The diet and feeding behaviour of feral cats, *Felis catus* at Marion Island

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Analyses of prey remains (n = 1 224) and stomach contents (n = 125) of feral domestic cats at Marion Island indicated that these exotic predators mainly feed on nocturnal burrowing petrels (fam. Procellariidae). Seasonality in their diet is discussed and predation rate on the various prey species seems to be a factor of availability rather than selection. An estimate of predation rate based on the energy requirements of the cat population and the caloric content of their most important prey species suggested that a single cat kills approximately 213 petrels per year.
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'n Analise van prooioorblyfsels (n = 1 224) en maaginhoude (n = 125) van wilde huiskatte op Marioneiland toon aan dat hierdie uitheemse roofdier hoofsaaklik op naglewende, grawende stormvoëls (fam. Procellariidae) voed. Seisoenaliteit in die dieet van huiskatte word bespreek en predasiedruk op die verskillende prooisoorte blyk eerder 'n faktor van beskikbaarheid as seleksie te wees. 'n Skatting van predasiedruk gebaseer op die energiebehoeftes van die katbevolking en die kaloretiese inhoud van hul prooisoorte toon dat 'n enkele kat op ongeveer 213 stormvoëls per jaar prooi.
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Studies on the diet of feral house cats *Felis catus* in a wide range of continental and island habitats, have been reviewed recently by Fitzgerald and Karl (1979). The present paper reports on the diet and feeding behaviour of a sub-Antarctic feral cat population and an estimate is made of predation rate. Domestic cats were introduced to Marion Island shortly after the establishment of a permanent meteorological station, which followed the South African annexation of the Prince Edward Island group in 1947/48. Some of the offspring of these pets subsequently became feral and in 1975/76 the population was estimated at 2 137 ± 290 individuals (van Aarde *in press.*). Ecological densities were estimated at 13,85 and 4,98 cats per km^2 for the coastal and interior regions respectively (van Aarde *in press.*).

The Prince Edward Island group (46°50′S, 37°45′E) consists of two volcanic islands with the largest, Marion Island, approximately 290 km^2 in area. Situated in the south Indian Ocean approximately 2 300 km south southeast of Cape Town (South Africa) this tundra biome is continually subjected to low temperatures, strong westerly winds and a high rainfall (Shulze 1971).

Twenty-nine bird species, of which twelve are small petrels which breed and shelter in burrows, are known to breed or are suspected of breeding on these islands (Williams, Siegfried, Burger & Berruti 1979). Surface nesting species comprise four penguins, five albatrosses, two giant petrels, one cormorant, two terns, one gull and one skua (Williams *et al.* 1979). No information is as yet available on the numerical status of the burrowing, mainly nocturnal petrels (families Procellariidae and Pelecanoididae).

Methods

Between December 1974 and April 1976 information on feeding was obtained by direct observation, the collection of prey remains, and by examining the stomach contents of 125 cats shot during the study period.

Prey remains (mainly wings) were collected at monthly intervals over a period of nine months in a study area of approximately 0,43 km^2, the area being more or less triangular in shape and bordered by the coastline, the Van den Boorgaard River and Skua's Ridge. Prey remains were grouped into one of three possible predator categories, these being:

– *Felis catus* category: remains collected in sheltered feeding sites, subterranean lair sites or in crevices, of which either the ulna or humerus or both showed signs of tooth damage by cats.

- *Stercorarius skua* category: remains collected in the vicinity of the nesting sites of brown skuas, in open areas or on sheltered slopes, which showed no signs of tooth damage by cats.
- Unidentifiable category: remains which could not be grouped into one of the above categories.

In addition to these, remains that could be grouped into the *Felis catus* category were also collected outside the defined study area (n = 515).

Prey remains were identified against reference material, in most cases to the species level. This was based on the size of wings, colour and relative size of feathers, and where possible on the size, shape and colour of beaks and/or legs. The contents of 125 cat stomachs were macroscopically identified after washing in hot water to loosen the food mass. One hundred and sixteen (92,8%) stomachs contained food matter and identification of bird remains were based on reference material as described above. Remains of the house mouse, *Mus musculus*, (the only mammalian prey species) could always be identified with certainty and relative ease.

Analyses of prey remains as well stomach contents are summarized by frequency of occurrence. In addition the contents of a subsample of 30 stomachs were analysed by percentage by volume (volumetric contribution of each prey item to the total volume of all stomachs).

Given the minimum requirements of cats for the various sex and reproductive classes (Scott & Scott 1967) and by taking into account population age distribution, adult sex ratio, population growth rate, seasonality in breeding (van Aarde 1978) and population size (van Aarde In press) the minimum energetic requirements of the total population during a period of one year (October 1974 – September 1975) has been estimated.

The estimate of predation rate was based on the energetic requirements of the cat population and the energy content of their most important avian prey species.

Results

Prey items

The frequencies of occurrence of prey items identified in stomachs (n = 116) and the prey remains collection (n = 1 224) for the *Felis catus* category are summarized in Table 1. Considering data obtained by using both these methods 15 different prey items could be identified. Examination of the 116 stomachs containing prey items indicated that 44,0% of burrowing petrel remains could not be identified to species level, while only 3,0% of the collected prey remains were unidentifiable. Approximately 30,0% of all stomachs contained remains of Salvin's prions(*Pachyptila vittata salvini*), while 60,0% of the 1 224 prey remains were identified as this species. Excluding prey items which did not occur in both samples, the frequency of occurrence of Salvin's prions in the stomach contents (54,2%) did not differ significantly (χ^2 = 0,823; p > 0,001) from that in the prey remains collection (62,9%) (Table 2).

Table 1 The frequency of occurrence of prey items identified in stomach contents and those collected in the field. Values in parenthesis represent sample sizes

	Percentage occurrence	
Food items	Stomach* contents n = 116	Prey remains collection n = 1 224
Pachyptila vittata salvini	30,2 (35)	60,1 (735)
Pterodroma mollis	6,0 (7)	9,4 (115)
Pterodroma brevirostris	5,2 (6)	12,8 (157)
Pterodroma macroptera	5,2 (6)	10,1 (123)
Procellaria aequinoctialis	5,2 (6)	0,7 (9)
Halobaena caerulea	0,9 (1)	2,5 (30)
Pelecanoides spp.	–	0,5 (7)
Fregetta spp.	0,9 (1)	0,1 (1)
Chionis minor	–	0,8 (10)
Mus musculus	16,4 (19)	–
Felis catus	0,9 (1)	–
Egg shells	5,2 (6)	–
Plant material	37,1 (43)	–
Penguin remains	6,9 (8)	–
Unidentifiable petrel remains	44,0 (51)	3,0 (37)

*Percentage of stomachs containing the specific food item

Differences observed for food items such as the soft-plumaged petrel (*Pterodroma mollis*), Kerguelen petrel (*P. brevirostris*), great-winged petrel (*P. macroptera*) (Table 1) through similar analyses were not significant (χ^2 – values 0,001, 0,698 and 0,729 for 1df respectively; Table 2). The low frequencies of occurrence of the white chinned petrel (*Procellaria aequinoctialis*) and blue petrel (*Halobaena caerulea*) precluded meaningful statistical comparisons. Nevertheless, all white-chinned petrel remains in stomach contents were from nestlings, while those identified in the prey remains were adults.

Although it did not occur amongst the prey remains collected, the house mouse, *Mus musculus*, was identified in 16,4% of the stomach contents. A percentage by volume examination however indicated that mouse remains comprised only 4,4% of the total volume of all

Table 2 Statistical comparison of the frequency of occurrence of prey species in stomachs with those in the prey remain collection

	Number of prey items		
Prey species	Stomach contents	Prey remains	χ^2-value
Pachyptila vittata salvini	39(44,9)	735(729,1)	0,823
Pterodroma mollis	7(7,1)	115(114,9)	0,001
Pterodroma brevirostris	7(9,5)	157(154,5)	0,698
Pterodroma macroptera	10(7,7)	123(125,3)	0,729
*Procellaria aequinoctialis**	7(0,9)	9(15,1)	–
*Halobaena caerulla**	2(1,9)	30(30,1)	–
Total	72	1169	

Expected values in parenthesis
*Expected frequencies too small for statistical comparison

food items while Salvin's prions comprised approximately 26,0%, soft-plumaged petrels 14,0%, Kerguelen petrels 5,0% and white-chinned petrels 17,0%. These values differ considerably from those based on frequency of occurrence (Table 1).

The occurrence of penguin (fam. Spheniscidae) remains in approximately 7,0% of the stomachs analysed is ascribed to scavenging (observed on several occasions) and no direct evidence of feline predation on any of the surface nesting species occurring on the island has been obtained.

Seasonality

A monthly (30/31 days, commencing on the 22nd of each month) presentation of information obtained through stomach content analysis suggests definite seasonal patterns in the frequency of occurrence for some of the prey species taken by cats (Fig. 1). With exception of the period 22 March to 21 May salvin's prions were taken throughout the year, with a definite peak during August – September. White-chinned petrel chicks were taken mainly during December, while the closely related soft-plumaged and Kerguelen petrels (Van Zinderen Bakker 1971) were taken throughout most of the year. Remains of the winter breeding great-winged petrel (chicks and adults) only occurred in stomachs collected from 22 June to 21 August.

Interspecific competition

A statistical comparison of cat and skua predation (Table 3), based upon the frequency of occurrence of species in the prey remains collected in the study area, indicated that the differences observed for Salvin's prions and white-chinned petrels were not significant ($\chi^2 = 1,10$ and $0,15$ respectively; $p > 0,01$), the difference observed for Kerguelen petrels was significant ($\chi^2 = 3,3$; $p < 0,01$), while that observed for soft-plumaged petrels and great-winged petrels was highly significant ($p < 0,001$) (Table 3).

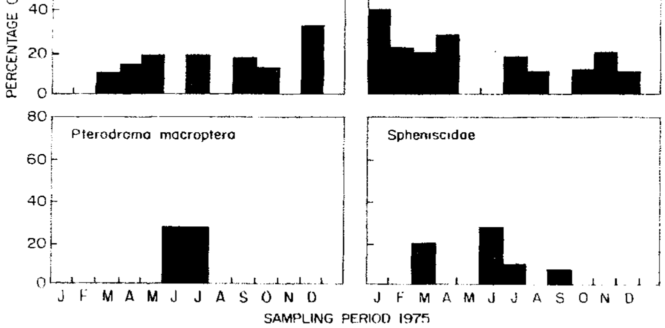

Fig. 1 Seasonal patterns in the frequency of occurrence of prey items in the stomach contents of cats.

Table 3 A statistical comparison of feral cat (*Felis catus*) and skua (*Stercorarius skua*) predation based on prey remains collected in the study area

Prey species	Frequency of occurrence (percentage) in predator categories: Cat	Skua	χ^2-value
Pachyptila vittata salvini	63,1	58,0	1,10
Pterodroma mollis	9,9	28,4	51,90**
Pterodroma macroptera	17,6	1,2	60,30**
Pterodroma brevirostris	7,8	11,2	3,30*
Procellaria aequinoctialis	0,8	1,0	0,15
Chionis minor[1)]	0,9	0,3	–

1) Expected frequencies too small for statistical comparison
** differences highly significant ($p < 0,001$)
* differences significant ($p < 0,01$)

Energetic requirements

Van Aarde (*in press*) estimated a population size of 2 137 cats at the onset of the 1975 breeding season. Intrinsic rate of natural increase was estimated at 23,3% (van Aarde 1978), suggesting a theoretical population size of 1 693 at the onset of the 1974 breeding season. Furthermore, an adult sex ratio of 1 ♂ : 0,55 ♀ (van Aarde 1978) suggests that the 1974 adult breeding population was comprised of 1 092 males and 601 females.

To simplify the estimation of energy requirements it was assumed that the population increase from October 1974 to September 1975 was the result of kitten production only. This suggests that only 444 (2 137 – 1 693) of the 1974 kitten crop would have attained adulthood towards September 1975 (adulthood attained at a mean age of 9 and 12 months in females and males respectively; Robinson 1977). For simplification it can therefore be assumed that the October 1974 to September 1975 population comprised at least 444 growing individuals, 601 adult females and 1 092 adult males.

Kittens were weaned at an age of approximately 50 days (Robinson 1977), attained subadulthood at 4,5 months of age (van Aarde 1978), and attained adulthood at a mean age of 9 and 12 months in females and males respectively (Robinson 1977). Based on the information in Table 4, annual caloric requirements for a growing individual was therefore estimated at 304 309,5 and 306 371 kJ for females and males respectively (Table 5). Assuming unity in sex ratio the total energy requirements for growing component of the population was estimated at 135 571, 071 $\times 10^3$ kJ.

Considering that an adult female will be pregnant for approximately 130 days of a year, (van Aarde 1978, Robinson 1977) and lactating for approximately 100 days (Robinson 1977) the caloric requirements of an adult female over a period of one year would be 599,590 $\times 10^3$ kJ (Table 6) and for the total female population 360 293,490 $\times 10^3$ kJ. The minimum energy requirement of the adult male population (1 092 individuals) was estimated at 530 948, 418 $\times 10^3$ kJ, resulting in the minimum energy requirements for the total population being 102 681, 2 979 $\times 10^4$ kJ.

Table 4 Daily energy requirements of the domestic cat during different phases of its life history

Age and reproductive class	Expected body weight* (kg)	Daily caloric requirements** (kJ/kg)	Ecological age and reproductive class***	Observed body weight*** (kg)	Estimated daily caloric requirements per individual (kJ)
10 weeks	1,0	836,8	Juvenile	1,00 ± 0,32	837,6
20 weeks	2,0	543,9	Subadult	1,88 ± 0,45	1 022,5
Adult male	4,5	334,7	Adult male	3,98 ± 0,53	1 332,1
Adult female	2,5	334,7	Adult female	2,99 ± 0,48	1 000,8
Pregnant female	3,5	418,4	Pregnant female	3,23 ± 0,30	1 351,4
Lactating female	2,5	1 046,0	Lactating female	2,76 ± 0,52	2 887,0

*From Scott and Scott 1967
**1 kKal = 4,184 kJ
***Van Aarde 1978

Predation rate

The frequency of occurrence of prey items does not take into account differences in the size of various prey species and therefore the relative contribution that each made to the food intake of cats. An attempt to estimate predation rate was therefore based on mean calorific content of the most important prey species of cats (Table 7) and the estimated minimum energy requirements of the populations over a period of one year.

The information obtained from the collected prey remains (Table 1) indicated that the seven bird species listed in Table 7 comprised 95,5% of the birds killed by cats, suggesting that the 1974/75 cat population obtained the bulk of their energy requirements from these species.

Table 5 Estimation of the annual caloric requirements of growing cats

Ecological age class	Period in specific age class (days)		Caloric requirements for total period (kJ/individual)	
	Females	Males	Females	Males
Juvenile	85*	85*	71 196,0	71 196,0
Subadult	135	230	138 037,5	235 175,0
Adult	95	–	95 076,0**	–

*Lactation period of 50 days (Robinson 1977) excluded.
**Caloric requirements regarded as that of a non-reproducing adult female.

Table 6 Estimation of annual caloric requirements of the adult female component of the population

Reproductive class	Period in specific class (days)	Caloric requirements for total period (kJ/individual)
Non-reproductive	135	135 108,0
Pregnant	130	175 682,0
Lactating	100	288 700,0
Total	365	599 490,0

Given the mean energy content per individual of each of these species (Percy Fitzpatrick Institute *pers. comm.*) the minimum number of birds killed by the 1974/75 cat population, to meet 95,5% (981 119,801 × 10^3 kJ) of its energy requirements, was estimated through the application of the percentage energy contribution of each species to the total requirements of cats (Table 7). According to this information a total of 455 119 birds, representing seven species, had to be killed to provide for the energy requirements of the cat population over a period of the year.

Discussion

All petrel species occurring in the areas over which cats were distributed (below 450 m.a.s.l.; van Aarde *in press*) were potentially susceptible to cat predation when entering or leaving their burrows, or when courting on the surface in front of burrows. Cats were observed to enter burrows of species such as Salvin's prions and species larger than these. Distinct trails running from cat lair sites to burrow entrances and/or from burrow entrance to burrow entrance, as well as direct observations indicated that the main hunting strategy of these cats consisted of methodical searching, and entering petrel burrows until a prey item has been obtained. Most adult petrels, either breeding or sheltering in burrows, were therefore not protected from predation and chicks as well as eggs (as indicated by stomach content analysis) were also preyed upon. The apparent absence of an anti-predator strategy, probably as a result of the absence of mammalian terrestrial predators during their evolutionary development, would suggest that the observed predation rate is a function of availability rather than food selection by cats. These observations agree with those observed elsewhere (Coman & Brunner 1972, Jones 1977, McMurray & Sperry 1941) and it is suggested that the cats under these situations are opportunistic predators and/or scavengers.

No remains of the winter breeding grey petrel (*Adamastor cinereus*) were found amongst stomach contents or prey remains, probably because of their small numbers rather than prey selection. Derenne and Mougin (1976) however suggested that at Kerguelen, where grey petrels are abundant, lack of cat predation may be ascribed to the size of these birds as well as their 'aggressive nature'.

Table 7 Estimation of the number of birds killed to meet 95,55% of energy requirements of the 1974/75 cat population

Prey species	Percentage occurrence in prey remain collection[1]	Number of individuals per hundred	Mean energy content per individual[2] (kJ)	Percentage energetic contribution to the diet of cats	Energetic contribution (kJ) to 95,55%[3] of the population's energy requirements	Number of birds killed to provide energy requirements
Pachyptila vittata salvini	60,05	62,85	1 273,18	37,12	364 191,670 × 10^3	286 049
Pterodroma mollis	9,40	9,84	3 130,11	14,29	140 202,019 × 10^3	44 791
Pterodroma macroptera	10,05	10,52	4 002,61	19,54	191 710,809 × 10^3	47 897
Pterodroma balvirostris	12,04	12,60	3 552,03	20,76	203 680,470 × 10^3	57 342
Procellaria aequinoctialis	0,74	0,77	13 262,76	4,74	46 505,078 × 10^3	3 506
Halobaena caerulea	2,45	2,56	2 016,40	2,39	23 448,763 × 10^3	11 629
Chionis minor	0,82	0,86	2 889,40	1,15	11 282,877 × 10^3	3 905
Total	95,55	100,00		99,99		455 119

1. Data from Table 1.
2. Percy Fitzpatrick Institute for African Ornithology *pers. comm.*
3. 981 119,801 × 10^3 kJ.

With reference to body size, however, it may be noted that this species is not bigger than the great-winged petrel preyed upon by cats at Marion.

The low occurrence of diving petrels (*Pelecanoides* spp.) in the prey remain collection (0,5% Table 1) and absence of it in stomachs analysed deserves special mention. Diving petrels can easily be detected hy humans when moving on the ground at night. In the period immediately after the introduction of cats (1951 – 1952) *P. urinatrix* were regarded as being common on the island (Rand 1954) but during 1965/66 no nests of this species were found (Van Zinderen Bakker 1971). Furthermore during a visit to the neighbouring cat-free Prince Edward Island during April 1976 this species was present in abundance (*pers. obs.*). It therefore seems feasible to suggest that the decline of this species at Marion Island is due to cat predation, even as early as 1965/66 when the cat population numbered approximately 200 individuals (van Aarde 1978). A similar argument might hold true for the storm petrels (*Fregetta* spp.) which are rather rare at Marion but abundant at Prince Edward Island.

The observed seasonality in the diet of cats is ascribed to seasonal breeding of petrels; the great-winged petrel being a winter breeding species while all the other petrels preyed upon were summer breeders. The size and possible defence behaviour of white-chinned petrels probably confined cat predation on them to their chicks, available only during the summer months, while the occurrence of the remains of adults in the prey remains collected could be the result of scavenging from skua kills, rather than predation. Interactions observed between skuas and cats indicated that the latter always gave way (see also Jones 1977).

The overlap in predation on petrels by skuas and cats is not at this stage considered as an indication of interspecific competition. Differences are ascribed to availability due to habitat selection (van Aarde *in press*) as well as seasonality; the skua being a summer breeding species occurring on the Island only from mid-August to April. Skuas furthermore seem to prey mainly on penguin chicks and eggs. Since remains of these were not included in those collected in the study area, the data in Table 3 should not be regarded as being representative of the total diet of skuas. However, even though skuas kill only some 50 000 petrels per year (Williams *pers. comm.*) a decline in petrel numbers due to cat predation may result in an increase in skua predation on penguin colonies, which may, for example, have an adverse effect on the Gentoo penguin (*Pygoscelis papua*). In accordance with observations on Cochons Island (Derenne & Mougin 1976) no indication of predation on the larger surface nesting birds was found. Cats always retreated during interactions observed between skuas and cats and penguins and cats. On the other hand Smith (1977) observed a Macaroni penguin (*Eudyptes chrysolophus*) being killed by a young cat. He also ascribed starvation of wandering albatross (*Diomedea exulans*) chicks to disturbances evoked by cats; both these observations could not be confirmed during the present study. Moreover cats were often observed to either walk through or to be among sooty albatross (*Phoebetria fusca*) colonies but there was no indication of predation on chicks or adults.

The estimated energy requirements for cats of various age and reproductive classes (Table 4) were based on an extrapolation of requirements published by Scott and Scott (1967). Their estimates were obtained from cats under laboratory conditions and the value presented for the Marion populations should therefore be regarded as an absolute minimum.

The assessment of predation rate based on annual caloric requirement estimation for the cat population had several shortcomings. It relied on a collection of prey remains gathered in a small area which might not be representative for the total range over which cats occurred. These data furthermore did not include the total range of food items identified for cats. It was also based on an estimation of energy requirements based on several assumptions (i.e. population structure) as well as published information for cats under ideal conditions. Nevertheless, this approximation of predation rate is valuable as at least an indicator of the influence that cats are having on the avifauna of the island.

The estimated values suggest that an individual cat killed approximately 213 birds per year. Predation rate estimated for cats at Macquarie Island based on body weight of prey needed per day by a cat, indicated that approximately 57 000 rabbits, 46 000 Antarctic prions *Pachyptila desolata* and 11 000 white headed petrels *Pterodroma lessonii* were killed by a population of 375 cats per year.

A quantification of the impact of the cat population on the island's avifauna would only be feasible with relevant data on the population dynamics of their prey species. However, the apparent decrease in the diving and storm petrel populations could be an indication of the destructive influence of feral cats. During the second half of the nineteenth century domestic cats were introduced to several sub-Antarctic and temperate islands (van Aarde *in press.*). Holdgate (1966) stated that on all these islands cats had an adverse effect on sea birds, ranging from populations being 'decimated' to 'severely damaged'. At Macquarie Island cat predation apparently played a major part in the reduction of white-headed petrels, diving petrels and blue petrels and was even responsible for the extermination of the grey petrel population (Jones 1977).

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