Analysis of diet and genetic variability of feral cats (*Felis catus*) on Robben Island

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ANALYSIS OF DIET AND GENETIC VARIABILITY OF FERAL CATS (*FELIS CATUS*) ON ROBBEN ISLAND

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ABSTRACT

Stomach contents and genetic material were obtained from a sample of 48 feral cats *Felis catus* killed during a three-month eradication programme on Robben Island near Cape Town, South Africa. These samples provided information about the diet and genetic variability of this isolated population. Surprisingly, reptiles formed the largest contribution to diet occurring at a frequency of 30.0%, while birds and mammals both occurred at a frequency of 27.5%. The largest single species contribution to diet was the European rabbit *Oryctolagus cuniculus.* Two highly polymorphic loci were used to examine the genetic variability of the Robben Island feral cat population. This was then compared with data previously obtained from the Cape Town (mainland) domestic cat population. Both populations were found to be in Hardy-Weinberg equilibrium ($p>0.05$). Moderate levels of population differentiation were detected. This could possibly be attributed to a small founder number, low levels of gene flow ($Nm = 1.5$) and repeated bottlenecking of the cat population on the island through repeated culling of the animals.

INTRODUCTION

Feral cat *Felis catus* populations have become established on several sub-Antarctic and offshore islands off southern Africa. Although originally introduced to deal with invasive mice and rats, these cat populations have caused severe depletions of certain birds including the Black oystercatcher *Haematopus moquini*, Swift terns *Sterna bergii* and Hartlaub's gulls *Larus hartlaubii* on Dassen Island (33°26'S 18°05'E; Cooper, Hockey and Brooke 1985), and the extinction of the Common diving petrel *Pelecanoides urinatrix* on Marion Island (46°54'S 37°45'E; Van Aarde 1980).

Domestic cats were probably first introduced to Robben Island in the mid 19th century, when the island was used to house a leper colony. The cats were recorded as "numerous" on the island in 1881 and appeared to be extinct in the mid 20th century (Brooke and Prins 1986). Subsequently cats were likely to have been reintroduced by staff from the Department of Correctional Services who originally kept the cats as pets, and were reported in the early eighties to be shooting feral cats "occasionally" (Paihr 1986). The cats were maintained at relatively low numbers until 1996, during which time prison staff on the island occasionally trapped and shot them.

Robben Island (33°49'S 18°22'E) lies in Table Bay, Cape Town. It is the largest South African island (507ha) and is situated approximately seven kilometres from the mainland and eleven kilometres from Cape Town harbour. One hundred and twenty nine species of birds have been recorded on the island and there are five species of seabird which breed regularly (Crawford *et al.* 1998). Four of these species, African penguin *Spheniscus demersus*, Bank cormorant *Phalacrocorax neglectus*, Crowned cormorant *Phalacrocorax capensis* and Hartlaub's gull, are endemic to southern Africa. A fifth species, the Swift tern, is a discrete population (Crawford *et al.* 1998). Many species of mammals occur on the island, however two exotic species, the European rabbit *Oryctolagus cuniculus* and European fallow deer *Cervus dama* are of particular historical significance (Crawford *et al.* 1998). The declaration of Robben Island as a World Heritage Site during 1999 raised the conservation status of the island.

In 1998 a survey was conducted by Marine and Coastal Management (MCM; formerly Sea Fisheries Research Institute). The survey found that some bird populations including Hartlaub's gulls and Swift terns had not bred on the island during the 1997 and 1998 breeding seasons (Crawford *et al.* 1998). Also, rodents were present in such low numbers that none were seen or captured during the survey (Crawford *et al.* 1998). Conversely, the survey indicated that cats were present on the island in relatively high numbers. The most plausible explanation as to why two species of birds were no longer nesting on the island and rodents were scarce was the recent increase in size of the feral cat population.

At the end of 1998, the Robben Island Museum commissioned the removal of feral cats from the island by a combination of trapping and hunting. One hundred and seven cats were removed between November 1998 and February 1999. As a result of the mass-reduction of the cats from the island in a relatively short period of time a "snapshot" of the population was effectively obtained. Material from these cats was used to examine their diet and the possible ecological impact on the fauna of the island, including a putative link between the feral cats and the non-breeding status of two resident seabirds.

The genetic variability of the Robben Island feral cats was examined using microsatellite loci and then compared to results obtained for domestic cat populations in a previous study by Wiseman, O'Ryan and Harley (1999). Wiseman *et al.* (1999) examined the genetic introgression between the African wild cat *F. lybica* and domestic cat *F. catus* populations using eight microsatellite loci. Hybrids of the African wild cat and the domestic cat are fertile, and extensive hybridisation between the two populations was thought to have occurred. Three cat populations were examined in the study, two domestic cat populations and one African wild cat population. One of the domestic cat populations sampled was in Pretoria and the other was in Cape Town, whilst African wild cat samples were obtained from various parts of southern Africa. Thus microsatellite data was available for the Cape Town domestic cat population to which the Robben Island feral cat population could be compared. Wiseman *et al's* (1999) results indicated low levels of introgression between the African wild cat and the domestic cat populations, and that the African wild cat population was genetically distinct. This raised the conservation status of the African wild cat (Wiseman *et al.* 1999) and demonstrated the need for control of feral cats particularly in and around game reserves.

To gain genetic information about relationships (structure and gene flow) between Robben Island and mainland 'Capetonian' cat populations, microsatellite markers were used.

Microsatellites are short tandemly repeated regions of DNA, each unit consisting of one to six base pairs e.g. $(CA)_n$. Microsatellite mutations are the result of the gain or loss of a single repeat unit as opposed to sequence substitutions (Slatkin 1995). Consequently, microsatellites can be interpreted as following a good approximation of a stepwise mutation process. Microsatellite loci have high mutation rates (10^{-3} to 10^{-6}) and often over a dozen alleles at a single locus, (Gottelli *et al.* 1994; Slatkin 1995) providing a powerful tool with which to detect variation not possible to detect with other methods.

One of the predictions of conservation biology is that as a population becomes smaller, alleles drift into fixation, which results in the rapid loss of heterozygosity (Avise 1994). Robben Island provides an opportunity to study the effects of a small original founder population number on genetic heterozygosity and allele variability and consequently, the ability to respond to evolutionary pressures. Based on theory (Lacy 1987) one would predict that small population size coupled with the introduction of few (or no) individuals would result in a decrease in both the heterozygosity and allele variability of the Robben Island cat population, in comparison with the mainland cats. However, the introduction of new alleles into the Robben Island population from mainland cats, particularly in the form of pets, is not unlikely due to the proximity of Robben Island to the mainland and the frequent change of personnel on the island. Thus, providing a buffer against heterozygosity loss through immigration.

METHODS

The heads and stomachs of 48 adult cats were removed by the MCM and frozen. MCM did not keep samples from 59 juvenile cats, all of which were less than twelve weeks of age. Heads and stomachs from each individual were kept together and labeled. The sex, weight and date the individual was shot was recorded. The stomach contents were washed in a sieve to remove fine particulate matter and identified as far as possible using reference material. Bird identification was based on the colour, size and structure of the feathers and the colour, size and structure of the beaks and legs. Specimens were preserved in 70% alcohol. The number and type of each item present was estimated and the frequency of occurrence of the items was recorded. A volumetric type of analysis was not used due to the difficulty in estimating the volumes of partially digested prey items.

The heads were defrosted and muscle biopsies performed. Approximately one centimetre cubed of muscle tissue was removed from the cheek area and samples were stored at –80°C. Care was taken to avoid any cross contamination of tissue. New scalpel blades were used for each specimen and hands and equipment were thoroughly washed with alcohol between specimens.

Although muscle biopsies were obtained for 48 feral cats, genetic analyses were carried out on 28 randomly selected samples. This was done to standardise the sample sizes with those used by Wiseman *et al.* (1999).

DNA was extracted from 28 samples of muscle tissue using standard phenol-chloroform extraction procedures (Sambrook, Fritsch and Maniatis 1989). Primer pairs to amplify two microsatellite loci were optimised for analysis of the genetic variability of the Robben Island cats. Mennotti-Raymond and O'Brian (1995) demonstrated these primers to be highly conserved across a range of Felidae. Primer pairs were chosen to target the more polymorphic loci according to Wiseman *et al.* (1999). 25pM of each forward primer was end labeled with γ^{32} P – ATP by incubating at 37°C for 90 minutes. Ten microlitre reaction volumes were used in performing the PCR under the following reaction conditions: 25pM of the each primer, 50mM of each deoxyribonucleotide triphosphate, 1.5mM $MgCl_2$ and 0.5U *Taq* polymerase (Bioline).

Cycling parameters for PCR amplification consisted of a four minute denaturing step at 94°C, followed by 35 cycles of: a one minute denaturing step at 94°C, one minute at the annealing temperature 62°C, and a 45 second extension step at 72°C. To decrease band non-specific amplification products, which may have arisen from incomplete PCR (resulting in shorter DNA fragments) a final ten-minute extension step was performed at 72°C. A 6% denaturing polyacrylamide gel was used to electrophorise the amplified product. The gels were dried and exposed to autoradiographic film. Genotypes were scored directly from the autoradiographs. Allele lengths (in base pairs) were determined by comparison with a sequence size ladder of the M13 polycloning site.

Data obtained for two loci for the Robben Island feral cat population was compared with data obtained for the same two loci by Wiseman *et al.* (1999) for the Cape Town and Pretoria domestic cat populations. To evaluate the use of only two loci in this study, the results obtained using Wiseman *et al's* data (1999) for two loci (Cape Town and Pretoria domestic cat populations) were then compared to Wiseman *et al's* (1999) results using eight loci (Cape Town and Pretoria domestic cat populations).

DATA ANALYSIS

Diet

All analyses were based on stomachs containing food (n=40). A table was constructed to show frequency of occurrence of prey items in the diet of *F. catus*. Data were analysed both in terms of single species contribution and group contributions to diet.

Unfortunately no records of locality on the island were kept during the culling of the cats. Calculation of the statistical percentage contribution of food categories to diet for different geographical regions of the island was therefore not possible.

Allelic Diversity and Genetic Variability

Observed heterozygosity and expected heterozygosity were calculated for each of the two loci using the Biosys-1 software package (Swofford and Selander 1981). The programme was also used to determine if the samples conformed to Hardy-Weinberg expectations. Pooled chi-squared tests and exact tests (Swofford and Selander 1981) were used to calculate the significance of the Hardy-Weinberg results (as opposed to the standard chi-squared test, which is not accurate where low allele frequencies

occur; Garcia-Moreno *et al.* 1996). The exact test was used to evaluate whether the allele frequency differences could be attributed to chance sampling (Raymond and Rousset, 1995b).

F_{st} (Wright 1965) although primarily designed for allozymes was used to evaluate differentiation and as a comparative test to R_{st} (Slatkin 1995). R_{st}, which has been designed for microsatellites and their stepwise mutation method, was used to further quantify the differentiation of the microsatellite loci.

Gene flow (Nm, number of migrants per generation) was estimated using the relationship $F_{st} = 1/(1+4Nm)$ (Slatkin 1995). This assumes the infinite allele model that is based on heterozygosity as opposed to allelic diversity and is therefore not suitable for microsatellites. There is, however, still much debate about the appropriate calculation to estimate gene flow.

RESULTS

DIET

The frequency of prey items recorded in 40 stomachs of *Felis catus* on Robben Island is summarized in Table 1 and detailed in Appendix 1. The largest single species contribution to the diet was the European rabbit (10%), followed by the Black rat *Rattus rattus frugivorous*, the Cape Dwarf chameleon *Bradypodium pumilum*, the Cape skink *Mabuya capensis* and the Cape legless skink *Acontias meleagris* which all occurred in the diet at frequency of 7.5%.

Reptiles formed the largest contributing category to diet occurring at a frequency of 30%, followed by birds and mammals which both occurred at a frequency of 27.5%. The percentage contribution of bird eggs was 20% thus the effective contribution of birds to diet was 47.5%. It was not possible to confirm the identification of the eggs however the colour and texture of the shells indicated they were probably African penguin eggs. If that was indeed the case then African penguin eggs could make up the largest single species contribution to diet. Arthropods were recorded in 25.5% of the stomachs. Plant material was found in 32.5% of the stomachs. The plant material was varied and included a variety of grasses, leaves and vegetables.

Scavenging made up at least 17.5% of the diet. Items such as plastic, spaghetti and salami were recorded. Fish contributed 22.5% to the diet and were recorded as a separate category, as the extent to which the fish had been scavenged from human refuse was impossible to ascertain.

Table 1: Frequency of occurrence of prey items in the stomachs of *Felis catus* on Robben Island (*n=40*)

Food Item	Number stomachs	% stomachs	Number prey items
AMPHIBIA			
Strongylopus grayii	1	2.5	1
ARTHROPODA			
Arachnida			
Harpactira baviana	1	2.5	1
Insecta			
Coleoptera, Scarabidae	1	2.5	1
Coleoptera, Tenebrionidae	1	2.5	1
Orthoptera, Acrididae	1	2.5	1
Orthoptera, Gryllotalpidae	1	2.5	1
AVES			
Sturnus vulgaris	2	5.0	2
Numida meleagris	1	2.5	1
Unidentified spp.	10	25.0	10
Egg shell	8	20.0	8
MAMMALIA			
Oryctolagus cuniculus	4	10.0	4
Rattus rattus	3	7.5	3
Chrysocloris asiatica	1	2.5	1
Unidentified spp.	3	7.5	3
PISCES			
Unidentified spp.	9	22.5	9
REPTILIA			
Cordylus cordylus	1	2.5	1
Scelotes bipes	2	5.0	3
Acontius meleagris	3	7.5	4
Bradypodium pumilum	3	7.5	3
Mabuya capensis	3	7.5	3
MISCELLANEOUS			
Mussel shell	2	5.0	2
Plant material	13	32.5	13
Plastic	4	10.0	4
Salami/ham	1	2.5	1
Spaghetti	2	5.0	2

MEASUREMENT OF GENETIC VARIABILITY IN TWO CAT POPULATIONS

Allelic Diversity

Both loci were found to be in Hardy-Weinberg equilibrium ($p>0.05$) using the chi-squared test with pooling and the exact test (Table 2). F_{is} values suggested that there were no excess of homozygotes, and hence no evidence of inbreeding.

Table 2: Chi-squared and exact test significance values (p) and F_{is} for each population at both loci.

Population	Locus	Significance value (p)		
		χ^2(pooling)	Exact test	F_{is} value
Robben Island	Fca35	0.185	0.366	-0.227
	Fca77	0.142	0.227	-0.156
Cape Town	Fca35	0.771	1.000	-0.041
	Fca77	0.801	1.010	-0.025

Both loci were polymorphic (Table 3) with the number of alleles per locus ranging from five to six. Direct allele counts revealed marginally higher polymorphism in the Cape Town cats (5.5 compared with 5.0 in the Robben Island cats). Although observed heterozygosity levels were found to be higher than those under Hardy-Weinberg (Table 3), chi-squared (with pooling) and the exact test results (Table 2).

Table 3: Allelic diversity and mean heterozygosity based on Hardy-Weinberg expectations

Population	Mean sample size	Mean no. alleles per locus	Mean heterozygosity Observed	Expected
Robben Island	28	5	0.607	0.513
Cape Town	27	5.5	0.667	0.646

Population differentiation

For locus Fca35 (figure 1a) the most common allele was 144 occurring at a frequency of 0.70 in the Robben Island population and 0.50 in the Cape Town population. For locus Fca77 (figure 1b) allele 144 occurred at a frequency of 0.04 in the Robben Island population and 0.56 in the Cape Town cat population. Allele 142 was most common at this locus in the Robben Island population occurring at a frequency of 0.63, versus 0.11 in the Cape Town population.

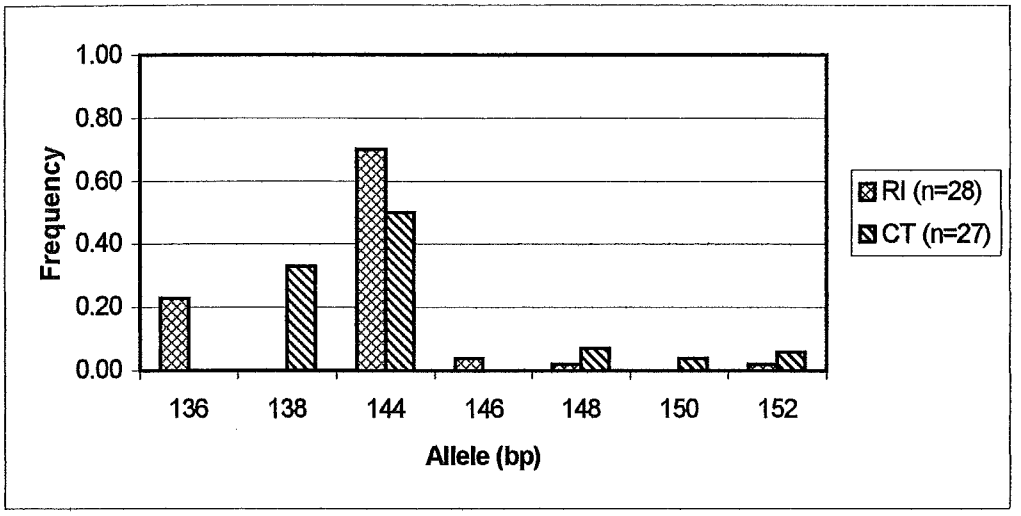

Figure 1a: Allele frequency distribution for both populations at locus Fca35.
(RI = Robben Island population; CT = Cape Town population)

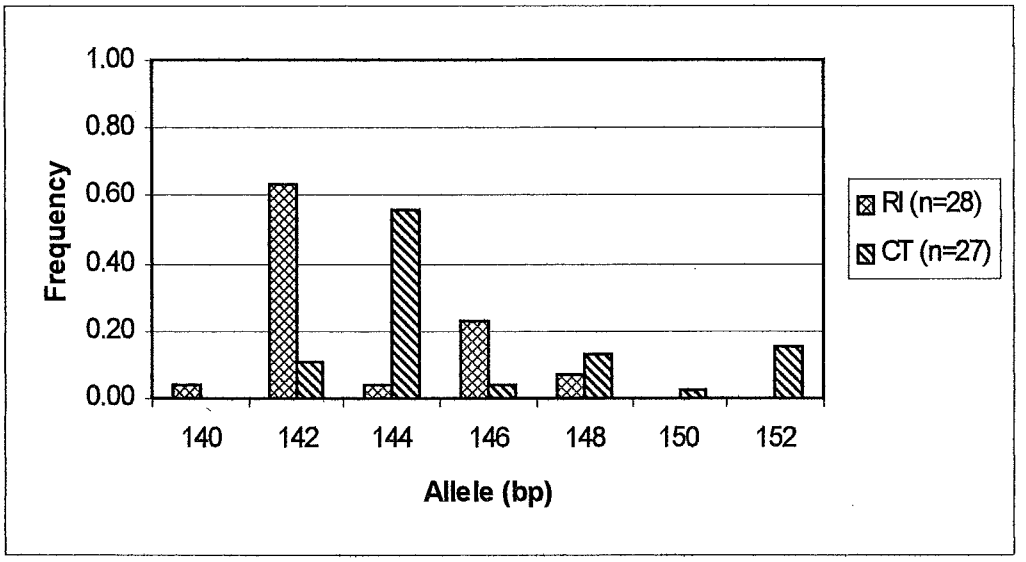

Figure 1b: Allele frequency distribution for both populations at locus Fca77.
(RI = Robben Island population; CT = Cape Town population)

Allele 136 at locus Fca35 occurs at a frequency of 0.23 in the Robben Island feral cat population but was absent in the Cape Town cats. Because this allele occurs at a frequency greater than 0.05 and only in one of the populations, it is therefore considered a private allele. Allele 138 at Fca35 and allele 152 at locus Fca77 are restricted to and therefore private alleles in the Cape Town domestic cat population.

F_{st} estimates of genetic differentiation (Table 4) showed moderately high differentiation between the Robben Island and Cape Town populations (F_{st} = 0.143). A comparison of the Robben Island cats and that recorded by Wiseman *et al.* (1999) for a Pretoria domestic cat population yielded a similar result (F_{st} = 0.160). A comparison of the Cape Town and Pretoria domestic cat populations using only two loci (Wiseman *et al's* data, 1999) yielded a similiar result (F_{st} = 0.017) to that obtained by Wiseman *et al.* (1999) for eight loci (F_{st} = 0.015). R_{st} values are consistent with the F_{st} results.

Table 4: Pairwise measures of population differentiation

Populations compared	Fst	Rst[1]	Nm[2]
Robben Island /Cape Town (TWO LOCI)	0.143	0.151	1.5
Robben Island /Pretoria (TWO LOCI)	0.160	0.172	0.034
Cape Town /Pretoria (TWO LOCI)	0.015	0.018	16.4
Cape Town /Pretoria (EIGHT LOCI)[3]	0.017	0.007	14.5

[1] Calculated according to Goodman (1997)
[2] Calculated using F_{st} values
[3] Wiseman *et al.* (1999)

Nm estimates calculated using F_{st} values (Table 4) suggest little gene flow ($Nm \leq 1.5$) between the Robben Island feral cat population and the Cape Town and Pretoria domestic cat populations, and high gene flow ($Nm \approx 15$) between the two domestic cat populations.

DISCUSSION

DIET

Analysis of the diet by frequency of occurrence of prey items is useful as it indicates what is eaten and provides an idea of the impact of *F. catus* on certain types of prey. A disadvantage is that all items within the diet are scored equally. This is clearly not the case as an individual Cape skink is not equivalent to a European starling in terms of its nutritional energy value. Thus this technique is not a good indicator of the importance of each prey item in the diet (Van Aarde 1978).

Volumetric analysis although valuable in this type of study was not feasible (Bloomer and Bester 1990). Often most of the body has already been digested and it is very difficult to determine the original volume of the prey item. Consequently the complete volume of the prey item may be incorrectly estimated.

Within three months of the culling of the feral cats on the island Hartlaub's gulls and Swift terns, which had not bred on the island for the previous two years, (Crawford *et al.* 1998) were seen to be abundant on the island again (R. Crawford pers. comm.). Until the withdrawal of staff from the Department of Correctional Services in 1996, the feral cat population had been kept at relatively low numbers by staff members who occasionally shot feral domestic cats. More recently cat numbers increased until they were seen as a problem at the end of 1998. The period of increase in cat numbers coincides with the cessation of breeding of these two species of bird. The resumption of breeding by these birds after the removal of the cats clearly illustrates the impact of the feral cats on these ground nesting bird populations. The breeding success of the Swift tern and Hartlaub's gull populations is of particular conservation importance. Until 1996 Robben Island supported up to half of Southern Africa's population of Swift terns (up to 2500 breeding pairs) and up to one third of the world population of Hartlaub's gulls (up to 4000 breeding pairs) (Crawford *et al.* 1998). The status of Robben Island as a World Heritage Site makes the preservation of these species even more critical.

Could have compared his results a bit more — with the effects of cats on other islands (or mainland)

Diet analyses suggest that as one of the largest contributing categories, birds formed an important contribution to the diet of *F. catus*. It is unfortunate that most species found in the stomachs could not be identified. The presence of European starlings in the diet would be of little concern given the birds status as an alien species. Eggshells, likely to be penguin, were found in 20% of the stomachs. If the feral cats routinely

incorporated penguin eggs in their diet, the impact could be widespread. The colony on Robben Island is one of only three colonies of African penguins that is presently increasing in size (Crawford *et al.* 1998). Many other colonies of the endangered African penguin are decreasing, thus presenting a classic case of source sink meta-population dynamics. If the cats were not preying upon the penguin eggs and therefore reducing the reproductive potential there may have been higher emigration rates to colonies which are in decline, thus increasing the probability of their survival.

As the most important single species contributor to diet, the population size of the European rabbit should be closely monitored. The short gestation period (30-40 days) coupled with the ability to produce a litter of between two and eight individuals, three to four times a year (Burton 1965) suggests a sharp increase in the rabbit population is likely. Although vegetation on Robben Island has already been greatly modified (Crawford *et al.* 1998) care should be taken to preserve the indigenous vegetation that remains. An explosion of the rabbit population could threaten remaining indigenous vegetation to the detriment of other biota particularly birds (Gillham 1963). Although Crawford *et al.* (1998) suggest mole snakes *Pseudaspis cana* will prey on juvenile rabbits, a study by Dyer (1996) indicates that predation by mole snakes on juvenile rabbits may be negligible.

Surprisingly, despite an absence of rodents captured by Crawford *et al.* (1998), the Black rat was found to be almost as common as the European rabbit in the diet of *F. catus,* and consequently Black rat populations could increase considerably now the cats have been removed. Indeed within three months of the culling of the feral cats, residents on the island have already reported noticeable increases in the rat population.

Reptiles formed a surprisingly large percentage contribution to diet. The large number of reptiles in the diet may reflect a shortage in availability of food on the island in which case the feral cat population may have been approaching maximum carrying capacity. The presence of the Cape Girdled lizard *Cordylus cordylus* in the diet is of some concern. It appears that that the *C. cordylus* population on Robben Island is isolated, as the nearest population of *C. cordylus* probably occurs at Blouberg (Mouton and van Wyk 1989). However, some species in the Cordylidae family are currently being reclassified and more research still needs to be done. Indications are that some reptile species such as the Cape Girdled lizard were under severe predation

pressure by the cats as scientists on the island located fewer individuals in recent years. The removal of the cats should reduce the predation pressure that the reptiles were under.

The diversity of the diet on the island is illustrated not only by the wide variety of prey items overall, but also by the variety of items within single stomachs. In only two cases were more than one individual of the same species present in the same stomach. This may further illustrate that prey for the feral cats were scarce at the time of the culling. The presence of arthropods in the diet, in particular a poisonous spider *Harpactira baviana*, further suggests the scarcity of prey on the island at the time of culling.

Almost one fifth of the stomachs contained material that suggested scavenging. Items such as spaghetti and salami were clearly scavenged, possibly from a rubbish dump on the western side of the island, or from the village on the eastern side of the island. Fish may have been taken from rock pools, although the large size of the fish vertebrae found in some stomachs suggests that at least some of the fish were scavenged.

Plant material was found in about one third of the stomachs. Although some of this may have taken in whilst eating other food, the large quantity of plant material found in some stomachs indicates deliberate ingestion. Bloomer and Bester (1990) had similar findings and Jones (1977) suggested that plant material aids in digestion and forms an important part of the diet.

The classification of Robben Island as a World Heritage Site raises the conservation status of the island, and indigenous fauna will have to be carefully preserved. Care should be taken to eliminate all cats on Robben Island, including pet domestic cats which are still present, to prevent feral cat populations becoming established in the future. The feral cat population on the island at the time of culling had a severe impact on the fauna of the island, particularly on the birds and reptiles. Feral cats have also impacted on species likely to attract tourists such as the Chukar partridges *Alectoris chukar*, the population of which has decreased in recent years (B. Dyer pers. comm.). The population of Chukar partridges on the island is the only wild population in southern Africa (Crawford *et al.* 1998). Other species such as the Cape skink, Cape legless skink, Silvery dwarf burrowing skink *Scelotes bipes*, Cape dwarf chameleons

and Cape golden moles *Chrysocloris asiatica* may be unique to Robben Island after 16 000 years of isolation.

Whilst control of the Black rat and European rabbit may become a problem, the reestablishment of *F. catus* is not an appropriate solution, as the impact of the cats on island fauna, particularly ground nesting birds, is too great. Bloomer's (1990) study of the *F. catus* on Marion Island illustrated that even though the house mouse *Mus musculus* was common on the island, birds were the preferred prey. However, the population numbers of both the Black rat and European rabbit should be closely monitored.

GENETIC INVESTIGATION

Many previous studies have made use of allozymes, and an investigation of introgression between the Scottish wild cat (*Felis silvestris*) and the domestic cat using allozyme and mtDNA analyses found little or no variation between the wild and domestic cat populations (French *et al.* 1988; Hubbard *et al.* 1992). Microsatellite loci used by Wiseman *et al.* (1999) have a much higher mutation rate and consequently much higher levels of polymorphism per locus than allozyme techniques. Wiseman *et al.* (1999) found significant differentiation between the African wild cat and domestic cat populations, which raises the conservation status of the African wild cat. Wiseman *et al.* (1999) also found a high level of gene flow between widely separated populations of domestic cats (from Cape Town and Pretoria).

This study examined the genetic differentiation between two domestic cat populations. One population was a small island population, probably with a small founder number, and had been "isolated" and heavily culled for approximately fifteen years. It was expected from theory (Lacy 1987) that this population would have a subset of genes of the mainland population, due to genetic drift. The other population was a mainland population that was for all intensive purposes infinitely large and had a high degree of gene flow with other domestic cat populations in South Africa (Wiseman *et al.* 1999).

F_{st} and R_{st} statistics provided quantitative information on population differentiation. R_{st} was specifically designed for the stepwise mutation model thought to be followed by microsatellites and should therefore be more accurate than F_{st} which follows the infinite allele model (Nei 1978). The original R_{st} (Slatkin 1995) did not allow for

unequal sample sizes, however Goodman (1997) allows for this as well as normalizing the variance between the loci, thus weighting the contributions of different loci equally.

Both loci conformed to Hardy-Weinberg equilibrium and negative F_{is} values indicated that there was no excess of homozygotes in the population and hence no inbreeding had occurred. Non-random mating in the Robben Island population and low founder numbers in particular could have led to deviations from Hardy-Weinberg equilibrium, however this was found not to be the case as high levels of heterozygosity were found to be present in the population, and it was in Hardy-Weinberg equilibrium. This suggests that the population was genetically healthy.

In the Robben Island population allele 136 at locus Fca35 may have arisen as a result of an early mutation, spread through the population and is seen at a relative frequency of 0.23 as a result of genetic drift. Genetic drift is thought to be a major driving force of differentiation in small populations.

Both F_{st} and R_{st} values indicate a moderate degree of differentiation between the Robben Island and the Cape Town cats. This could be attributed to a small founder number, low levels of gene flow (indicated by the low Nm value) and repeated bottlenecking of the cat population over at least a fifteen year period (from the mid eighties to early 1999).

Low levels of differentiation were found between the Cape Town and Pretoria domestic cat populations by Wiseman *et al.* (1999). A comparison between the two domestic cat populations using only two loci (Wiseman *et al's* data, 1999) yielded similar low levels of differentiation between the two domestic cat populations. In both cases high Nm values suggested high levels of gene flow within the two domestic cat populations and this could be ascribed to the high migration rates of pet cats around the country. The congruency of my results with the results of Wiseman *et al.'s* (1999) study, suggest that the analysis of only two loci in this study is valid, although up to eight loci may be examined in the future to confirm these results.

This study demonstrates that microsatellite analysis is useful in both ecological and genetic studies, and that ecology and genetics are not mutually exclusive. Genetic results indicate that a small founder number and low levels of gene flow are sufficient

to regenerate large population sizes even with bottle necking. Repeated bottlenecking over a fifteen-year period had little impact on the reproductive potential of the population, and consequently the feral cats could recover to a size that threatened many species of indigenous fauna on the island. Every effort should be made to eliminate all cats on Robben Island to prevent this happening in the future, particularly now that Robben Island has been classified as a World Heritage Site. This study illustrates the potential effects that relatively small feral cat populations could have on the indigenous fauna, and in particular ground nesting birds, of any island.

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Appendix 1a: Frequency table showing prey items present in the stomach of each cat ('p' denotes presence)

Cat no.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Sex	m	m	m	m	f	f	m	f	m	f	m	m	m	m	f	f	m
Food Item:																	
Acontius meleagris					p,p											p	
Bradypodion pumilum																	p
Chrysocloris asiatica																	
Coleoptera, Scarabidae										p							
Coleoptera, Tenebrionidae																	
Cordylus cordylus					p												
Egg shell					p			p				p					
Harpactira baviana					p												
Mabuya capensis									p								
Mussel shell								p			p						
Numida meleagris																	
Orthoptera, Acrididae																	
Orthoptera, Gryllotalpidae																p	
Oryctolagus cuniculus							p		p				p		p		
Plant material										p	p						
Plastic																	
Rattus rattus																	
Salami ham																	
Scelotes bipes					p												
Spaghetti											p						
Strongylopus grayii																	
Sturnus vulgaris				p													
Unidentified bird							p				p					p	
Unidentified fish			p					p				p					p
Unidentified mammal																	

Appendix 1b: Frequency table showing prey items present in the stomach of each cat ('p' denotes presence)

Cat no.:	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Sex	m	m	f	m	f	m	m	f	f	m	f	m	m	f	f	f	m
Food Item:																	
Acontius meleagris																	
Bradypodion pumilum																	
Chrysocloris asiatica																	
Coleoptera, Scarabidae																	
Coleoptera, Tenebrionidae																	
Cordylus cordylus																	
Egg shell													p	p		p	
Harpactira baviana																	
Mabuya capensis														p			
Mussel shell																	
Numida meleagris	p																
Orthoptera, Acrididae														p			
Orthoptera, Gryllotalpidae																	
Oryctolagus cuniculus																	
Plant material	p	p	p		p					p	p			p	p		
Plastic			p						p								
Rattus rattus										p							p
Salami ham															p		
Scelotes bipes																	
Spaghetti															p		
Strongylopus grayii																	
Sturnus vulgaris																	
Unidentified bird					p	p			p								
Unidentified fish				p			p										
Unidentified mammal											p						

Appendix 1c: Frequency table showing prey items present in the stomach of each cat ('p' denotes presence)

Cat no.:	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Sex	m	f	f	m	f	m	f	m	m	m	m	f	m	unk
Food Item:														
Acontius meleagris									p					
Bradypodion pumilum						p			p					
Chrysocloris asiatica				p										
Coleoptera, Scarabidae														
Coleoptera, Tenebrionidae							p							
Cordylus cordylus														
Egg shell		p				p								
Harpactira baviana														
Mabuya capensis					p									
Mussel shell														
Numida meleagris														
Orthoptera, Acrididae														
Orthoptera, Gryllotalpidae														
Oryctolagus cuniculus														
Plant material					p					p				p
Plastic			p											p
Rattus rattus														p
Salami ham														
Scelotes bipes									p,p					
Spaghetti														
Strongylopus grayii		p												
Sturnus vulgaris						p								
Unidentified bird			p		p		p	p						
Unidentified fish	p				p							p		
Unidentified mammal							p		p					

Appendix 2: Sample sizes and allele frequencies for each population at all loci

Locus	Population	Sample size	Allele size (bp) and frequency						
Fca35			**136**	**138**	**144**	**146**	**148**	**150**	**152**
	Robben Island	28	0.23	0.00	0.70	0.04	0.02	0.00	0.02
	Cape Town	27	0.00	0.33	0.50	0.00	0.07	0.04	0.06
Fca77			**136**	**142**	**144**	**146**	**148**	**150**	**152**
	Robben Island	28	0.04	0.63	0.04	0.23	0.07	0.00	0.00
	Cape Town	27	0.00	0.11	0.56	0.04	0.13	0.02	0.15