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Distribution and density of the feral house cat *Felis catus* on Marion Island

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Feral cats were found to be well established all around Marion Island over an area of 234 km², up to the 450 m contour line. Estimated crude and ecological densities for the coastal and interior regions were 9,75 and 13,85 and 1,31 and 4,98 cats per km² respectively. Cat distribution seems to be influenced by that of their avian prey species, which in turn appears to be influenced by the availability of soft soil in which to burrow. The majority of cats inhabited the coastal region, with the highest densities occurring on the grey lava slopes, followed by Cotula*-hillocks, and areas of vegetated black lava. No cats occurred on barren black lava flows. Extrapolation from region specific density data gave a population estimate of 2 139 ±290 individuals.*

Wilde huiskatte is oor 'n oppervlakte van 234 km² rondom Marioneiland tot op 'n hoogte van 450 m bo die seevlak versprei. Die ru- en ekologiese digthede vir die kus- en binnelandse gebiede is op onderskeidelik 9,75 en 13,85, en 1,31 en 4,98 katte per km² geskat. Die katte se verspreidingspatroon word deur dié van hul stormvoëlprooisoorte beïnvloed, wat op sy beurt waarskynlik beïnvloed word deur die beskikbaarheid van sagte grond om nesgate in te grawe. Die meeste katte bewoon die kusvlaktes, met die hoogste digtheid op die gryslawahellings, gevolg deur die Cotula*-bulteveld en begroeide swartlawavloeiings. Geen katte kom op kaal swartlawavloeiings voor nie. 'n Ekstrapolering van gegewens oor gebied spesifieke digtheid het aanleiding gegee tot 'n bevolkingskatting van 2 139 ±290 katte.*

Introduction

Human activities on islands in the Southern Ocean resulted in the establishment of feral domestic cat *Felis catus* populations on at least eight islands in the 19 principal groups of sub-Antarctic and temperate islands, these being Tristan da Cunha (Elliot 1953), Auckland, Falklands and Nouvelle Amsterdam (Holdgate 1966), Marion (Anderson & Condy 1974), Kerguelen (Derenne 1976), L'ile aux Cochons (Derenne & Mougin 1976) and Macquarie Island (Jones 1977).

The introduction of cats to Marion Island followed the establishment of a permanent South African Meteorological Station during 1948. Towards 1949 five cats (then household pets) were kept by members of the meteorological relief team (D.O. Triegaardt, pers. comm.). Some of the offspring of these cats turned wild and in 1951 the first feral cat was observed at Wild Cat Creek, approximately 14 km north-west of the Base Station (H. le Grange, pers. comm.). During 1965, 16 years after their introduction, cats and signs of their activities were found around the periphery of the island (E. M. van Zinderen Bakker, pers. comm.), suggesting a minimum dispersal rate of approximately 2,0 km per year. Anderson and Condy (1974) noted during their preliminary survey (August 1973 to March 1974) that cats were well established all around the island and that they were possibly having a deleterious effect on its burrowing petrel fauna. The present paper reports on the distribution and density of this cat population, the data being collected during a study period from December 1974 to April 1976.

The study area

Marion Island (46°52'S, 37°51'E), situated in the south Indian Ocean is approximately 290 km² in area, domelike in profile and completely volcanic in origin. Two major volcanic phases have been recognised, the first producing the pre-glacial grey lava flows with a smooth profile and the second the highly irregular black lava flows (Verwoerd 1971). The island is a

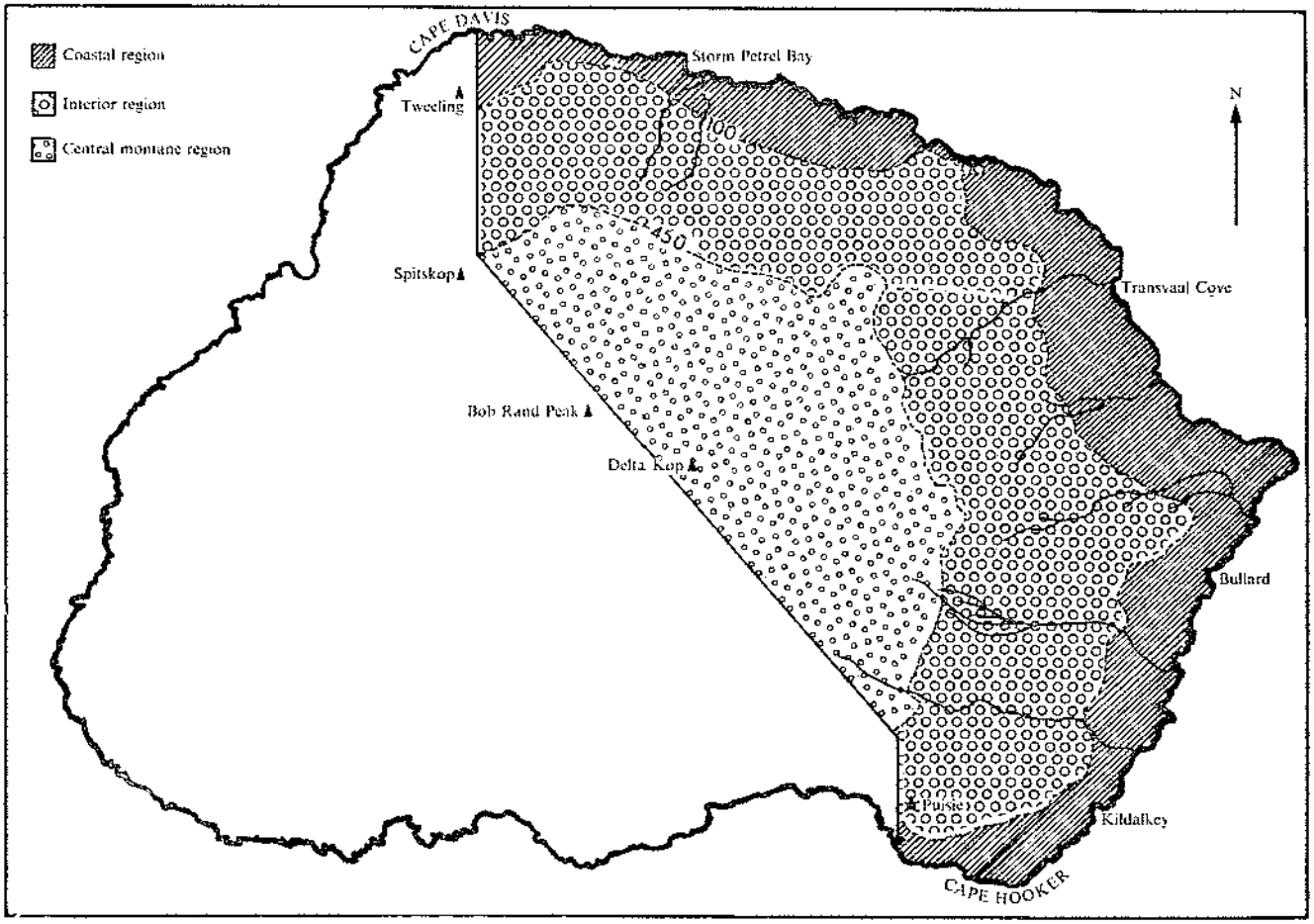

Fig. 1. The main study area (172 km²) on Marion Island, showing the three regions based on altitude (in metres) above sea level.

tundra type biome and four main plant communities, *viz.* maritime, slope, swamp and feldmark have been distinguished (Huntley 1967).

The main study area of 172 km² on the north-eastern sector of the island comprised three principal regions, these being the coastal region (0-100m a.s.l.), the interior region (100-450m a.s.l.) and the central montane region (area above 450m a.s.l.; Fig. 1). The coastal region, which sloped gradually towards the coastline, is 54,3 km² in area and varied in width from 0,8 to 2,0 km. Scattered about within this area are volcanic cones and numerous lakes, some of which are drained by streams. Although not always separable from the coastal region, the interior region was considered as the inland gradient of the island. Characterized by its undulating topography, this region is approximately 76,4 km² in area and width varies from 2,8 to 5,2 km. The central montane region is approximately 41,3 km² in area. No closed plant communities occurred above the 500 m contour line and ice and snow fields occurred over much of this region. Based on physiognomical characteristics, the coastal and interior regions were divided into six and five ecological habitat types respectively, these being similar for both regions with the exception of *Cotula*-hillocks which occurred only in the former region (Table 1). Detailed descriptions of these habitat types have been given in Van Aarde (1977).

Table 1

Altitudinal division of the study area into regions, and sub-division into habitat types. The latter have been described in detail by Van Aarde (1977).

Region	Habitat type	Area (km²)
Coastal (0-100 m a.s.l.)	Grey lava slopes	10,1
	Vegetated black lava	18,1
	Volcanic cones	1,4
	Cotula-hillocks	9,4
	Barren black lava	4,7
	Grey lava ridges	10,7
Interior (100-450 m a.s.l.)	Grey lava slopes	1,3
	Vegetated black lava	38,2
	Volcanic cones	2,0
	Barren black lava	12,7
	Grey lava ridges	22,1
Central montane (above 450 m a.s.l.)		41,3
	Total	172,0

Methods

To facilitate quantification of cat distribution and density, a grid based on fractions of degrees (30 second intervals) of

latitude and longitude, was superimposed on a topographical map of the island, each of the grid blocks being 0,67 km² in area. Each grid block was characterized by one of the habitat types listed in Table 1, and in some instances where more than one habitat type occurred in a single grid block, the grid block was characterized by the habitat type which covered the largest portion of it.

The number of cats inhabiting grid blocks representative of each habitat type, in the three regions, was determined by identifying individuals using coat colour, pattern and texture characteristics (Van Aarde & Robinson, 1980), differences in body size (Van Aarde 1978) and when applicable, on locality and known associations with other individuals (Van Aarde 1978). Care was taken to avoid repetitive sightings of the same cats and doubtful records were excluded. The grid blocks were searched whenever the opportunity arose, and use was also made of transects of indefinite width. A total of 1 086 hours were spent on this, of which 59,9 per cent (651 h) was spent searching the coastal region, 38,7 per cent (420 h) searching the interior region and 1,4 per cent (15 h) searching the central montane region (Table 2.) Estimates for ecological densities were obtained by dividing the number of cats identified in each region, or habitat type, by the number of grid blocks per region, or habitat type, in which cats were observed. Estimates for crude densities were obtained by dividing the total number of cats observed by the total number of grid blocks per region or habitat type. These unconventional methods adopted to obtain data on density, rather than more common methods, such as fixed transects of indefinite or definite width as described by Caughley (1977), deserve explanation. Field experience indicated that the shy, elusive and mainly nocturnal habits of cats, as well as the physiognomical characteristics of the study area, would result in an underestimation of density. Van Aarde and Erasmus (unpublished information) found, for instance, that mean density estimated along a transect line of 15 km and of indefinite width, was 6,64 cats per km² compared to 9,75 cats per km² estimated by using the present method.

Table 2

Sampling effort (hours per grid block) and number of cats identified per hour in each of the topographical regions of the study area.

Region	Hours spent per region	Percentage of total time per region	Sampling effort per grid block*	Number of cats identified per hour
Coastal	651	59,94	8,04	0,813
Interior	420	38,67	3,68	0,238
Montane	15	1,38	0,24	0,000

*Number of hours per grid block.

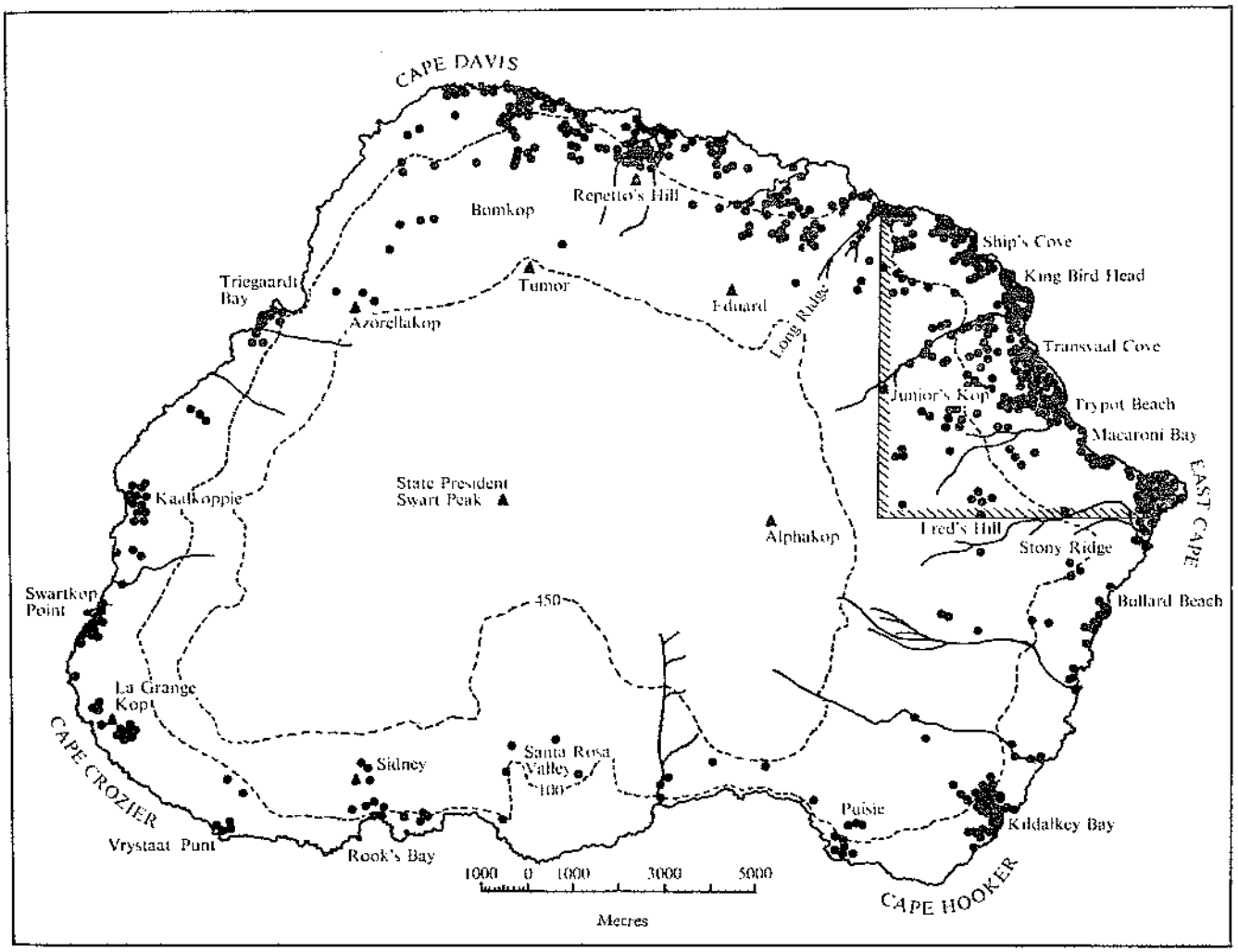

Fig. 2. The distribution of feral cats *Felis catus* on Marion Island. Each dot represents a single observation. The shaded sector illustrates the area (32,8 km²) on which the population estimate was based.

Extrapolation from density data obtained in an area of 32,8 km² surrounding the Base Station (shaded area in Fig. 2) provided the basis for an estimate of total population size. This area, containing all habitat types in which cats occurred, was more frequently surveyed than any other part of the study area and the density estimates were therefore more reliable than those obtained for the total study area. With sampling units (i.e. grid blocks) of equal size (0,67 km²), the estimate for the total number of animals, Y, in the population is:–

$$\hat{Y} = \sum_i N_i \bar{y}_i$$

where N_i is the total number of grid blocks in the i^{th} region, $\bar{y}_i$ is the average number of animals per grid block over the n_i blocks sampled, and Σ denotes summation over all regions. The circumflex of $\hat{Y}$ signifies "an estimate of".

The standard error of $\hat{Y}$ is estimated as var $(\hat{Y})$ where:–

$$\text{var}(\hat{Y}) = \sum_i \frac{N_i (N_i - n_i)}{n_i} S^2_{y_i}$$

$$\text{and } S^2_{y_i} = \frac{1}{n_i - 1} \Sigma y^2_i - \frac{(\Sigma y_i)^2}{n_i}$$

and y_i is the number of animals in an individual grid block (Jolly 1969). Construction of the distribution map (Fig. 2) was based on sightings of cats recorded throughout the study period.

Results and discussion

Distribution and density

Figure 2 illustrates the distribution of all cat sightings made between December 1974 and March 1976. During this period 961 sightings were recorded, some of which were undoubtedly resightings. Although biased through observer activities (number of sightings related to the time spent in a specific area) the distribution of sightings is considered to be a true reflection of the actual distribution of cats. This was borne out by the results of the grid searches, which also showed a similarly clumped pattern. The distribution pattern also approximates that given by Anderson and Condy (1974) and is similar to that observed for the populations at L'ile aux Cochons (Derenne & Mougin 1976) and Kerguelen Island (Derenne 1976). Clumping probably arises from the tendency of cats to stay in family groups or units (Dards 1978, McDonald & Apps 1978, Van Aarde 1978), as well as from environmental heterogeneity.

Cats were widely distributed over most of the island (234 km²), up to the 450 m contour line (Fig. 2). The apparent absence of cats in the central montane region is ascribed to a lack of prey and the relatively inhospitable conditions. According to Van Zinderen Bakker (1971) only a few South Georgian diving petrels *Pelecanoides georgicus* nest in this area, a species which was only of minor importance in the diet of the cats (Van Aarde 1977).

Most sightings (86,9 per cent) were made in the study area (Fig. 1), due to greater observer activity there and the density of sightings for the rest of the island is probably underrepresented in Fig. 2. The relatively even spread of sightings within a few kilometres (shaded area in Fig. 2) of the Base Station at Transvaal Cove, may be due to the fact that this area surrounds the point of introduction, as well as increased observer activity and possibly the prevalence of suitable habitat types. Derenne (1976) also found a more even distribution of cats around the point of introduction (Port aux Francais), than elsewhere on Kerguelen.

Details of the sampling effort are given in Table 2. In spite of a disproportionate sampling effort (hours spent per grid block), the number of cats identified per hour in the coastal region (0,813) was higher than that observed in the interior region (0,238). This suggests that density in the coastal region was higher than in the interior region. Although it might be argued that the number of cats identified per hour was related to sampling effort, Jolly (1969) stated that if "one stratum is of greater interest than another, or has a relatively high density of animals, it is advisable to sample this stratum more intensively".

Crude and ecological densities per grid block (0,67 km²) and per km² are given in Tables 3 and 4. Of the 835 observations recorded in the main study area, 206 were resightings. Density estimates were therefore based on 629 individual cats that were identified. Crude and ecological densities for the interior region (1,31 and 4,98 cats per km²) were lower than for the coastal region (9,75 and 13,85 cats per km²). Crude and ecological densities for the three regions combined were 3,65 and 10,61 cats per km² respectively. The data in Table 4 indicate that 38,19 km² (70,4 per cent) of the entire coastal region was inhabited by cats, while only 20,10 km² (26,32 per cent) of the entire interior region was inhabited.

At Macquarie Island, Jones (1977) estimated a density of 4 to 7 cats per km² on the coastal slope and terrace. Density on L'ile aux Cochons was estimated to be 2,5 cats per km² during the winter months and 8 to 9 cats per km² during the summer (Derenne & Mougin 1976). Derenne (1976) estimated a density of 6,7 cats per km² for the area (900 km²) in which cats occurred on Kerguelen. The estimated ecological density at Marion Island is higher than that of any other studied population in the sub-Antarctic. However, density estimates for this species vary considerably. Hubbs (1951) reported a density of 12,5 cats per km² in rural America, while McDonald and Apps (1978) reported a figure of six cats per km² for English farm cats compared to 200 cats per km² in the Portsmouth Dockyard (Dards 1978).

Although the same habitat types occurred in both coastal and interior regions, with the exception of *Cotula*-hillocks, habitat specific densities in the former were significantly higher than those in the latter on grey lava slopes ($t = 1,06$; $P < 0,01$; $n = 15$), vegetated black lava ($t = 4,46$; $P < 0,01$; $n = 82$) and grey lava ridges ($t = 4,71$; $P < 0,01$; $n = 45$). Sample size ($n = 5$) precluded statistical analysis for volcanic cones. These differences were probably due to the presence of deeper and better drained soil in the coastal region, which enabled a greater concentration of burrowing petrels on which cats preyed extensively. The major factor determining density and distribution of the cats seemed to be the distribution of their prey species, rather than the availability of refuge and sheltering sites.

In spite of the abundance of subterranean shelter sites in barren black lava, hardly any cats were observed in it and very few petrels made use of it. In habitat types with suitable breeding sites for birds, but limited natural refuge for cats, the latter tended to use the burrows of their prey species for shelter and lairs (e.g. grey lava slopes and volcanic cones). On grey lava ridges, which constituted a relatively big portion of the coastal and interior regions (10,72 and 22,10 km² respectively), cats were not evenly distributed and tended to concentrate in the riverine valleys. Animals observed on the

Table 3
Crude densities per habitat type for each inhabited region in the study area on Marion Island

Region	Habitat type	Number of individual cats sighted	Crude density of cats: Number of grid blocks per habitat type	Crude density of cats: Density per grid block (mean±S.D.)	Crude density of cats: Density per km²
Coastal	Grey Lava Slopes	164	15	10,93 ± 11,89 (0-33)*	16,32
	Vegetated Black Lava	192	27	7,11 ± 9,56 (0-35)	10,61
	Cotula-hillocks	132	14	9,43 ± 12,13 (0-43)	14,07
	Volcanic Cones	17	2	8,50 ± 6,36 (4-13)	12,68
	Barren Black Lava	0	7	0	0
	Grey Lava Ridges	24	16	1,50 ± 1,67 (0-5)	2,24
	Total (combined)	529	81	6,53 ± 9,67 (0-43)	9,75
Interior	Grey Lava Slopes	5	2	2,50 ± 0,71 (2-3)	3,74
	Vegetated Black Lava	70	57	1,23 ± 2,09 (0-8)	1,83
	Volcanic Cones	19	3	6,33 ± 8,50 (0-16)	9,45
	Barren Black Lava	2	20	0,10 ± 0,32 (0-2)	0,16
	Grey Lava Ridges	4	32	0,12 ± 0,42 (0-2)	0,18
	Total (combined)	100	114	0,88 ± 0,88 (0-16)	1,31

*Range in brackets

Table 4
Ecological densities per habitat type for each region in the study area on Marion Island.

Region	Habitat type	Number of individual cats sighted	Ecological density of cats: Number of occupied grid blocks	Ecological density of cats: Density per grid block (mean±S.D.)	Ecological density of cats: Density per km²
Coastal	Grey Lava Slopes	164	13	12,62 ± 11,92 (1-33)*	18,83
	Vegetated Black Lava	192	21	9,13 ± 9,96 (1-35)	13,65
	Cotula-hillocks	132	12	11,00 ± 12,45 (1-43)	16,42
	Volcanic Cones	17	2	8,50 ± 6,36 (4-13)	12,69
	Barren Black Lava	0	0	0	0
	Grey Lava Ridges	24	9	2,67 ± 1,32 (1-5)	3,98
	Total (combined)	529	57	9,28 ± 10,37 (1-43)	13,85
Interior	Grey Lava Slopes	5	2	2,50 ± 0,71 (2-3)	3,74
	Vegetated Black Lava	70	22	3,18 ± 2,26 (1-8)	4,75
	Volcanic Cones	19	2	9,50 ± 9,19 (3-16)	14,18
	Barren Black Lava	2	1	2,00	2,99
	Grey Lava Ridges	4	3	1,33 ± 0,58 (1-2)	1,99
	Total (combined)	100	30	3,33 ± 3,16 (1-16)	4,98

*Range in brackets

flat, exposed ridges were probably strays from the river and stream valleys. The wide range in the number of cats identified per grid block for each habitat type is ascribed to topographical and geomorphological heterogeneities within each habitat type.

Population estimates

The shy, elusive, and mainly nocturnal activity of the cats made direct counting an impractical and unreliable method for obtaining an estimate of population size. The estimate was therefore based on region specific densities determined in the area of 32,8 km² (shaded area in Fig. 2) surrounding the Meteorlogical Station. Extrapolation of these data resulted in a population estimate of 2 136 adult cats (Table 5). However, due to the existence of a stratified density pattern, the population has been estimated at 2 139,86 ± 290,01 adults (Table 6, ± = S.E., Jolly 1969).

The population at Macquarie Island was estimated to be 250 to 500 in 1975 (Jones 1977), at L'ile aux Cochons, 400 individuals at the end of the 1975 summer season (Derenne & Mougin 1976) and at Kerguelen, 1750 (1500 to 2000) cats in 1971 (Derenne 1976).

Table 5

Maximum population estimate extrapolated from density estimates in the intensive study area (32,8 km²) within a few kilometres of the Base Station (see Fig. 2).

Region	Area surveyed (km²)	Number of individuals identified	Density (per km²)	Total area inhabited on island (km²)	Total population on island
Coastal	19,43	350	18,01	99	1 783
Interior	13,40	35	2,61	135	353
Total	32,83	385		234	2 136

Table 6

Population estimate based on Jolly (1969), where $\hat{Y}=\Sigma_I N_I \bar{y}_i$ and the standard error is $\sqrt{\text{var}(\hat{Y})}$.

Region	Total number of grid blocks (N_I)	Number of grid blocks surveyed (n_I)	Average number of cats per grid block ($\bar{y}_i$)	Estimate of population size ($\hat{Y}=N_I\bar{y}_i$)	Variance ($\hat{Y}$)
Coastal	148	29	12,07	1 786,36	76 387,50
Interior	202	20	1,75	353,50	7 720,44
Total	350	49		2 139,86	84 107,94
					$\sqrt{\text{var}(\hat{Y})}$ =290,01

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