Cat densities at the island tip are the result of a TNR campaign, in which caught feral nuisance cats and unwanted pet cats were neutered and set loose, instead of being euthanized. Most cats at the garbage tip are neutered and feed principally on garbage stored overnight for incineration the next day.
5) Eliminating access of cats (or rats in absence of cats) to garbage at the island landfill would greatly limit food availability and help reduce carrying capacity of these invasive predators.
6) The feral cats of Saba appear to be in poor health and diseased compared to cared-for pet cats. TNR may be cruel and should be discontinued on Saba. Unwanted animals should not be abandoned in the wild but should be put up for adoption when possible (if not adopted, euthanization is likely the most humane solution). Feral cats should be humanely put to rest.
7) Public opinion is strongly in favour of the tropicbird and support for cat and rat removal is high among the Saba residents.

Algar and Johnston (2010) have outlined the conditions that need to be met for successful eradications on an island. These are: a) community support and cooperation; b) all target species should be addressed; c) the target species can be killed faster than replaced; d) the target species can be detected at low densities; e) the funds are sufficient to eradicate all target animals; f) lines of authority that allow the lead organization space to take all necessary actions.

Strategic options

Depending on how these conditions are met, there are four strategic options to choose from

a) Eradicate both cats and rats
b) Eradicate cats and control rats
c) Eradicate rats and control cats
d) Provide broad control of cats and rats across key parts of the island.

Eradication costs for a species on an island can be quite high, funds which are not immediately available (Campbell et al. 2011). Costs for successful campaigns against cats typically amount to upwards of 100 dollars per hectare (Campbell et al. 2011). Hence, eradication of cats from Saba would easily cost a few 100 thousand US$. Also, as for rats, the potential for eventual re-infestation from animals arriving by boat is high which means that rat eradication success depends greatly on on-going integrated environmental education, biosecurity and rapid response capability (Howald et al 2007). On small islands with limited funding and capabilities meeting such conditions is often the greatest challenge.

Eradication of cats, could potentially benefit the tropicbird even if rat abundance increases. This is because the tropicbird is a relatively large and aggressive bird and apparently able to fend off most rats (Van Halewijn and Norton 1984, Campbell 1991). However, higher rat densities could have grave consequences for countless smaller animals ranging from birds to reptiles. While support is high for eradication, most other constraints for fail-proof eradication likely cannot be met in the case of Saba. Therefore we recommend option **d) to provide broad control of rats and cats across the island**. In our recommendations we strive not only to develop and test the use of control techniques to alleviate the most immediate crisis, but also aim to incorporate measures that when implemented, will eliminate the problem of feral cats in the future.

5 Recommendations

Based on this work, we recommend seven management measures for implementation and two main research issues for further investigation.

5.1 Management

1) Upgrade legislation and implement regulations on pet cat keeping practices.

This is needed to provide the legal underpinnings for action. Upgraded legislation is a necessary but not sufficient condition. At present the only legislation addressing animal husbandry and pets on Saba is the 2004 Saba "**Island Ordinance on Identification and Registration of Livestock and Domestic Animals"**. This regulates very little and is not actively enforced, but it does provide nature management with full legal conditions to remove and eradicate (shoot) all roaming animals that cannot be easily caught and brought to slaughter or the animal pound. The law should be upgraded to prohibit the importation and keeping of unneutered cats. Cat sterilization forms an component of successful feral cat eradication (Algar et al. 2011). Raising cats is not an industry or hobby on Saba and residents previously cooperated extensively with sterilization program (95% of cats are already neutered).

2) Capacitate the SFPCA to enforce the mandatory registration of domestic animals.

The SFPCA functions purely based on volunteers. Their most urgent needs are support for data management (computers, database and human capacity). At present they make use of free office and work space at the Agricultural Station.

3) Discontinue the TNR program and from now on euthanize all unwanted pet and stray nuisance cats.

Cats and rats have been present on Saba for centuries along with the endangered seabirds without causing acute crises (otherwise the tropicbirds would no longer be present). However, in recent years the problem of mortalities among the seabird colonies has been revealed as a significant problem. Mortalities due to predation now largely exceed the reproductive capacity of the species. This can be directly traced to a TNR program (from 2002 to August 2012) in which, instead of putting unwanted and stray cats down, more than 1000 cats were neutered and released into the wild (E. Peterson, pers. comm.). Our results suggest that TNR may actually be cruel to the released cats.

4) Conduct periodic rigorous cat control from key problem areas using internationally developed methods.

Out of 103 cat eradications that have been attempted on islands world-wide 87 have been successful. All but one of these primarily utilized predator baits with fast acting toxins. Large campaigns that did not use toxins all failed (Campbell et al. 2011). Toxins are quick and effective and have been used on Saba successfully before to cull cats as well as on Klein Curacao where the island cat population was eradicated swiftly and efficiently in one night (Debrot et al. 2009; Campbell et al. 2011). Risks of side-effects and poisoning of non-target species can be avoided or minimized by proper placement and clean-up afterwards.

5) Evaluate and update the rat control strategy

For more than 15 years government rat control has used brodifacoum as the main rodenticide (Fig. 21), but rats remain a widespread and unrelenting problem on Saba. This suggests that the rats might well have become partly resistant to this anticoagulant toxin and that the time has come to alternate to a different rodenticide. Brodifacoum is the most used and best rodenticide used to eradicate rats from islands world-wide. It acts by blocking the synthesis of the vitamin K dependent clotting factors and causes death by uncontrolled bleeding. Donlan et al (2003) found that the less toxic diphacinone and cholecalciferol based toxins may also be used. Alternating use of rodenticides is the internationally recommended practice for rat control, to prevent development of resistance and to prevent animals from learning. It is already being practiced on nearby St. Eustatius where rat problems are much less acute than on Saba (but where feral fruit trees are also less abundant and landfill practices are also less favourable to vermin).

Anti-predator toxins usually kill swiftly with little or short distress. whereas the anticoagulant toxins often applied to rodents kill over the course of days with much suffering and present persistent risks to non-target animals as well. On the other hand methods to emerge as relatively humane are cyanide and alpha-chloralose one-exposure toxins (Mason and Littin (2003). On tropical islands, land crabs may seriously interfere with baiting against rodents and can accumulate rodent toxins through consumption of bait and rodent cadavers. While crabs are not affected by typical anticoagulant toxins (like brodifacoum) they do accumulate these in their tissues and present a health hazard to humans that eat the crabs and birds and other fauna that feed on the crabs (Cuthbert et al. 2012). Use of rodenticide should be done in swift extensive campaigns instead of continuously at low dosage.

There is little doubt that rat populations on Saba are strongly influenced by “natural” food availability (especially from feral fruit trees) and human waste disposal practices.

Other ideas to limit the food availability to rats on Saba might include:

a) Improved waste collection, disposal and destruction practices
b) Separate collection of biological waste in support of a cottage industry producing hogs, humus, or methane
c) Not letting feral fruit go to waste but use it to develop a cottage industry of biological jams, juices and fruit preserves.
d) Removal of feral (non-native) fruit trees from nature. This not only could help limit food supply to rats but also in recovery of natural forest vegetation. (If this is considered great care must be taken to ensure that open patches are not primarily colonized by invasive plants (Van de Burg et al. 2012).

Figure 21. Head of Agriculture Station, Michael Hassell showing the containers in which the brodifacoum WeatherBlok XT rodenticide is delivered from the USA. (Photo: a. Debrot)

6) Addressing the problem of overnight storage of garbage at the garbage tip.

At present garbage is burnt daily in a system of controlled open air burning in a specially designed steel container (Fig. 22). The system depends on materials being burnt with fuel supplied as part of the garbage brought in. If time runs out and there is insufficient fuel for an effective burn, garbage is stored overnight for the next day (Fig. 23). This happens almost every day and consequently the cats at the landfill have an almost unlimited food supply. A relatively inexpensive solution would be to construct a vermin-proof concrete overnight pen at the landfill.

Figure 22. Open air burner of the Saba landfill in operation. (Photo A. Debrot).

Figure 23. Sheep feeding on garbage to be stored overnight for burning the next day. Upper left, supply of wooden pallets for use as fuel in the burner. (Photo: A. Debrot)

7) **Finally, execute an effective communication strategy to accompany implementation of measures.**

Our work shows that public receptivity for implementation of measures is high. Saban residents are practical outdoors people that are comfortable with hunting and shooting. Nevertheless, the importance of pest eradication as a key component of ecology–based economy centred on ecotourism needs to be convincingly explained (Ogden and Gilbert 2009). Many measures will require public cooperation to be successful (e.g., keeping yards clean of debris, keeping trash bins shut) and cannot be effectively implemented without active public communication

5.2 Research

8) **Investigate the role of rats as predators.**

Worldwide rats are widely known to cause damage to island floras and faunas and many eradications have been conducted, especially on uninhabited islands (Howald et al. 2007). Rats may not only affect seabirds but native forest birds in the forested zone where they are most abundant. In the forested areas clearly rats are not controlled by cat predation as cats avoid these areas. The impact of rats on avifauna are not known or understood. Studies are needed to see in what way and in which species rats play a role as predators. Such information may help define priorities for rat control in the context of wildlife conservation.

9) **Assess the effect of cat removal on tropicbird breeding success and on rat population density, as well as the broader predator-prey relationships on the island.**

In the lower shrubland sections of the island where cats are abundant, they may serve to limit rat populations. Therefore, in these areas it is not only important to evaluate the effect of their removal on tropicbirds survival but also on rat population density as more rats may translate into a different level or pattern of predation on native flora and fauna.

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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.

Justification

Report C011/14
Project Number: 4308701027

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

Approved: Ir. S.C.V. Geelhoed
researcher

Signature:

Date: February 5th , 2014

Approved: F.C. Groenendijk, MSc.
Head of Department

Signature:

Date: February 5th, 2014

Appendix 1

Saba Cat Questionnaire

Good morning/afternoon,

I'm Martin Ruijter. I'm here to do a research project for the Saba Conservation Foundation. I study the feral cat and rat population on Saba and the possible problems they cause.

For that I am doing a survey of the opinions of Saban residents. If you don't mind I would like to interview you shortly about the feral cats and rats and the possible problems they generate.

Native Saban / Student / Expat residents (long term) / Home owner *SCF / SFPCA / NONE*
18-30 / 31-50 / 51-70 / 71+

Date: __:__:2012

City:

Gender:

I first have some general questions.

1) **What are your ties with Saba:**
   a) born on Saba,
   b) family ties to Saba,
   c) coming from the former Dutch islands,
   d) from the Netherlands,
   e) from elsewhere?

2) **Do you keep cats at home?** (Y/N)
   a) how many males (___), how many females (___), how many young kittens (___)?
   b) how many of these have been neutered?
   c) Are these real house cats or do you let them roam free a lot? (House, free)

I will now want to ask some questions concerning the wild cats on Saba.

3) **Do you think the wild cats are an environmental problem on Saba?** (Y/N/U)
   Why are the wild cats a problem? Multiple answers are possible.
   a) Too many,
   b) Nuisance,
   c) Threat to wildlife,
   d) Diseases/parasites,
   e) Cat scat in the garden
   f) Other, namely:

4) **Which of the following animals do you feel are under threat on Saba? Which of these are under threat by the feral cats?** If animals are under threat but not by feral cat what is the threat?

a) Saban Anole	(Y/N/U)	(Y/N/U)	
b) Saba Least Gecko	(Y/N/U)	(Y/N/U)	
c) Black (Red-Bellied) Racer	(Y/N/U)	(Y/N/U)	
d) Saba Green Iguana	(Y/N/U)	(Y/N/U)	
e) Domestic cats		(Y/N/U)	
f) Red-billed Tropicbird	(Y/N/U)	(Y/N/U)	
g) Audubon's Shearwater	(Y/N/U)	(Y/N/U)	(Wedrego bird)
h) Landcrab	(Y/N/U)	(Y/N/U)	
i) Soldiercrab	(Y/N/U)	(Y/N/U)	

5) Of the various threats to the Saba red-billed tropicbird colonies, which is in your opinion the most serious threat? Multiple answers are possible.

a) Egg/chick-collecting,
b) Human disturbance,
c) Goats,
d) Stray dogs,
e) Feral Cats,
f) Rats,
g) Erosion,
h) Other, namely:

The problem with the Red-billed tropicbird is that around 40% of the total population breeds on Saba but they almost had no breeding success here for the last two years. A study showed that almost all nests have been raided by cats and rats pushing this species to the brink of extinction if nothing is done to stop this.
I would like to ask you some questions concerning the population control of cats and rats.

6) How many tropic-bird chicks would in your opinion need to be saved from death to justify euthanizing one feral cat.

a) No number of saved tropic bird chicks could justify killing a cat,
b) 1,
c) 10,
d) 20,
e) 50,
f) More than 50,
g) Have no opinion about it.

7) To limit the most urgent problem quickly, <u>some people</u> want the feral cats to be removed from the wild. These will then need to be euthanized in a humane fashion. How do you feel about this.

a) Euthanization is not acceptable under any circumstances.
b) Euthanization is acceptable, as a routine management measure,
c) Euthanization is acceptable but only for rare use, if things get out of hand,
d) Euthanization is acceptable, but should only lead to a structural solution,
e) I have no opinion concerning euthanization of wild cats.

8) To help control the cat problem on the long-term on Saba would you be willing to support possible government measures to:

a) Register all cats (Y/N/U) if N, why?
(Is already a law, no. 71/05: Saba Island ordinance on identification and registration of livestock and domestic animals.)

b) Make neutering cats mandatory (Y/N/U) if N, why?
(Is already partly in place. Have to pay $5.50 to have cat neutered or pay $55.00 for not neutering.)

c) Legally limit the number of cats to be kept per household (Y/N/U) if Y, how many(___), if N, why not?

d) Compulsory collar with a little bell for domestic cats (Y/N/U) if N, why?

e) Possible total eradication of wild cats in the future? (Y/N/U) if N, why?

f) Continuous cat removal from important seabird breeding sites? (Y/N/U) if N, why?

9) Besides the wild cats, rats are expected to also pose a threat to Saban wildlife. Do you think there is a rat problem (Y/N/U) if Y, what is the problem and what is the cause? Multiple answers are possible.

Problem

a) Diseases/parasites,
b) Disgusting,
c) Threat to wildlife,
d) Damage to crops
e) Damage to property
f) Other, namely:

Cause

a) It's natural,
b) Tourists and their waste,
c) Residents waste,
d) Landfill,
e) Lack of predators,
f) Debris in yards,
g) Other, namely:

10) To help control the rat population on Saba on the long-term would you be willing to support possible government measures to:

a) Poison rats systematically at the landfill and bird breeding sites (Y/N) if N, why?

b) Poison rats systematically throughout the island (Y/N) if N, why?

c) Placement of rat proof garbage collection bins throughout the island (Y/N) if N, why?

d) Separated collection of kitchen waste to reduce excess food availability (Y/N) if N, why?

11) Now I have a few questions about free roaming goats and chicken.

a) Do you think the free roaming goats on this island form a threat to the environment? (Y/N/U)
b) Do you think the free roaming chicken form a threat to the environment? (Y/N/U)
c) Do you think these populations should be managed? (goat Y/N, chicken Y/N)

12) For students, SCF and SFPCA:

Do you think the medical school should install regulations concerning pets (Y/N/U)

Thank you for your cooperation, do you have anything to add?
With kind regards, Martin Ruijter

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