ECOLOGY OF THE FERAL CAT *FELIS CATUS* ON GREAT DOG ISLAND.

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Submitted in Partial Fulfilment of the requirements for the
Degree of Bachelor of Science with Honours.

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Hobart
1992

'There are certain things in Nature in which beauty and utility, artistic and technical perfection, combine in some incomprehensible way: the web of a spider, the wing of a dragon-fly, the superbly streamlined body of the porpoise, and the movements of a cat'.

Konrad Lorenz

ABSTRACT

Aspects of the ecology of feral cats on Great Dog Island, Bass Strait, were investigated from May to September 1991. Population structure and dynamics, morphology and phenotypes, condition and gastro-intestinal parasites and diet were studied.

A culled sample of 189 feral cats displayed a male: female ratio of 1:1 and indicated a pre-eradication density of at least 56.9 cats/km^2. Juveniles and sub-adults made up 44.9% of the population. A breeding season was inferred by kitten age and by changes through time in the population structure. Approximate life expectancy was estimated to be 73-84 months for males and 85-96 months for females. Counting cementum annuli in the teeth was shown to be an effective method of age determination.

The length and weight of male and female feral cats of Great Dog Island was comparable to that of feral cats found on the mainland Australian. However, a decline in the weight of females between autumn and winter suggested the occurrence of a seasonal nutritional stress. The relationship between age and length in adult males suggests that greater length offers an advantage to longevity. The presence of seven mutant pelage-related genes, in addition to the wild type, indicated a comparatively high degree of genetic diversity within the feral cat population of Great Dog Island. The long hair allele is probably being selected against as juveniles suffer high mortality. The expression of the inhibitor allele is bias toward males. No significant relationships were found to occur between coat colour and weight or length.

The analysis of gut contents showed that a total of 26 species were ingested: 2 bird, 1 mammal, 5 reptile and 18 arthropod species. The gut of 16 cats were either empty or contained only residual food stuffs. Most cats had soil and plant matter in the gut. There was no evidence of cannabalism and no human refuse was present. It is likely that some arthropod prey were excavated. There was no advantage in age or body size in obtaining prey species.

Generally, the coat skin and tooth condition of cats on Great Dog Island was very good. The nutritional condition (fat deposits) of cats suggested that cats were generally in good condition in autumn. Both males and females underwent a large decline in fat reserves from autumn to winter and reserves were further depleted as winter progressed. This resulted in the general nutritional condition of the winter cats being poor.

Gastro-intestinal parasites present were *Taenia taeniaeformis*, *Toxocara cati* and *Cylicospirura felineus* . Parasite infestation was biased toward females. Loss of condition did not generally result in increased susceptibility to parasite infestation. This was instead better explained as a response to diet and climate.

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1 INTRODUCTION

1.1 INTRODUCTION

The domestic cat and humans have had a long association. Artistic representations of the cat in Egypt date back to 2000 BC, and a recent discovery of a cat jawbone in an archaeological site in Cyprus suggests that domestication of the cat may have begun as early as 6000 BC (Serpell, 1991). It is likely that all the modern domestic breeds of cats are descended from the north African sub-species of wild cat *F. silvestris libyca* (Serpell, 1991), although a few authorities argue in favour of some hybridization between the European subspecies of wildcat *F.s.silvestris*, the jungle cat *F. chaus*, and Pallas' cat *F. manul.* (Sunquist, 1991).

Domestic cats have had a chequered relationship with humans. Ancient Egyptians worshipped cat-headed goddesses and the cat was deemed a sacred animal, often being mummified. During the Middle Ages the domestic cat was associated with witchcraft and black magic, and subject to torture and extermination as a result (Serpell, 1991). By and large, cats were valued as predators of small mammal pests especially mice and a liaison between man and cat was developed. Consequently, the domestic cat has accompanied humans all over the world resulting in it being the most geographically widespread species of terrestrial mammalian predator. The domestic cat now occurs on all continents except Antarctica and has been introduced to a multitude of islands from the equator to the sub-Antarctic.

Unlike its larger cousin the lion *Panthera leo* or members of the dog family, domestic cats are not cooperative hunters and can therefore revert quickly to independence. The result of this is the presence of feral cats in probably all areas where it has been introduced. A feral cat is an independent domestic cat that survives and reproduces without a close association with man. However their degree of independence is very variable and different populations of feral cats can have different lifestyles (Jones, 1989). A population of remote feral cats may obtain food by hunting naturally occurring prey and maintaining numbers by reproduction. Alternatively a population of urban feral cats may obtain most of their food by scavenging human food scraps and can maintain their numbers by interbreeding with domestic cats, or by the recruitment of strays from the domestic population (Jones and Horton, 1984).

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Domestic cats were introduced into Australia with the first European settlers and cat populations on the southern islands probably arrived with sealers (Davies and Prentice, 1980). The dispersion of feral cats through mainland Australia was aided in the 1880's when thousands of cats were released to help control extensive outbreaks of the rabbit *Oryctolagus cuniculus* (Bayly, 1976, Davies and Prentice, 1980). Today, the feral cat is found in most terrestrial habitats and their distribution is Australia-wide (Jones, 1989).

The impact of the feral cat in different habitats is varied depending on the relative abundances of prey species. For example, the impact of the feral cat as a predator on populations of small mammals may differ if the prey species are introduced or native. On the Australian mainland, rabbits and mice *Mus musculus* generally occur at relatively high population densities. In these cases, heavy predation may do little more than remove a surplus of animals that were doomed, irrespective of predators (Coman and Brunner, 1972). In contrast, most of the smaller native mammal species have low population densities. Under these circumstances, losses due to predation by cats might be significant in reducing their populations (Coman and Brunner, 1972).

The high population densities of rabbit and mouse on the Australian mainland are rarely witnessed in Tasmania. Consequently, predation on the native fauna of Tasmania may be higher than that on the Australian mainland. Additionally, Tasmania, an island state, lacks foxes and dingoes. This presents a unique opportunity to study the role of the feral cat in isolation from canid predators. Tasmania is also a refuge for many species such as the eastern barred bandicoot *Perameles gunnii*, the tiger quoll *Dasyurus maculatus* and the eastern quoll *D. viverrinus* that are threatened with extinction on the mainland. There is an urgent need to determine for the effect of the feral cat on these species.

Effective management of a species requires sound baseline studies to describe the role and requirements of that particular species in its environment. Before decisions are made regarding the management of an introduced predatory species, such as the feral cat, it is important to establish the effect that the animal is having on native or introduced fauna and flora.

1.2 STUDY AIMS

There is little documentation about feral cats in Tasmania. The aim of this study is to address this issue by exploring aspects of the ecology of feral cats on Great Dog Island. This will be considered under four main themes, with each theme encompassing one chapter.

Theme one (chapter three) addresses population structure and and short-term dynamics, and asks the following questions:
1. What is the density of feral cats on Great Dog Island and how does this compare to densities of populations investigated in other studies?
2. What are the ages of feral cats on Great Dog Island? What points need to be considered for age estimation?
3. What is the age and sex structure of the cat population on Great Dog Island and how does it compare with studies on populations elsewhere?

Theme two (chapter four) addresses morphology and phenotypes and asks:
1. What size is obtained by feral cats on Great Dog Island? What relationships occur between age, sex, size and season?
2. What pelage (coat colour and length) related genes are expressed on Great Dog Island? How does the frequency of mutant alleles (as per Jones and Horton, 1984) compare with other feral cat populations?
3. Are there any relationships between pelage and weight, length, sex and age in the population of cats of Great Dog Island.

Theme three (chapter five) addresses the condition of the cats (both physical and nutritional) and the occurrence of gastro-intestinal parasites, and asks the following questions:
1. What is the general coat, skin and tooth condition of cats on Great Dog Island?
2. What is the nutritional condition of cats? Are there any differences in nutritional condition between animals of different sexes, lengths, and ages and season (Winter and Autumn)?
3. Which gastro-intestinal parasites occur on Great Dog Island? How does this compare to studies elsewhere?
4. Is the degree parasitic infestation related to nutritional condition, age, size, weight or sex of feral cats.

Theme four (chapter six) addresses the diet of the feral cats on Great Dog Island and considers the following questions:

1. What is the diet of the feral cat on Great Dog Island, and what hunting strategies are evident?

2. Does age, sex, body size or coat colour confer an advantage in obtaining prey species.

3. Are there any seasonal variations in the diet of feral cats.

Findings from this study will be summarized and suggestions for further research will be presented in chapter seven, 'Conclusions.'

2 GREAT DOG ISLAND

2.1 LOCATION AND STATUS

Great Dog Island is located in Franklin Sound, between Flinders and Cape Barren Islands in the Furneaux Group, off the north-east coast of Tasmania (see Fig. 2.1). The island is approximately 3.5 km. long, 1.5 km. wide, and has an area of about 332 hectares. The island is generally low lying, and is dominated in the east by Great Dog Hill (65 metres above sea level). It is classed as a conservation area and muttonbird (short-tailed shearwater) reserve, and is the third largest muttonbird *Puffinus tenuirostris* rookery in state. An estimated 900,000 adults arrive on the island each year after migration and produce an estimated 400,000 young. The muttonbirds of Great Dog Island are harvested commercially. The season commencing on the 27th. of March and closing on the 30th. of April results in an estimated 100,000 birds being harvested each year (I. Skira, Pers. Comm.)

2.2 HABITATION

There are no permanent residents on the Great Dog Island. One vacated homestead built about 75 years ago stands testimony to when the island was permenantly inhabited. Seven muttonbirders huts are on the island and are used during the muttonbird season (see Fig. 2.1).

2.3 GEOLOGY

Great Dog Island is granitic in origin. The medium to coarse grained sands derived from this rock enable the muttonbird to burrow over much of the island. Intrusions of basalt and fine grained dolerite were observed around the exposed shoreline of the island.

2.4 VEGETATION

The main vegetation type is a tussock grassland of *Poa poiformis*, interspersed with *Senecio lautus*, *Lomandra longifolia* and *Solanum laciniatum*. On both the north-east and south-east side there are mixed forests of She-oak *Casuarinna stricta*, Oyster Bay Pine *Callitris rhomboidea*, *Eucalyptus viminalis*, *Leptospermum scoparium*,

GREAT DOG ISLAND

Great Dog Hill

One Tree Hill

Homestead

N

	Poa poiformis
	Senecio lautus
	Solanium laciniatum
	Pasture
	Scrub/forest

● Muttonbirders huts

+ Fauna survey trap sites

0   1000m
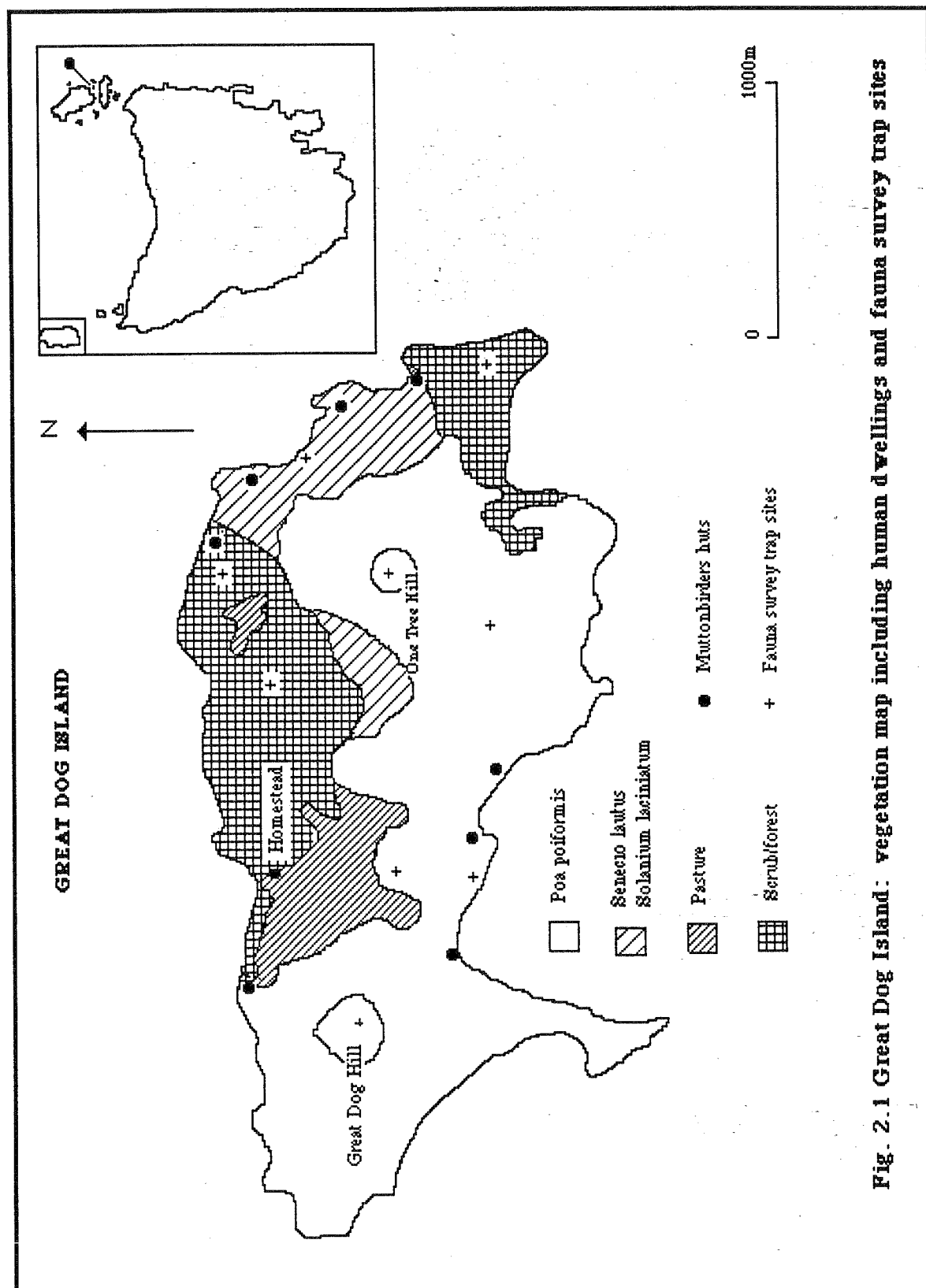
Fig. 2.1 Great Dog Island: vegetation map including human dwellings and fauna survey trap sites

L. laevigatum, *Acacia sophorae*, *A. mucronata*, *Melaluèca ericifolia* and *Bursaria spinosa*.

Surrounding the vacated homestead there are a few hectares under pasture. There is also small areas of pasture on One Tree Hill and in the north-eastern forest.

2.5 FAUNA SURVEY

A fauna survey of Great Dog Island was conducted in May 1992 (one year after the commencement of the cat eradication programme). Elliot and pitfall traps were placed at ten sites throughout the island (see fig 2.1). At each site, 5 Elliot and 10 pitfall traps were distributed randomly, except for one site which had only two Elliot traps (Great Dog Hill). The presence of fauna were also noted from direct observation and from field signs. Inclement weather throughout the survey time hampered data collection, especially the avifauna of the islands.

The vertebrate fauna on the island are listed in Table 1.1. Invertebrates are listed in Appendix 1.

Table 1.1 Census of Vertebrate Fauna found on Great Dog Island, May 1992.

MAMMALS.
Feral cat *Felis catus*.
House mouse *Mus musculus*.
Water rat *Hydromys chrysogaster*.
Black rat *Rattus rattus*.

REPTILES
Southern blue-togued lizard *Tiliqua nigrolutea*
Three-lined skink *Niveoscincus trilineata*.
Metallic skink *N. metallica*.
Spotted skink *N. ocelatus*.
Bougainville's skink *Lerista bougainvilli*.
Tiger snake *Notechis ater*.
Copperhead snake *Austrelaps superba*.
White-lipped whipsnake *Drysdalia coronoides*.

BIRDS
Little pied cormorant *Phalacrocorax melanoleucos*.
White-faced heron *Ardea novaehollandiae*.
Cape Barren goose *Cereopsis novaehollandiae*.
Brown falcon *Falco berigora*.
Pied oystercatcher *Haematopus longirostris*.
Sooty oystercatcher *H. fuliginosus*.
Silver gull *Larus novaehollandiae*.
Pacific gull *L. pacificus*.
Crested tern *Sterna bergii*.
Welcome swallow *Hirundo neoxena*.
Flame robin *Petroica phoenicea*
Grey fantail *Rhipidura fuliginosa*.
Tasmanian thornbill *Acanthiza ewingii*.
New Holland honeyeater *Phylidonyris novaehollandiae*.
White-fronted chat *Ephthianura albifrons*.
Green finch *Carduelis chloris*.

No amphibians were seen or heard on the island.

2.6 ERADICATION PROGRAMME

An eradication programme was commenced on Great Dog Island on the 25th. of May 1991 by the Department of Parks, Wildlife and Heritage in an attempt to rid the island of feral cats. 91 of the 189 cats (48.1%) caught between 25/05/91 and 16/09/91 were used in this study. These consisted of cats trapped over 11 days between late autumn and early winter (25/05/91-04/06/91, N=75), and cats trapped over 48 days from mid-winter to early spring (30/07/91-16/09/91, N=16). In this study, cats caught between late autumn and early winter will be referred to as 'autumn cats', while those caught between mid-winter and early spring will be referred to as 'winter cats'.

3 POPULATION STRUCTURE AND DYNAMICS

3.1 INTRODUCTION

A prerequisite for the management or study of any animal population is the determination of its age and sex structure. Such profile data, allows questions such as whether the population is declining or increasing and the likely fate of the population in the future can be addressed.

Pertinant questions in reference to the cat population of Great Dog Island are:
1. What is the density of feral cats on Great Dog Island and how does this compare to densities of populations investigated in other studies?
2. What are the ages of feral cats on Great Dog Island? What points need to be considered for age estimation?
3. What is the age and sex structure of the cat population on Great Dog Island and how does it compare with studies on populations elsewhere?

Data gained in this chapter will be used in chapter 4, Morphology and Phenotype, to determine what relationships occur, if any, between age, sex and size, and age, sex and phenotype; in chapter 5, Condition, to determine if there is a correlation between age, sex and nutritional condition and parasite load, and in chapter 6, Diet, to explore any relationship between age, sex and diet.

3.2 BACKGROUND ON AGE DETERMINATION IN MAMMALS

Many methods exist to determine the age of mammals. Ungulates are often aged by the sequence of tooth eruption and tooth wear, and by annular rings on horns. Examination of the sequence of epiphyseal fusion in bones has been used to age hedgehogs *Erinaceus europaeus* (Morris, 1971), and rabbits *Oryctolagus cuniculus* (Taylor, 1959). Eye lens weight has also been used for aging as this crystalline organ grows throughout life and does not shed cells (Larson and Taber, 1980).

Counting the incremental layers that occur in both the periosteum region of the mandible and the cementum of teeth (cementum annuli) is a common method of age determination in many mammal species. Studies on many mammals indicates that layers are deposited annually, yet the causative factor(s) for their formation is little

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understood. Kolb (1978), working on foxes *Vulpes vulpes* suggested that depositions of cementum annuli were due to 'endogenous effects', such as those related to the development and regression of the sexual organs or to the moult cycle rather than 'environmental factors' such as food shortage or severe climatic conditions. van Aarde (1983) reached similar conclusions from work on cats *Felis catus* finding that cementum lines occurred in the canine teeth of known-age samples even though these cats had been kept in captivity and had a constant food supply.

There are two ways in which cementum annuli can be examined. Firstly, the chosen tooth can be ground and polished then viewed under a dissecting microscope. This has worked particularly well on mammals with larger teeth, including the southern elephant seal *Mirounga leonina* (Carrick and Ingham, 1962), and the bottlenose dolphin *Tursiops truncatus* (Hohn *et al.*, 1989). Alternatively, for smaller teeth, the tooth usually needs to be decalcified, sectioned by the standard paraffin method or freeze microtome, stained and examined under magnification. This procedure has been applied to the red fox *V. vulpes* (Allen, 1974), the gray fox *Urocyon cinereoargenteus* (Root and Payne, 1984), the bobcat *Lynx rufus* (Crowe, 1972), and the domestic cat *Felis catus* (van Aarde, 1983).

The presence of periosteal lines in the mandible have been described in the hedgehog *E. europaeus* (Morris, 1970) and the rabbit *O. cuniculus* (Henderson and Bowen (1979) These were viewed under magnification after sectioning and staining . The adhesion or growth lines in periosteal bone lends itself to age determination procedures as the bone tissue is dense and wide, allowing well-defined annual lines to be deposited (Morris, 1970). However, because to teeth are relatively easier to obtain, the use of periosteal bone for aging is less frequent.

Weight has been used as a method to sort feral cats into age groups (i.e. juveniles, sub-adults and adults) on Macquarie Island (Brothers *et al.*, 1985), and on the Australian mainland (Jones and Coman, 1982c). The age groups were as follows; 1. Juveniles; male (< 2200g.), female (< 1900g.). 2. Sub adult; (essentially fully grown but not completed first breeding season), male (2200 - 3400g.) and female (1900 - 2500g). 3. Adults; (fully grown and completed one or more breeding seasons), male (> 3400g.) and females (> 2500g.). The ability to predict the age group in the feral cats of Great Dog Island will be investigated in chapter 4, Morphology and Phenotypes.

3.3 METHODS

3.3.1 Determination of the Density of Feral Cats on Great Dog Island

The density of cats was calculated by dividing the total number of captured cats by the area of the island.

3.3.2 Determination of the Sex of Feral Cats on Great Dog Island

Sex was determined by physical examination of the genitalia: the presence or absence of testes, and the relative distance from the external urinary opening to the anus. Further verification was made based upon the presence or absence of ovaries.
In addition to this, a data set compiled by the Department of Parks, Wildlife and Heritage during the eradication programme provided sex and weight details of those cats not forwarded for this study.

3.3.3 Determination of Age of Feral Cats on Great Dog Island

Age determination was carried out by counting cementum annuli in adult canine teeth and by tooth eruption and the presence of deciduous teeth in the juveniles. This method of age determination was chosen as it uses techniques that are known to provide satisfactory results. Due to time constraints alternative methods of age determination were not considered.

Juvenile cats generally obtain all their permanent teeth between six and seven months. Milk teeth are usually fully erupted at five weeks of age. They generally obtain 12 permanent incisors at four months, four canines at four and a half months and 14 molars between six and seven months.

For adults, the canine tooth from the right side of each mandible was removed with pliers and placed in a 5.0 ml. test-tube. A decalcification solution of 20 parts formic acid (98%), 3 parts formulin and 77 parts distilled water (Allen, 1975) was added to the test-tube to remove dentary calcium deposits, thereby softening the tooth for sectioning. After 3-4 days the portion of the tooth initially above the gum line was cut off and discarded. This allowed deeper penetration of the solution. Tooth hardness was checked twice daily. Initially, completion of decalcification was tested by inserting a needle into the tooth to check for hardness. This process however, proved inadequate as some teeth were unable to be sectioned. This was overcome with the use of a 5% sodium (Na) oxalate solution to check for calcium in the decalcification solution

(Humason, 1972). In this process, 1 ml. of 5% Na-oxalate was added to 5 ml of the decalcification solution. If a precipitate formed, calcium was still present. If the solution was clear, decalcification was complete. To avoid over-decalcification, once a tooth was softened enough for a needle to be inserted, the decalcifying solution was diluted to 87 parts distilled water, 10 parts formic acid and 3 parts formulin. This slowed the process, allowing completion to be detected before damage to the cementum annuli took place. Once decalcified, the teeth were nuetralized by washing in running tap water for 24 hours.

The decalcified teeth were sectioned, stained and mounted on slides by laboratory staff of the Anatomy Department of the University of Tasmania using established methods for the examination of bone tissue. This process is lengthy, taking approximately 5 days to complete.

The methods are as follows;

1. The Paraffin Method. This is a relatively simple process in which paraffin invades tissue after being placed under a vacuum. The paraffin acts gives support to the tissue enabling thin sections to be cut without the tissue collapsing.

   The decalcified teeth were dehydrated in 70% alcohol for 2 days, then placed in 95% alcohol for 3 periods of 2 hours each (6 hours in total), and left in 95% alcohol overnight. The following morning the teeth were placed in fresh 95% alcohol for one hour. Alcohol was then cleared out of the tissue with two changes of benzine (half an hour each), making the tissue suitable for cutting and staining. Paraffin infiltration of the teeth was completed in 3 stages. The teeth were initially placed in melted paraffin for 2 hours, then still in paraffin, placed under a vacuum of 10 in. Hg for one hour. The final stage consisted of 3 hours under a higher vacuum of 25 in./Hg. Prepared teeth were placed in a mould, embedded in paraffin and left for 24 hours to set. Serial sections 10 microns thick were obtained using a rotating microtome.

2. Staining. (a) The sections were floated onto sub-slides (slides covered in gelatine and chrome alum) and processed through two changes of xylene for 10 and 5 minutes respectively to ensure the tooth sections were cleared. This was followed by two changes each through 100, 95 and 70% alcohol and then into water. Staining was accomplished by immersion in Mayers haematoxylin for 30 minutes, washing for 20 seconds, then immersion in eosin for 2 minutes followed by a quick rinse in water. The mounted sections were then placed in 70% alcohol for approximately 20 seconds (or '20 moderate swishes'), then taken up through 5

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minutes in 95% alcohol, 2 changes in absolute alcohol, and 2 changes of xylene at 5 minutes each. Coverslips were then added and the slides dried. The sections were then ready for examination.

(b). A related staining procedure was investigated for comparison with the fore going. Thirty cat mandibles were selected randomly from the larger sample and the remaining canine tooth from each was removed and decalcified using the above technique. Also a transverse section 5 mm from 10 mandibles, was removed from directly behind the molar and decalcified. The teeth and the mandible sections were then processed using protocols derived from Thomas (1977). Once decalcified and neutralized, tooth sections 30 microns thick, and mandible sections 50 microns thick, were obtained using a freeze-microtome. Staining was achieved by immersing sections for 60 minutes in a 0.04% solution of toluidine blue. Sections were then ready for examination.

The canine teeth from two control cats of known-age cats (10 months and 16 months) were processed using the freeze-microtome/ toluidine blue method.

The cats were placed in one of the 10 age classes recognised by van Aarde (1983), and were categorised as follows:

Age class I (0-7 months), presence of deciduous (referred to as juveniles).

Age-class II (8 to 12 months), permanent teeth, open-rooted canines with no cementum lines (referred to as sub-adults).

Age class III (13-24 months), the presence of one cementum line.

Age class IV (25-36 months), the presence of two cementum lines.

Age class V (37-48 months), the presence of three cementum lines.

Age class VI (49-60 months), the presence of four cementum lines.

Age class VII (61-72 months), the presence of five cementum lines.

Age class VIII (73-84 months), the presence of six cementum lines.

Age class IX (85-96 months), the presence of seven cementum lines.

Age class X (97-108 months), the presence of eight cementum lines.

Age classes III to X referred to as adults.

One canine tooth from the mandible from each of three adults were also ground, polished and examined under a dissecting microscope to determine if annuli could be viewed by this simple method.

Fusion of epiphyses in the lumbar vertebrae was also to be investigated as a method of age determination, however, the lack of known age material for correlation purposes made this impossible and the procedure was abandoned. Combined eye lens mass

was not considered as this method of age determination has been dismissed as unreliable (van Aarde, 1983).

3.4 RESULTS

3.4.1 Density and Sex Ratios of Feral Cats on Great Dog Island

A total of 189 feral cats was obtained during the eradication programme. Assuming uniform dispersion, the cat density on the island was therefore estimated at 56.9 per km^2.

Of these cats, 95 were male and 93 were female, a ratio of 1: 0.98, and not significantly different from unity ($x^2 = 0.022$, 1.d.f.; $P < 0.1$). The sex of one kitten was undetermined.

Of the 189 cats trapped, 91 were forwarded for this study; 53 were male and 38 were female, a ratio of 1: 0.72. The 98 cats not forwarded for this study, composed of 42 males and 55 females, a ratio of 1: 1.31. Neither of these departures from unity were statistically significant ($x^2 = 2.48$ and 1.73, 1.d.f., $P < 0.1$ respectively.).

However, within the autumn cats (N=75) significantly more males than females were trapped ($x^2 = 5.88$, 1.d.f., $0.01 < P < 0.05$). The sample of 16 cats caught later in the season (the winter cats) included 11 females, but the sample size was too small to be confident of a meaningful sex ratio.

Three male cats were bilaterally cryptorchid, i.e. the testes had failed to descend into the scrotum. The nipples of two female cats were extended, indicative of lactation. No embryos were found *in utero*. The ovaries were not examined for corpora lutea, nor were seminiferous tubules examined for the presence of spermatozoa.

3.4.2 Age Classes of Feral Cats on Great Dog Island

Both methods of sectioning and staining canine teeth enabled cementum annuli to be successfully viewed. Annuli were observed from the root tip to approximately half way along the tooth section (see Fig. 3.1).

The initial problem of adequately assessing tooth hardness resulted in data from two male cats being lost.

1.mm

Fig. 3.1 A Section from the Lower Canine Tooth of a Feral Cat.
One annuli can can be seen in the cementum layer.

The results of tooth sections from the two known-age cats, support the notion that the deposition of cementum lines occur yearly. The 10 month old cat had open-rooted canine teeth with no cementum lines, while the 16 month old cat had one cementum line. No variations in the number of annuli were detected between right and left canine teeth. The sexes of these cats were unknown, but it is assumed that no variation in the deposition of annuli is likely between sexes.

The age-sex structure of the cats was the determined and summarized in table 3.1.

TABLE 3.1. Age-sex structure of 89 Feral cats from Great Dog Island Age classes after van Aarde (1983).

Age Class	Estimated age	Males	Females	Total
I	(< 7 months)	12	8	20
II	(8-12 months)	12	8	20
III	(13-24 months)	7	6	13
IV	(25-36 months)	6	2	8
V	(37-48 months)	2	5	7
VI	(49-60 months)	6	4	10
VII	(61-72 months)	5	2	7
VIII	(73-84 months)	1	1	2
IX	(85-96 months)	0	1	1
X	(97-108 months)	0	1	1
Total		51	38	89

Juveniles (age class I) made up 22.5% of the sampled population, and accounted for 23.5% of the male and 21.1% of the female populations. Of these cats, 6 were estimated at 4-6 weeks of age (4 males and 2 females), 12 were estimated at 13-16 weeks of age (7 males and 5 females) and 2 were estimated at 6 months of age (1 male and 1 female). Cats ≤ 12 months of age (age classes I and II) made up 44.9% of the population. 47.1% occurred in the male and 42.1% in the female populations. The cats ≤ 24 months, made up 59.6% of the population. This age group accounted for 60.8% of male and 57.9% of the female populations.

Two lactating females were in age classes III and VI respectively.

3.4.3 The Use of Cementum Lines as a Method of Age Determination

The presence of annuli in the teeth of well-fed domestic cats suggests that cementum depositions are an endogenous response and not due to seasonal restrictions of food supply (van Aarde, 1983).

The use of cementum annuli is a relatively simple method for estimating the age of cats. For veiwing annuli, both the techniques described above are equally effective. However, for practical purposes, the use of metachromatic staining techniques as described by Thomas (1977) is a less expensive method, both in time and money, especially if the sections are to be discarded after use. Once teeth are decalcified, the sectioning, staining and examination of teeth can be achieved in the same day. With practice in the use of a freeze-microtome, 25-30 teeth per day should be achievable. Although dehydration to permanent slides is feasible the rest line sharpness and colour contrast between rest lines and background cementum is impaired (Thomas, 1977).

Points to be considered concerning the use of cementum annuli in this study are: 1. Lack of known age material. 2. Variations in the structure of annuli (Dapson, 1980) and 3. Over-decalcification during preparation.

1. An underlying assumption in determining age is that deposition of annuli occurs yearly. During this study, attempts were made to acquire known-age samples of cat teeth to validate predictions of age based on annuli counts in feral animals. However, only two known-age pairs of canines became available. The presence of one cementum line in the 16 month old cat, and none in the ten month old cat, support the finding of van Aarde (1983) that reflect a pattern of yearly deposition. Canine teeth from older known-age cats need to be obtained to validate the older feral cat age classes.

2. A second problem is variation in annuli structure. These are largely due to splitting or fusing of the annuli, or to variations in clarity between annuli. This was overcome by counting cementum annuli at the root tip and tracing the lines along the body of the tooth. Annuli that split along the length of the canine section were counted as one, while annuli that fused along the length of the section were considered seperately. For example, if two annuli fused, they were counted as two not one annuli. Variations in clarity or contrast were treated in the same manner. Also, for each tooth, at least four sections were examined so as to eliminate any variations that may occur within one section.

3. Over-decalcification of the canine teeth was avoided by regular monitoring. As mentioned previously, when tooth decalcification was nearly complete (as tested by the ability to insert a needle with only slight resistance) the decalcification solution was diluted to slow the process. This allowed completion of decalcification to be detected before damage to tooth tissue took place. Needles were inserted at right angles to the longitudinal plane of the tooth. This allowed the hardness of the tooth to be tested, while minimising tissue damage to the plane at which the teeth would be later cut.

Cementum annuli were unable to be seen adequately in canine teeth that were ground and polished. Thus sectioning, staining and examination under transmitted light is the simplest method by which cenentum annuli can be viewed.

Adhesion or growth lines occurred in the periosteal region of the selected cat mandibles. For each cat, the number of adhesion lines appeared to correspond with the number of cementum annuli in the tooth. This suggests that the age of cats may be able to be determined by using these structures. These lines are thick, and so are more easily observed than cementum annuli in teeth.

3.5 DISCUSSION

3.5.1 Density of Feral Cats on Great Dog Island

The calculated population density of 56.9 cats/km^2 on Great Dog Island is generally higher than densities reported for non-urban feral cats elsewhere. In north-west Victoria, a mean winter density of 0.7 cats/km^2 and a mean summer density of 2.4 cats/km^2 was reported by Jones and Coman (1982). Herekopare Island 1.2 cats/km^2. (Fitzgerald and Veitch, 1985) Cats on New Zealand farmland had an average density of between 3.5 cats/km^2 (Langham and Porter, 1991). van Aarde (1986) reported 13.8 cats/km^2 in the coastal region and 4.9 cats/km^2 in the interior of Marion Island in the southern Indian Ocean. Dassen Island off the coast of South Africa had densities of 48 cats/km^2 (Apps, 1986). Fish dumps in Japan have been reported to have up to 2000 cats/km^2 (Liberg and Sandell, 1988). Clearly cat populations display great variation in density.

3.5.2 Factors Influencing the Density of Cat Populations

The density of cats is correlated with the availability and the dispersion of resources (Carr and Macdonald, 1986), primarily the abundance of food, and secondarily the availability of shelter. The distribution of prey species was a major factor in determining the density and distribution of cats on Marion Island, South Africa. The cats utilized the burrows of prey for shelter and lairs in preference to natural refuge and sheltering sites which were limited in the area directly, but readily available where prey species were less abundant (van Aarde, 1979). Jones and Coman (1982c), agreed that densities may be related to prey availability as feral cats were most abundant on those islands which contained large populations of burrowing petrels.

Although direct comparisons are difficult to make, Liberg and Sandell (1988) related general prey availability to three density categories and found that densities of more than 100 cats per km² were found in areas rich in food such as garbage and fish dumps. 5-50 cats per km² were found in areas of more limited food supply, such as farms, other households or bird colonies on oceanic islands. Less than 5 cats per km² were generally found in areas where food is scarce, dispersed or patchy.

The relatively high densities of cats reported here implies that food items were readily available on Great Dog Island for at least a substantial part of the year. Adequate shelter is available in the form of *Poa poiformis* tussocks.

3.5.3 Implications of High Cat Densities

The high density of cats on Great Dog Island raises questions of interactions within the cat population and issues such as the size of home ranges. Simply stated, the home range is that area in which all normal requirements of the animal such as food, shelter and reproduction, are met.

The sizes of the home range of cats vary according to sex, prey distribution, and energy and reproductive requirements. Home ranges in the Orongorongo Valley, New Zealand, averaged 80 hectares for females and 140 hectares for males (Fitzgerald and Karl, 1986), while home ranges in the Galapagos Islands ranged from 82 hectares for females and 304 hectares for males (Konecny, 1987). The mean home ranges of feral cats in north-west Victoria, were 6.2 km² for males and 1.7 km² for females (Jones and Coman 1982c). On Dassen Island, with a similar density of cats as Great Dog Island, the mean ranges were 44 hectares for adult males 19 hectares for adult females and 18 hectares for juveniles (Apps, 1986).

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Home ranges are most often not exclusive to an individual animal. They may overlap with others of the same sex depending on available resources, and adult males will tend to encompass, and be dominant over, the ranges of a group of females which are potential mates. Members of the same group may use the same path, but are separated temporally to avoid conflict (Langham and Porter, 1991). Within each range lies a smaller core area or territory, which may be exclusive and defended, or alternately, intruders may be tolerated if they retreat before the territory holder and do not attempt to utilize resources within the territory (Konecny, 1987). For example, females probably have an area that becomes exclusive for den sites (Langham and Porter, 1991). Territorial behaviour then, is affected by resource availability. Where resources are unlimited, territoriality has no advantage. At lower resource levels territoriality ensures at least minimal requirements, however, at extremely low resource levels, territoriality becomes too expensive to maintain (Carpenter and MacMillan, 1976). As females tend to have smaller home ranges than males but have equivalent energy needs during pregnancy and lactation, Konecny (1987) reasoned that they should select areas of high productivity and be intra-sexually more exclusive. This was found to occur as female range overlap was significantly less than male overlap (Konecny, 1987).

The size of home range and territory may also be important in evolutionary terms. Langham and Porter (1991) propose that males holding territories large enough to include several mature females will tend to produce more offspring than those with smaller territories. Additionally, females in groups are more easily defended than dispersed females, thus reducing energy expenditure (Konecny, 1987). This improvement of evolutionary fitness by defending groups of females has been referred to as female-defence polygyny (Emlen and Oring, 1977).

Dassen Island, with a high density feral cat population, had ranges that were neither exclusive nor defended, nor was there evidence to suggest that dominance relationships changed with location (Apps, 1986). This could be due to the formation of a heirarchical system which may occur at high densities. Young males establish a place in the heirarchy or dominance order system after initial fighting (Liberg, 1980). Once this place is established little fighting occurs.

However, the cat is not exclusively solitary because groups of cats are frequently observed. Most of the cats on Marion Island were reported to be solitary but groups of 2 to 5 were noted. This grouping was not confined to the breeding season, and may be related to thermoregulatory behaviour (Skinner et al., 1978). Of cats studied in north-west Victoria by Jones and Coman (1982c) 18% occurred in groups of three

or more, but always with a single adult. Groups of two adults consisted of one male and one female, and family groups were comprised of an adult female and subadults. The sub-adults were never more than an estimated 7 months of age. Liberg (1980), studying spacing patterns of feral and domestic cats in southern Sweden, found that three quarters of females lived in social groups with at least one other female.

In view of their high density, it is possible that the cats on Great Dog Island had a heirarchical system as food is assumed to be abundant for most of the year and home ranges would have greatly overlapped. Defence of a territory may have been impractical. (The question of conflict between cats is adressed in the Morphology Section of chapter 4 as general body condition will be discussed).

3.5.4 Sex Ratios of Feral Cats

The ratio of males to females (sex ratio) on Great Dog Island did not differ from unity, and is similar to sex ratios in north-west Victoria (Jones and Coman, 1982c) and Marion Island (van Rensburg, 1986). However, sex ratios departing significantly from unity have been recorded elsewhere. A surplus of females (0.63: 1) in a population of rural free-roaming cats was noted in southern Sweden (Liberg, 1980), whereas, sex ratios on Macquarie Island (Brothers et al., 1985) and the Galapagos Islands and other archipeligoes (Konecny, 1987) were male dominated (1: 0.80, and 2.62: 1 respectively), perhaps due to greater nutritional and reproductive stress imposed on females on small islands (Konecny, 1987).

Although the overall sex ratio for cats on Great Dog Island did not differ from unity, the 75 cats trapped in autumn were significantly bias toward males of all age groups. Trapping on Marion Island (Skinner et al., 1978) and Macquarie Island (Jones, 1977) also yeilded a bias toward adult and sub-adult males. Reasons for this could be that:
1. A bias was present in the inital sampling.
2. Females are initially more trap wary than males. The swing to a near 1:1 sex ratio later in the trapping season may be hunger driven, with females more willing to take baits as food availability declines.
3. Males are more curious or adventurous than females and are thus more likely to enter traps (i.e. are more trappable).

The presence of males of all age groups also implies that a new food source (e.g. a bait) may not be the exclusive property of larger or heavier individuals and so a social organisation on the island, if present, may be only loosely structured. Further studies may shed light on these questions.

Again the implication arises that food availability on the island is generally adequate, as male dominated ratios seem to occur where the population experiences greater nutritional stress (Konecny, 1987). The nutritional status of the sampled cats is investigated further in chapter 5, Condition.

3.5.5 Age Structure of Feral Cats on Great Dog Island

The age stucture indicates that this population may be increasing, as 44.9% of cats are juveniles and sub-adults. The absence of extended nipples and embryos *in utero* suggested that females aged less than one year had yet to produce their first litters, even though most had attained the size of females those in older age classes.

Once adulthood is achieved, both sexes undergo a general decline in numbers through each age class. For males, two periods of marked decline occured. These are between age classes II and III, and age classes VII and VIII. Male cats leave home between 1 and 3 years of age (Liberg, 1980). van Aarde (1983) reported high mortality in male cats during the 36 month period following adulthood and suggested that this is the time between the male leaving the social group and establishing itself as a 'competitive male'. On Great Dog Island, the critical period seems to be the first year of adulthood with mortality levelling off in later years. Assuming that food availability is reduced during the winter, the first decline may be due to the inability of the young adult male to acquire adequate foodstuffs or fat reserves to service energy demands during its first winter. This is occurring while the male is either still associated with its mother or independant of the maternal group. With the exception of age class V, the relatively low decline in adult male numbers between age classes III and VII suggests improved ability to acquire sufficient foodstuffs and/or fat reserves to last the winter. The presence of only one cat in age class VIII and none in age class IX and X implies that the probable maximum life expectancy of a male cat on Great Dog Island is 73-84 months (6-7 years).

Three adult-sized males in age class II were bilaterally cryptorchid, and therefore probably infertile (Robinson, 1977). It is possible that the lack of mature age cats displaying this disorder may signify that it reduces survival to adulthood. Jones and Coman (1982, b) found one case of cryptorchidism in a sample of 88 male cats from south-eastern Australia.

With the exception of age class IV, the female population displayed no marked decline between any age classes. The lack of a decline between age classes II and III,

may be the result of females maintaining a family group. Remaining in groups probably does not increase the chances of young adults acquiring adequate foodstuffs of fat reserves but it may be beneficial in thermoregulatory behaviour as suggested by Skinner *et al.* (1978). Cats huddling in shared resting places will not expend as much energy on maintaining body temperature as solitary cats,and therefore fat reserves and energy acquired from foodstuffs will last relatively longer. This may in turn explain the longevity displayed in females. This explanation has yet to be tested. The energetic cost of reproduction must be quite high for females as the mother has to gain adequate nourishment for both herself and her litter. This may explain the steady decline of females through their reproductive years. Contrary to van Aarde (1993), the females on Great Dog Island may outlive the males with one female in age class IX (85-96 months) and one in age class X (97-108 months).

It is probable that juvenile mortality is quite high in both sexes. Less than 43% of juveniles on Macquarie Island survive to adulthood, but those born earlier in the season are more likely to survive (Brothers *et al.*, 1985). This supports the proposition that the accumulation of fat deposits increases the chances of survival through the first winter as these cats are larger and better able to acquire these reserves.

The maximum ages reached by cats on Great Dog Island are comparable /with the 8 and 9 years for females and males respectively on Marion Island (van Aarde, 1983). However this is much lower than ages reached by pet domestic cats, which can exceed 20 years (Robinson, 1977, Comfort, 1956). van Aarde (1983) suggested that the longevity of Marion Island cats was short due to their exposure to severe environmental stresses, as reflected in high mortality rates in their first year of life.

3.5.6 Seasonality of Breeding in Feral Cats on Great Dog Island

The results suggest that breeding on Great Dog Island is seasonal. The autumn population consisted of juveniles, sub-adults and adults. Two females had extended nipples suggesting they were still lactating and implying the presence of unweaned juveniles. No females were pregnant implying the breeding season had ceased. The winter population consisted of adults and one sub-adult. No juveniles were present and no females were lactating or pregnant.

Seasonality in breeding may be a general phenomenon on temperate islands. Brothers *et al.* (1985) described the breeding season on Macquarie Island as markedly seasonal with females pregnant only between 6 October and 26 April, and lactating between 9 December and 26 May. This supported the observation by Jones (1977) that most

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births occur from November to March. Seasonality is also evident on Marion Island. From December to February the population consisted of juveniles and adults. As juveniles mature from March to May and young litters are still present, the population structure changed to juveniles, sub-adults and adults. From May to September, only adults and sub-adults occur, marking the end of the breeding season and the recruitment of juveniles to sub-adults. Between May and September, there is a decrease in the number of sub-adults as they are recruited into the adult population (Skinner *et al.*, 1978).

However in south-eastern mainland Australia, the season was less defined with births recorded in all months except April (Jones and Coman, 1982b). Most births occurred between September and March especially in early spring (September and October), and early summer (December and January). From October to January all females caught were pregnant or lactating (Jones and Coman, 1982b).

The ages of juvenile cats indicated that births on Great Dog Island occurred between November and mid to late April. Of the 20 juveniles, 12 were estimated to be born during February, while 6 were born between mid and late April. The oldest 2 juveniles were estimated to have been born in November.

3.6 SUMMARY

1. The density of cats on Great Dog Island was estimated at 56.93 cats per km^2. This is generally much greater density than reported for non-urban feral cats.
2. This implied that food items were readily available on Great Dog Island for a substantial part of the year.
3. The factors influencing and implications of high densities were discussed, such as the effect on home range size and social systems.
4. A balanced male: female sex ratio (1: 0.98) was apparent. Evidence for elsewhere suggests that male dominated ratios may occur where the population experiences greater nutritional stress. This is further evidence that food items are available at least for a substantial part of the year.
5. Counting cementum annuli in the teeth was shown to be an effective method of age determination. By comparison with two known-age samples and incorporating the findings of van Aarde (1983) 89 cats were assigned to estimated age classes.
6. The age structure of the sampled cats was that of an increasing population with a strong recruitment of juveniles. Juvenile mortality may be high, especially in the the first winter.

7. Age-sex structure and life histories were comparable to that of other feral cat populations.

8. Complications in the use of cementum annuli include: i. Limited access to known age material. ii. Variations in the structure of annuli, and iii. Over-decalcification.

4 MORPHOLOGY AND PHENOTYPES

4.1. INTRODUCTION

The aim of this chapter is to determine the size and phenotypes of the feral cats on Great Dog Island, and in doing so to address the following questions:

1. What size is obtained by feral cats on Great Dog Island? What relationships occur between age, sex, size and season?
2. What pelage (coat colour and length) related genes are expressed on Great Dog Island? How does the frequency of mutant alleles (as per Jones and Horton, 1984) compare with other feral cat populations?
3. Are there any relationships between pelage and weight, length, sex and age in the population of cats of Great Dog Island?

Information gained in this chapter will be used in chapter 5, Condition, to determine what relationships, if any, occur between size and phenotype on the condition and/or parasite loads of feral cats, and in chapter 6, Diet, to determine if what relationships, if any, occur between size, phenotype and diet.

4.2. BACKGROUND: THE PELAGE GENETICS OF CATS

Cats display visible polymorphisms, or variable traits, in regards to coat colour, pattern, fur texture (Todd, 1977), and body conformation (Robinson, 1977). The cat 'type' to which all coat colours, patterns and textures are compared is the short-haired mackeral tabby (Robinson, 1977). This cat type possesses a rufous-grey ground colour coat (a colour known as agouti) under even, gently curving vertical stripes. The hair shafts on the agouti are not a solid pigment but are banded and/or tipped with yellow (Robinson, 1977). This coat type is the same as that found in the European wild cat *Felis sylvestris* and is referred to as the wild or non-mutant type. Polymorphism is due to the expression of genes or combinations of genes that are mutants of the wild or non-mutant type. The allele (one of two or more alternate forms of the gene) of the wild type is commonly designated the symbol (+).

Pairs of alleles commonly found in domestic cats, as derived by Robinson (1977) and Kinnear (1980), are:

1. Striped (t^+) vs. blotched (t^b). These designate the types of striping expressed. The striped pattern is that seen in the mackeral tabby. The blotched type differs from the striped in that the stripes are wide and form curls or whorls. Mackeral is dominant to blotched.

2. Agouti (a^+) vs non-agouti (a). This gene is involved with the distribution of pigment along individual hairs. The agouti allele places a light band on the tip of the hair. The non-agouti allele eliminates the light tip, leaving the hair shaft uniform in pigmentation, and is most commonly seen in the black cat. Agouti is dominant to non-agouti.

3. Dominant piebald (white) spotting (S) vs. non-spotted (s^+). The S allele is epistatic (i.e. dominant) to melanic alleles and if present will express itself. A cat which is homozygous SS will have extensive spotting and may sometimes appear, for example, to be a white cat with patches of pigmentation on the head and/or back and tail. A cat which is heterozygous Ss will have less extensive spotting, for example, on the feet, neck, chest, and abdomen. However, the expression of small white patches on the ventral surface may be due to the effect of genes other than that of piebald spotting. Spotting is due not to the presence of a pigment but to the lack of pigment.

4. Short hair (l^+) vs. long hair (l). The long hair allele is recessive to the short haired wild type.

5. Intense (d^+) vs. dilute (d). This gene controls the density of pigment along the shaft of hair, with the homozygous recessive dd acting to dilute pigment. This results in self or one-coloured cats being diluted from, for example, black to grey or blue, and orange to cream.

6. Inhibitor (I) vs. non-inhibitor (i^+). These are the alternate alleles to another gene which affects pigment. The action of the I allele is virtually opposite to that of the agouti allele in that it restricts pigmentation to the tip of the hair shaft. The effect of this allele can be seen for example in smoke coloured cats in which a lighter zone of fur can be seen when the fur is parted. The I allele is also responsible for the coat of silver tabbies, which almost appears to be a very light smoke with striping. I is dominant to i^+.

7. Orange (O^o) vs. non-orange (O^+). The orange alleles are sex-linked and located on the X-chromosome. A male cat, (having one X-chromosome), can be either of two genotypes; i.e. orange (O^o) or black (O^+). On the other hand, a female (having two X-chromosomes) can be one of three genotypes; orange ($O^o O^o$), black ($O^+ O^+$), or tortoiseshell ($O^o O^+$).

8. The fur of an all white cat is unpigmented. The alternate alleles for this gene are;

all-white (W), or non-white (w⁺). Non-white is recessive to all-white. The all-white in combination with unilateral or bilateral blue eyes is associated with deafness, as it is with other mammals.

Many of these genes are also found in the feral populations (Jones, 1989). Gene frequencies of these alleles have been reported for a group of feral cats from an agricultural habitat in Tasmania (Dartnall, 1975) and for various habitats in south-eastern Australia, including Macquarie Island (Jones and Horton, 1984).

Polymorphism has been implicated in the survival of the feral cat in various environments. The most frequently occurring alleles of feral cats throughout much of the semi-arid and arid areas of inland Australia are striped and agouti (the wild type), although blotched, orange and piebald spotting also occur (Jones, 1989). This may be due to this phenotype being more cryptic in this environment and so increasing either its success rate in capturing prey and/or its ability to avoid predators when young.

Increasing darkness in the coat colour of cats has been associated with a decrease in body weight. On Marion Island, the wild type were significantly heavier than those carrying the blotched allele (Jones and Horton, 1984). Increasing darkness has also been associated with decreased adrenal activity, indicating coat colour genes having plieotropic effects on physiological parameters, these in turn may influence behavioural patterns (van Aarde, 1986). One such behavioural pattern is the tolerance of high population densities. It has been noted that some domestic cat populations show progressive increase in dark colouration with increasing urbanisation (Jones and Horton, 1984). This has been recorded for example in the United Kingdom and Eire where the smallest darkest animals were the best adapted to high population levels (van Aarde, 1986). It is also suggested that darker phenotypes, such as blotched tabby and black, are better adapted to severe environmental conditions, such as low temperatures and high wind and rainfall, as the phenotypes and associated plieotropic effects act to abate a presumed cold stress (van Aarde and Robinson, 1980). For example, the frequency of darker mutant alleles was higher at sub-Antarctic Marion Island than were other populations recorded. This has been attributed both to founder effect and to selective advantage under prevailing conditions (van Aarde, 1986). However, there was no significant difference in the frequencies of non-agouti cats between Macquarie Island and Hattah-Kulkyne Park. The former a sub-Antarctic island and the latter located in semi arid north-western Victoria where no cold stress would occur (Jones and Horton, 1984).

However, some phenotypes are either absent or less common in feral populations. The presence of the all-white phenotype has not been scored in studies on feral cat populations on mainland Australia and Macquarie Island (Jones and Horton, 1984), Marion Island (van Aarde and Robinson, 1980) or in rural Tasmania (Dartnall, 1975). Possible reasons for its absence are varied. Firstly, auditory cues are a major component of the hunting strategy of the cat. As this phenotype in combination with unilateral or bilateral blue eyes is associated with deafness, it is placed at a distinct disadvantage. Secondly, the conspicuous nature of this phenotype may make the cat itself, especially the young, more prone to predation, while the lack of a cryptic coat colour may serve as a warning to potential prey. Thirdly, these cats are susceptible to certain kinds of skin cancer (Todd, 1977).

Long hair is seldom associated with feral populations as problems such as grooming and drying after rain would place this character at a disadvantage (Dartnall, 1975). Dominant piebald spotting is also not common in feral populations and may be due to the conspicuous nature of this phenotype.

In general, genetic diversity in populations of feral cats is greater when associated with rural or settled areas as these areas have a greater number and variety of domestic cats. These domestic cats maintain a flow of genes to the feral population that may otherwise be selected against. As a result, there is a slower rate of removal of any less fit genes due to reduced pressure from natural selection. The absence of phenotypes in feral populations is either due to those genes not present in the founder population or to their subsequent loss (Jones and Horton, 1984).

Population genetics involves itself not with the phenotype frequencies but with mutant-allele frequencies. The reason for this is that it is the gene pool which is evolving, cats are just the transient package of this information. When compared, the frequencies of each are quite different due to interactions between traits and paths of inheritance (Todd, 1977).

4.3. METHODS

The assessment of morphology and phenotypes involved the following. Each cat was weighed with the use of spring scales to the nearest 100 g. Body and tail length were measured to the nearest 2.0 mm using a tape measure. Body length was measured in a straight line between the tip of the nose and anus. Tail length was measured from the anus to the tip of the tail. All other measurements were to the nearest 0.5 mm using vernier calipers. Head length was measured between the widest points of the

premaxilla and occipital bones (along the median sagittal plane). Head width was measured between the widest points of the temporal bones (along the trransverse plane). The dimensions of the mandible (removed for age estimation as described in chapter 3) were also recorded. Mandible length was measured between the angular process and the anterior of the mandibular symphysis. The ramus height was measured between the angular process and the coronoid process. The condyloid process was measured between the widest points. Mandible height and width were measured at the widest points directly posterior to the molar tooth.

For each cat heavier than 1000 g the following pairs of mutant alleles were determined and scored by visual examination: striped (t^+) vs blotched (T^b); agouti (a^+) vs non-agouti (a); orange (O) vs. non-orange (O^+); dominant piebald spotting(S) vs. non-spotted(S^+); short hair (L^+) vs. long hair (L); intense (d^+) vs. dilute(d); and silver (I) vs. non-silver (i^+).

Recessive mutant frequencies (q) were obtained by taking the square roots of the corresponding phenotypic frequencies, and dominant mutant frequencies (p) were obtained from (1-q). Standard errors were calculated from the expression $\pm\sqrt{[(1-q^2)/4N]}$ (Jones and Horton, 1984) and $\pm\sqrt{[(2-p)p/4N]}$ (van Aarde and Robinson, 1980) where N = the total number of cats expressing the allele and its alternates. The occurrence of limited white spotting on the ventral surface was ignored.

The degree of 'darkness' of the coats were scored for the sampled cats. Light cats (1) were those under the influence of the inhibitor allele (I) or with high grade spotting (S). Medium cats (2) were of the wild type. Dark cats (3) were either non-agouti (a) or blotched tabby (t^b). Spearman rank correlation coefficients were used to ascertain if relationships occurred between cat pelage with age, gender and size.

4.4. RESULTS

The juvenile cats were in three distinct size classes. For the purposes of this chapter however, all juveniles will be combined.

4.4.1 Weights of Feral Cats on Great Dog Island

Mean weights by age class and sex are presented in Table 4.1. The mean weight of all males was 3.493 ± 1.61 kg (minimum 0.4 kg, maximum 5.9 kg). By age group, the juvenile males had a mean weight of 1.192 ± 0.629 kg. The sub-adults had a mean weight of 3.058 ± 0.326 kg, while the adults had a mean weight of 4.626 ± 0.968

kg. The mean weight of all females was 2.495 ± 0.88 kg, (minimum 0.4 kg, maximum 4.2 kg). By age group, the juvenile females had a mean weight of 1.25 ± 0.67 kg. The sub-adults had a mean weight of 2.475 ± 0.43 kg, while the adults had a mean weight of 2.955 ± 0.585 kg.

For adults, a significant relationship (Mann-Whitney U test, P = 0.0007) occurred between body weight and sex. Adult males averaged 156.5% heavier than adult females.

A significant relationship for all cats occurred between body weight and age class (Spearman rank correlation coefficient, P = 0.0001). For adult females (age classes ≥ III) this relationship was weakly significant (Mann-Whitney U test, P = 0.0262). For adult males (age classes ≥ III), the relationship was strongly significant (Mann-Whitney U test, P = 0.0002).

Table 4.1. Age class, Weight and Weight Range for Male and Female Feral Cats on Great Dog Island

	Age class	Male weight, stand. dev. and weight range (kg)	Female weight, stand. dev. and weight range (kg)
I	< 7 months	1.192 ± 0.182 (1.40-2.70)	1.250 ± 0.237 (0.40-2.50)
II	8-12 months	3.058 ± 0.094 (2.50-3.50)	2.475 ± 0.152 (1.60-2.90)
III	13-24 months	3.614 ± 0.620 (2.90-4.50)	2.417 ± 0.440 (1.80-3.00)
IV	25-36 months	4.617 ± 0.674 (3.50-5.60)	2.850 ± 0.071 (2.80-2.90)
V	37-48 months	5.250 ± 0.071 (5.20-5.30)	3.360 ± 0.654 (2.60-4.20)
VI	49-60 months	5.125 ± 0.637 (4.10-5.75)	3.025 ± 0.624 (2.40-3.70)
VII	61-72 months	5.340 ± 0.598 (4.60-5.90)	3.150 ± 0.212 (3.00-3.30)
VIII	73-84 months	5.200 ± 0.000 (5.20-5.20)	3.700 ± 0.000 (3.70-3.70)
IX	85-96 months	0.00	3.100 ± 0.000 (3.10-3.10)
X	97-108 months	0.00	2.800 ± 0.000 (2.80-2.80)

4.4.2 Lengths of Feral Cats on Great Dog Island

Mean lengths by age class and sex are presented in Tables 4.2 and 4.3. The mean male head and body length was 44.236 ± 8.377 cm, (minimum 23.6 cm, and maximum 55.0 cm). By age group, the mean length of juvenile males was 31.525 ± 5.851 cm. The mean sub-adult male body length was 43.4 ± 2.777 cm, being significantly longer than juvenile cats (x^2 = 4.47; 1.d.f.; 0.01 < P < 0.05). Adults were 49.841 ± 3.432 cm. There was no significant increase in body length from the sub-adults.

The mean female head and body length was 41.137 ± 6.326 cm (minimum 20.6 cm, maximum 50.2 cm). By age group, the mean length of juvenile females was 31.625 ± 7.222 cm. The mean sub-adult body length was 41.775 ± 1.529 cm, being a marked but not statistically significant increase in length over juveniles ($x^2 = 3.26$; 1.d.f.; 0.05 < P < 0.10). Adults were 44.364 ± 2.611 cm. This was not significant increase in body length from the sub-adults. The mean head and body length of adult males was on average 112.3% longer than adult females.

Generally, cat head and body length increased significantly with age (Spearman rank correlation coefficient, P = 0.0001). Adult females (≥ age class III) indicated no significant relationship between age class and body length (Spearman rank correlation coefficient, P = 0.2412). Adult males (≥ age class III), however, indicated a strong relationship between age and body length (Spearman rank correlation coefficient, P = 0.0008).

The Spearman rank correlation coefficient was used to determine if a relationship existed between body length and the parameters mentioned (Table 4.3). Dimensions measured varied uniformly with body length (Spearman rank correlation coefficient, P = 0.0001). However, although males were generally proportionally larger than females. There was a noticeable, but not significant, increase in relative head width, mandible depth, and mandible width in males.

Table 4.2. Age class, Sex and Mean Head and Body Length for Male and Female Feral Cats of Great Dog Island

	Age class	Male length and stand. dev.(cm)	Female length and stand. dev. (cm)
I	< 7 months	31.5 ± 1.689 (23.6-42.2)	31.6 ± 2.553 (20.6-40.6)
II	8-12 months	43.4 ± 0.802 (37.2-47.0)	41.8 ± 0.540 (39.0-43.4)
III	13-24 months	46.6 ± 3.274 (42.6-51.0)	42.3 ± 2.288 (39.2-44.6)
IV	25-36 months	50.9 ± 1.729 (47.8-52.6)	46.9 ± 4.667 (43.6-50.2)
V	37-48 months	50.8 ± 1.131 (50.0-51.6)	45.6 ± 1.612 (43.0-47.2)
VI	49-60 months	51.0 ± 2.440 (48.4-55.0)	43.3 ± 1.465 (42.2-45.4)
VII	61-72 months	52.4 ± 0.817 (51.4-53.6)	44.6 ± 1.414 (43.6-45.6)
VIII	73-84 months	52.2 ± 0.000 (52.2-52.2)	47.2 ± 0.000 (47.2-47.2)
IX	85-96 months	0.00	48.2 ± 0.000 (48.2-48.2)
X	97-108 months	0.00	42.0 ± 0.000 (42.0-42.0)

(range of lengths in parentheses)

Table 4.3. Mean Body and Mandible Measurements for Adult Male and Female Feral Cats on Great Dog Island (includes standard deviations)

Parameter	male	female	% difference
Head and Body length (cm.)	49.841 ± 3.432	44.364 ± 2.611	112.35
Tail length (cm.)	26.348 ± 1.791	24.577 ± 1.355	107.21
Head length (cm.)	10.310 ± 0.721	8.982 ± 0.484	114.79
Head width (cm.)	7.566 ± 0.714	6.462 ± 0.333	117.08
Heel-pad (cm.)	9.959 ± 0.533	9.032 ± 0.275	110.26
Pad length (cm.)	1.439 ± 0.115	1.273 ± 0.097	113.04
Pad width (cm.)	1.748 ± 0.143	1.570 ± 0.110	111.34
Ramus lth. (mm.)	28.513 ± 2.962	25.226 ± 1.429	113.03
Condyle lth. (mm.)	14.029 ± 2.073	12.516 ± 0.974	112.09
Mandible lth. (mm.)	58.858 ± 3.866	53.726 ± 1.847	109.55
Mandible dth. (mm.)	11.946 ± 1.512	10.114 ± 0.515	118.11
Mandible wth. (mm.)	7.311 ± 1.377	5.800 ± 0.597	126.05

The striped tabby or wild type was the most frequently occurring phenotype on Great Dog Island followed by non-agouti (black) (Table 4.4). There was a significant difference between the number of males and females with inhibitor (I) with a bias toward males. ($X^2 = 9.14$; 1.d.f.; $0.001 < P < 0.005$) (Tables 4.4 and 4.5).

No significant relationship occurred between coat 'darkness' and sex, age or size, although there is a tendency for a slight reduction in weight and length occurs as coats get darker (Table 4.6).

Table 4.4. Sex Ratios and Phenotypes for 189 Feral Cats from Great Dog Island, 1992.

Phenotype	Males N = 87	Females N = 83	Total N = 170	% of total
Striped tabby (wild type)	41	42	83	48.8%
Blotched tabby	1	1	2	1.2%
Black	25	27	52	30.6%
Inhibitor	15	7	22	12.9%
Long hair	7	7	15*	8.8%
Piebald spotting	5	4	9	5.3%
Dilute	1	0	1	0.6%
Orange	0	1	1	0.6%
Tortoiseshell	0	1	1	0.6%

*One unsexed juvenile expressed the long hair allele and so was included in the total.

Table 4.5. Mutant Allele Frequencies for 189 Male and Female Feral Cats (> 1 kg) on Great Dog Island, 1992.

(standard deviations in parentheses)

Allele	Males	Females	Total
Blotched t[b]	0.154 (0.076)	0.152 (0.075)	0.153 (0.053)
Non-agouti a	0.611 (0.048)	0.621 (0.047)	0.616 (0.034)
Orange O	0	0.018 (0.010)	0.018 (0.007)
Spotted S	0.029 (0.013)	0.024 (0.012)	0.027 (0.008)
Dilute d	0.107 (0.053)	0	0.077 (0.038)
Long hair l	0.284 (0.051)	0.290 (0.053)	*0.297 (0.037)
Inhibitor I	0.090 (0.022)	0.043 (0.016)	0.067 (0.014)

* one unsexed juvenile expressed the long hair allele and so was included in the total.

Table 4.6. Mean Adult Weight and Length and Degree of Darkness for Male and Female Feral Cats of Great Dog Island.

(standard deviations in parentheses)

	Male			Female		
	1*	2*	3*	1*	2*	3*
Weight. (kg.)	4.825 (1.001)	4.775 (1.065)	4.364 (0.854)	2.900 (0.010)	3.100 (0.679)	2.650 (0.389)
Length. (cm.)	50.75 (2.062)	49.857 (4.432)	49.491 (2.2386)	46.267 (2.106)	44.077 (2.106)	44.033 (3.186)

*1 = light, 2 = non-mutant tabby, 3 = dark or black.

4.5. DISCUSSION

4.5.1 Weight and Length and Inter-relationships with Age of the Feral Cats of Great Dog Island

The mean and maximum weights of both male and female cats from Great Dog Island are comparable to other Australian studies. The mean weights of adult male and female cats sampled from south-eastern Australia were 4.771 ± 0.573 kg and 3.270 ± 0.451 kg respectively (Jones, 1989). Male and female cats from Macquarie Island weighed 4.518 ± 0.516 kg and 2.844 ± 0.276 kg respectively (Jones, 1977).

Adult male and female cats from the Orongorongo Valley on the New Zealand mainland weighed 3.67 and 2.72 kg respectively. On surrounding islands mean adult weights are generally lower ranging from 2.46 - 3.36 kg for males and 1.74 - 2.75 kg for females (Fitzgerald, 1990). Likewise, the adult feral cats of the Galapagos Islands were lighter than those recorded in Australia with males weighing 2.7 kg and females 2.1 kg (Konecny, 1987).

The cats of Great Dog Island displayed a general increase in weight with age. The increase in weight between age classes I and II of both males and females indicates the rapid growth period from juvenile to sub-adult. For females, once the sub-adult weight was attained there was a weakly significant weight gain through the remaining age classes. This loosely implies that it is the larger females that attain greater ages, even though the oldest cat was below the mean adult weight. The adult males exhibited a strong tendency for increased weight with age, suggesting that the heavier cats attain greater ages.

Fluctuations in body weight may occur in response to seasonal nutritional stress. This is especially so for females as weights will be additionally effected by the demands of pregnancy and lactation. For this reason a comparison of weight between and within populations should be done with caution. Within the Great Dog Island population a noticeable weight difference occurred between adult female cats collected early and those collected later in the winter season. The females obtained early in the season had a mean weight of 3.233 ± 0.580 kg, while those taken at the end of the season had a mean weight of 2.620 ± 0.397 kg. This decrease in weight was most probably due to fat loss as the mean length of these cats did not vary from that of the mean adult length for all females. This will be further investigated in chapter 5, Condition. Seasonal fluctuations may account for the low weights exhibited by the feral cats of New Zealand.

The mean head-body and tail lengths of the Great Dog Island cats were similar to studies elsewhere. The mean body and head lengths of adult male and female cats sampled from south-eastern Australia were 53.0 ± 0.35 cm and 48.3 ± 0.30 cm respectively. Mean tail lengths were 28.8 ± 0.19 cm for males and 26.7 ± 0.18 cm for females (Jones, 1989). The mean lengths of adult cats on Macquarie Island were for males; a head and body length of 52.2 ± 0.20 cm, and a tail length of 26.9 ± 0.16 cm. For non-pregnant females the mean head and body length was 47.8 ± 0.21 cm and the mean tail length was 25.2 ± 0.12 cm. (Jones, 1977).

Although generally lighter in weight, the cats of the New Zealand mainland and offshore islands maintained similar lengths to that of Australian feral cats. Males ranged from 47.3 - 51.4 cm in mean head and body length, and from 24.7 - 28.3 cm in mean tail length, while females ranged from 44.0 - 47.7 cm. in head and body length, and 23.2 - 25.2 cm in tail length (Fitzgerald, 1990).

It should be noted that comparison of lengths between populations should be carried out cautiously as methods of measuring lengths can vary with the observer. This can be minimised by standardising the measuring technique.

The Great Dog Island population showed a significant increase in mean head and body length with age. This was largely associated with rapid growth between the juvenile and sub-adult age groups. Adult females displayed no significant relationship between age and mean body and head length beyond their first year. For example, the oldest female, in her eighth year, was the same size as a female in its second year of life. This suggests that length offers no advantage to longevity. In fact it is advantagous to the female to reach maturity quickly as it allows her to reproduce relatively early in life. Selection for early maturation may have led to a decrease in mean body size for females (Clutton-Brock and Harvey, 1978).

As cats generally cease linear growth in their eleventh month, the relationship between age and body and head length in adult males suggests that greater length offers an advantage to longevity. It is possible that males of increased body size are better able to defend a territory and/or to compete for resources. It may also be inferred that a social system based on dominance, as opposed to a heirarchy, existed on Great Dog island, however, increased size may be of benefit a cat in establishing its place in a heirarchy. Intra-sexual selection favours an increase in male body size and promotes dominance. This results in a male-dominance polygyny mating system (Emlen and Oring, 1977).

Weight has been used as a method to sort feral cats into age groups (Brothers et al., 1985, Jones and Coman, 1982c). The age groups were as follows: 1). Juveniles, male (< 2200g), female (< 1900g). 2). Sub adult (essentially fully grown but not completed first breeding season), male (2200 - 3400g) and female (1900 - 2500g). 3). Adults (fully grown and completed one or more breeding seasons), male (> 3400g) and females (> 2500g). The age groups of the cats of Great Dog Island generally conformed to those predicted by this method. It was found, however, that adult females of age class III (13 - 24 months of age) would have been included in the sub-adult age group. An examination of the weight of all feral cats on Great Dog

Island indicated there were 54 adult males and 56 adult females. This method would not be able to be applied on the feral cats of the Galapagos Islands as adult males and females weighed 2.7 kg and 2.1 kg respectively.

Generally, significant relationships were found to exist between adult body length and parameter as outlined in Table 4.3. A comparison of mean linear allometric measurements of adult males and females indicates that generally the parameters measured increase proportionately with body length. The head and body length of males are generally 12 % longer than females. Of interest is that head width, and especially mandible width and depth, are noticeably though not significantly larger than that of females. The reasons for this are unclear, it may either be a function of the larger body size, or an adaptation to allow the male greater strength in the jaw for taking larger prey. If the latter is so, it may be that adult males select different prey items to adult females. This could be useful to cats, especially at high densities, as differential selection of prey items could reduce intra-specific competition.

4.5.2 Gene Frequencies and the inter-relationships of Size, Gender and Age on the Feral Cats of Great Dog Island

The presence of seven mutant pelage-related genes, in addition to the wild type, indicates a comparatively high degree of genetic diversity within the feral cat population of Great Dog Island. In comparison, Marion Island had four mutant allele types: blotched (0.59), non-agouti (0.91), dilution (0.14) and spotting (0.17) (van Aarde and Robinson, 1980); while Macquarie Island had three: blotched (0.79), non-agouti (0.35) and sex-linked orange (0.50) (Jones and Hörton, 1984). Comparable numbers of pelage-related genes have only been recorded in urban and rural areas where domestic cats can provide a greater diversity of genes to the feral population; genes that may otherwise be selected against (Jones and Horton, 1984). As the phenotypes of the founder population of Great Dog Island are unknown, it is not known if the genes present are an example of the founder effect or due to subsequent random introductions to the island over time. As mice are present on the island it is possible that shack owners occassionally introduce cats to the island as a control measure.

The frequency of the non-agouti allele (0.62) in the Great Dog Island population was similar to that of rural Tasmania (0.63) and settled rural north-central Victoria (0.64), and higher than those found in north-western Victoria (0.38), south-western N.S.W (0.13) and in the eastern highlands (0.57) (Jones and Horton, 1984). This may be due to the founder effect and/or to selection taking place at this locus in response to the relatively high densities of cats on the island. The relatively mild climate of the

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area, together with the abundant cover on the island, makes it unlikely that the frequency of the non-agouti allele is in response to severe climatic conditions.

The frequency of the blotched allele (0.15) is lower than any recorded in the Australian feral population. Conversely, feral populations in rural Tasmania had the highest frequency (0.84) (Dartnall, 1975). The blotched allele was considered to be advantageous, or at least nuetral in the Tasmanian context, while other genes were at a disadvantage (Dartnall, 1975). These cats, being quite dark, could be expected to respond to selection pressure somewhat similarly to that expressed by the non-agouti phenotype. The low frequency of this allele on Great Dog Island may therefore be the result of a more recent introduction of this mutant-allele to the island rather than its slow removal from the gene pool.

The frequency of the long hair allele in the Great Dog Island population (0.30) is much higher than found in the feral cats of rural Tasmania (0.18) (Dartnall, 1975) and is comparable to those found in feral populations in rural areas (see Jones and Horton, 1984). Long hair in feral populations is usually found in association with an incoming gene flow from domestic populations. Within feral populations on the Australian mainland for example, this allele is absent in areas of low human densities (< 1-3 km^2). The allele is considered to be detrimental in feral populations as it is thought that problems in drying and coat maintenance would put cats at a disadvantage. Of the fifteen cats possessing long coats on Great Dog Island only four were of reproductive size. For cats on Great Dog Island there is an almost 1: 1 ratio of freqency of pelage-related alleles between reproductive and pre-reproductive cats, however, in the case of the long hair allele the ratio was 1: 2.75 in favour of the pre-reproductive age group. This suggests that amongst this phenotype, a higher than average mortality may occur once the cats have achieved adult size. The high mortality could be a result of independant cats leaving the litter and maternal care and being unable to groom and/or adequately maintain their coat. This allele therefore is probably being selected against and in time, without further introductions of this allele, may have been lost to the population gene pool.

The low frequencies of sex-linked orange, dilute, spotted and silver may indicate selection against lighter phenotypes. This may be due to an inability to tolerate high densities as mentioned above, or to the darker coats being more cryptic for camouflage and/or prey ambush. The possibility that the low frequencies of these lighter genes are the result of recent introductions cannot be discounted. However, the population was bias toward the wild and non-agouti types.

Of interest, is the presence of the inhibitor or silver gene (I) in the population. The frequency of this gene (0.07) was found to be higher than that found in a Hobart sample of domestic cats (0.03) (Dartnall and Todd, 1975). This gene has not been noted in genetic studies of feral populations in Australia. The study did not determined if this gene was absent from these populations or was present but not scored. Of interest was that the frequency distribution of all mutant-alleles was even between the sexes, except for the inhibitor (I) allele which was significantly bias toward males (x^2 = 9.14; 1.d.f.; 0.001 < P < 0.005). Of the adults with this gene, three were female and six were male, while sub-adults and juveniles consisted of four females and nine males. The reason for this bias is puzzling. Differential mortality may offer an explanation, however, selective pressure could be expected to operate evenly on both males and females, especially in pre-reproductive cats as differences in size and behaviour are at a minimum. The reason may lie in the mode of inheritance of this allele.

As demonstrated in Table 4.6, no relationships were found to occur between coat darkness and weight or length. However, for adult males and females, the darker phenotypes (blotched and non-agouti) were slightly, but not significantly, smaller than the light coloured phenotypes. Non-agouti males and females in mainland feral populations were also found to be lighter than other mutant-alleles (Jones and Horton, 1984). It is beyond the limits of this study to determine if the small difference in size between the darker ([#]3) and lighter phenotypes ([#]1), or the cryptic coat colour, or a combination of both offer a selective advantage (if any) to cats.

4.6 SUMMARY

1. The cats of Great Dog Island were of comparable weight to feral populations in Australia. Adult females (mean adult weight, 2.955 kg) gained weight slowly once the sub-adult weight was attained, loosely implying that larger females attain greater ages. The adult males (mean adult weight, 4.626 kg) exhibited a strong increase in weight with age, suggesting that the heavier cats attain greater ages. Seasonal fluctuations in body weight occurred especially in females which is possibly a response to nutritional stress.

2. Mean weight of adult females declined between autumn and winter associated with fat loss due to nutritional stress. The mean adult female weight fell from 3.233 kg in autumn to 2.620 kg in winter.

3. The mean body and head, and tail lengths of the Great Dog Island cats were also comparable to other studies. Adult females (mean body and head length, 44.364 cm) of Great Dog Island displayed no significant relationship between age and length beyond their first year, suggesting that length offers no advantage to longevity. For adult males (mean body and head length, 49.841) the relationship between age and length suggests that length may offer an advantage to longevity.

4. A comparison between adult males and females indicates that generally males are proportionately larger than females. Male head width, mandible width and depth, are noticeably though not significantly larger than that of females.

5. The presence of seven mutant pelage-related genes, in addition to the wild type, indicates a comparatively high degree of genetic diversity within the feral cat population of Great Dog Island. This compares with records in urban and rural areas. It is unknown if the genes present are an example of the founder effect or due to subsequent random introductions to the island over time.

i). The frequency of the non-agouti allele may be due to the founder effect and/or to selection taking place at this locus in response to the relatively high densities of cats on the island. It is unlikely that the frequency of the non-agouti allele is in response to severe climatic conditions.

ii). The frequency of the blotched allele may be the result of a more recent introduction of this mutant-allele to the island rather than its slow removal from the gene pool.

iii). The long hair allele although relatively high in frequency, is probably being selected against as juveniles suffer high mortality (an adult: juvenile ratio of 1: 2.75)

iv). The low frequencies of sex-linked orange, dilute, spotted and silver may indicate selection against lighter phenotypes. The population expresses a bias toward the wild and non-agouti types. The expression of the inhibitor allele is bias toward males (a ratio of 1: 0.5)

6. No significant relationships were found to occur between coat darkness and weight or length. However, for adult males and females, the darker phenotypes (blotched and non-agouti) were slightly, but not significantly, smaller than the light phenotypes.

5 CONDITION AND GASTRO-INTESTINAL PARASITES

5.1 INTRODUCTION

The aim of this chapter is to determine the physical and nutritional condition of the feral cats of Great Dog Island and address the following questions.

1). What is the general coat, skin and tooth condition of cats on Great Dog Island?

2). What is the nutritional condition of cats? Are there any differences in nutritional condition between animals of different sexes, lengths, and ages and season (Winter and Autumn)?

3). Which gastro-intestinal parasites occur on Great Dog Island? How does this compare to studies elsewhere?

4). Is the degree parasitic infestation related to nutritional condition, age, size, weight or sex of feral cats?

5.2 BACKGROUND: THE ASSESSMENT OF CONDITION IN MAMMALS

5.2.1 Introduction

The importance in assessing body condition is that it gives an indication of the health or the general energy reserves of an animal. These are assumed to correlate with an individual's future survival and reproductive performance, and hence its 'fitness', i.e. its condition in an ecological sense (Martin, 1977; Cattet, 1990; Read, 1990). There is, however, no general agreement on methods to assess condition (Humphreys *et al.*, 1984).

The literature dealing with the assessment of condition in non-domestic mammals is largely based on the assessment of condition of moderate-sized herbivores of commercial value, in particular the white-tailed deer *Odocoileus virginianus*, as the results may be extrapolated, with due care, to domesticated or exploited wild herds. Too few studies determine the condition of carnivores. Generally, parameters of condition fall into two broad areas, those of morphology (e.g., fat reserves), and physiology (e.g. haemoglobin and hormone concentrations).

5.2.2 Morphological Criteria

The condition of an animal may be indicated by morphological assessment. For example, clinical or sub-clinical states due to parasite burdens or disease may be inferred from certain morphological clues. Also, time series biomass measurements can indicate recent nutritional history. From an analysis of internal morphology, pathological states such as ulcers or adrenal hyperplasia can be observed grossly, while others such as changes in the proportion of lymphoid elements in the spleen, can be observed histologically (Humphreys *et al.*, 1984).

5.2.2.1 Fat as an index of condition

Whereas an animal's physical fitness, disease status, and parasites etc., all contribute to its condition, the term 'condition' is often used as a synonym for fat reserves, which is simply a single measurable statistic (Bamford, 1970). Measures of fat deposits are singled out almost exclusively by researchers for morphological analysis of condition, as it is reasoned that the possession of adequate energy reserves is an attribute of good condition, and thus, is a useful positive correlate. This line of argument is strengthened by the suggestion that fat reserves appear to be related to the rate of increase of some mammal populations. For example, Martin (1977) noted in a study of rabbits *Oryctolagus cuniculus* that 3 populations with a high mean fat index experienced high rates of increase, while 3 populations with low mean abdominal fat values were in decline.

Measurements of fat depots are sometimes direct, for example, fat-depth measurements at slaughter (Anderson *et al.*, 1972). More often they are measured indirectly, equating fat reserves with body weight, deriving an index based on weight (Bamford, 1970), or with water space, or a score indicating fat depth. The choice of a suitable descriptive attribute is probably the function of a number of factors including size (differences in surface area to volume ratios), diet (herbivore, omnivore, or carnivore), social behaviour (solitary, communal), habitat and geographical location. To use fat as a statistic for comparing populations, only '...those cohorts of age and sex and those seasons of the year which are homogenous with respect to fat reserves can justifiably be pooled' (Bamford, 1970, p. 418).

5.2.2.2 Total fat (the use of weight) as an index of condition

Although the use of total weight as an indication of fat reserves may be limited during inanition, and by the tendency for an animal to maintain a standard weight, Bamford (1970), working on possums *Trichosurus vulpecula* found that the index based on weight gave good results (a linear relationship) when derived from a large sample. The use of weight also foregoes the need to sacrifice animals.

5.2.2.3 Visual scores as indices of condition

A relatively simple condition index used by Fitzgerald and Veitch (1985) was one in which cats *Felis catus* were rated fat, medium or thin, based on the relative amount of internal fat. Fat cats were those with fat under the skin, around stomach and covering the kidneys; medium cats were those with less stomach fat and having kidneys partly exposed; thin cats were those with virtually no fat around the stomach or kidneys.

Kistner *et al.* (1980), used the sequence of visible fat deposition in *O. virginianus* to develop a technique to evaluate the physical condition of deer in the field. The sequence of deposition is: 1. base of the heart and in the coronary groove; 2. pericardium; 3. omentum; 4. around kidneys and 5. in subcutaneous areas, simultaneously on rump and brisket areas. The assessment of condition was based on visual estimation of relative amounts of fat at these sites and was scored 0 to 15 in 5 point increments. These were: no visible fat (0), slight (5), moderate (10) and heavy (15). Also estimated, was fullness of body musculature and the symmetry of the carcass (0 or 5). The mobilization of fat was found to occur in reverse sequence to its deposition unless stress, from disease or extreme weather, caused rapid weight loss during which fat was depleted from all depots.

The system outlined above also allowed the researcher to differentiate between fat deposition and fat mobilization, and also between exhaustion of fat reserves and protein inadequacy in forage. Firstly, fat is white during deposition and yellow or red during mobilization. Secondly, musculature is metabolized for energy requirements if dietary protein inadequacy occurs or if fat reserves are exhausted resulting in skeletal prominences becoming apparent as muscle masses lose fullness. Dietary protein inadequacy can occur while fat reserves are still present, and may be indicated when skeletal prominances appear even though fat is present. Kistner *et al.* (1980) found that this technique agreed with objective laboratory methods, after using Pearsons product moment correlations to compare this technique with femur marrow fat, kidney fat index and a condition index. This technique is useful as it requires minimal time,

equipment and training. Watkins *et al.* (1991) remarked that the Kistner technique provides a reasonable index to body fat concentration in *O. virginianus* fawns and gives the best prediction of body gross energy concentration, even though it is disadvantaged by subjective scoring.

5.2.2.4 Subcutaneous fat as a condition index

Scores based on subcutaneous fat, such as back fat thickness, are often used in assessing the nutritional condition of ungulates. However, as with other indices, limitations in its application occur. The early depletion of subcutaneous fat in *O. virginianus* (between 15 and 34% body fat) limits the use of back fat in this species to evaluating moderately fat animals (Watkins *et al.* 1991). Adamczewski *et al.* (1987) reported that in Caribou *Rangifer tarandus*, subcutaneous fat was the largest deposit in fat animals, while internally, little fat was deposited. This makes the use of this fat depot attractive. Adamczewski *et al.* (1987) did not find a discrete sequence of fat mobilization in *R. tarandus* as was found in *O. virginianus*, but agreed with Watkins *et al.* (1991) that it was not measurable in lean animals. Anderson *et al.* (1972) noted great variability in the depth of back fat and percentage of carcass fat in mule deer *Odocoilius hemionus* and so recommended caution.

Read (1990), in assessing the condition of harbour porpoises *Phocoena phocoena* both directly, by measuring blubber mass, and indirectly, by measuring blubber thickness and girth, found that blubber thickness and girth were poorly correlated with blubber mass even when corrected for body size. This was due to blubber deposition over the body surface not being uniform, as well as variation in other components (e.g. core girth). A multivariate approach was suggested incorporating several measures of blubber thickness and girth. However, although yeilding a better predictive power, time and effort may be better spent measuring blubber mass directly (Read, 1990). A multivariate approach was considered the best for live animals, especially if blubber thickness was able to be estimated using ultrasound.

Ultrasound has been used to estimate the subcutaneous fat reserves of southern elephant seals *Mirounga leonina* and has also been shown to be an accurate means of quantifying fat reserves and changes in them, while being safe, non-invasive and logistically practical (Gales and Burton, 1987).

5.2.2.5 Mesogastric fat as a condition index

Bamford (1970), estimating the fat reserves in *T. vulpecula*, found mesogastric fat (from the mesentery which suspends the stomach and spleen) to be the most suitable for estimating abdominal fat, as the fat was discrete and in well-defined depots. The index was found to be most efficient, and accurately predicted total body fat except at low levels where the marrow fat index was more suitable; neither of these indices were influenced by gender.

5.2.2.6 Femur fat as a condition index

In ungulates, femur marrow fat is widely used as a condition index (Watkins *et al.*, 1991). To eliminate errors resulting from dessication prior to analysis, femur fat concentration is often expressed on a dry weight basis (Neiland, 1970; Verme and Holland, 1973) as it standardises for evaporative water loss. This index was found to be of limited use in *O. virginianus* fawns as it is not mobilized until body fat is less than 15%, with only little change occurring between 15-49% body fat (Watkins *et al.*, 1991). Femur fat is only of use as a measure in: i. very lean animals (Adamczewski, *et al.*, 1987), and ii. in detecting chronic malnutrition resulting from prolonged draught (such as in the collared peccary *Tayassu tajacu* Lochmillar *et al.*, 1989). Martin (1977) also mentioned the limited value of marrow fat but agreed it was a sensitive indicator of body fat at extremely low levels of condition. The index also displays seasonal trends when related breeding activity, tending to support the hypothesis that marrow fat content is affected by hormonal rather than environmental influences (Martin, 1977). Pond (1978) remarks that fat-depleted marrow can be recognised by sight as it becomes watery and gelatinous.

5.2.2.7 Kidney fat as an index of condition

As with subcutaneous fat, the use of the kidney fat index (KFI) is widespread in the literature. This index is based on a ratio between kidney weight and the weight of associated perirenal fat. The use of the KFI requires caution however, as its application is also limited. Watkins *et al.* (1991) found in *O. virginianus* that once body fat exceeded 35%, small differences in body fat had marked effects on KFI. At less than 20% body fat, great changes in body fat made little difference in the total KFI. Watkins *et al.* (1991) went on to suggest combining both femur fat and KFI (e.g. the Conindex) to evaluate condition over a wider range, as it correlated highly with body fat concentration. Adamczewski *et al* (1987) suggested the best indicators of dissectible fat were kidney fat weight and depth of back fat (DBF). Contrary to Watkins *et al.*

(1991), who found little justification in trimming perirenal fat to standardize the KFI, Adamczewski *et al.* (1987) considered that trimming kidney fat useful, as the designation of perirenal fat is repeatable; the identification of perirenal fat is otherwise relatively subjective.

Inherent in the KFI is the assumption that: i. kidney mass consistantly reflects lean body mass, and ii. the kidney fat weight is strongly proportional to total fat. However, the first assumption was not found to be valid in *O. virginianus* fawns (Watkins *et al.*, 1991), or in *R. tarandus* (Adamczewski *et al.*, 1987), with both studies recommending caution. Anderson *et al.* (1972), working on *O. hemionus*, found significant differences in weight between the right and left kidney, as well as significant seasonal variation in kidney weight. Contrary to this, Finger *et al.* (1981) while working on *O. virginianus*, looked for a quantitative relationship between KFI and amount of total body fat, and found a correlation of 0.87 in percent body fat and KFI. The latter study concluded that kidney weight variation was not a major factor unless changes in kidney weight were associated with major changes in body composition in a precise way.

Likewise, Pond (1978) stated that kidneys alone among abdominal organs do not change in volume, except in pathological situations, hence they are not influenced by fat build up. Weight changes for example, occur in the liver, due to seasonal changes in diet, breeding status, and digestive efficiency. Mice on a high protein diet have a high liver weight while those on a low protein diet have a low liver weight (Mawhinney and Millar, 1990). Dauphine (1975), however, concluded that *R. tarandus* kidneys undergo such pronounced seasonal weight fluctuations that they are unsuitable for use as a measure of body size in any index intended to display seasonal changes in another physical attribute, especially in the comparison of different seasons. The KFI may be valid for intraseasonal comparisons as long as kidney weights are checked for seasonal differences (proportionality) and adjusted if neccessary.

Bamford (1970) found the KFI was not suitable as the required measurements were subject to great observer error due to the difficulties in defining the precise limits of perirenal fat. In addition, the kidney weight in *T. vulpecula* may fluctuate seasonally (as was also found in *R. tarandus*, Adamczewski *et al.*, 1987) resulting in distorted values. Anderson *et al.* (1990), using *O. hemionus*, recommended the use of the more easily measured and less ambiguous kidney fat mass as the best index of the annual fat cycle. Van Vuren and Coblentz (1985) concurred that it was more meaningful to compare perirenal fat weight to the body weight of each animal.

5.2.2.8 Weight and length relationships

Cattet (1990) pointed out the unsuitability of measuring nutritional condition by dissection and weighing of fat depots, as it is expensive in time, cost of labour, and in the need for dead animals. What is required therefore, is more research into estimating nutritional condition by easily measurable and non-invasive indicators. Such an approach was undertaken by Bakker and Main (1980) in developing a condition index based on a weight/length relationship using the cube root of body weight and tibia length. This was only after several considerations were made: '...1. The length measurement should be easily made on a live animal with a high degree of precision. 2. The length measurement should act as a predictor of the weight of the animal over its entire lifespan. 3. The relationship between the length measurement and the weight should be the same for all individuals in the population which are in equally good or bad condition, and an independant measure of condition should be used to test the validity of this assumption' (Bakker and Main, 1980, p. 397). The index was validated by measuring body water, observing that decreasing percentage fat and total energy was associated with increasing percentage total body water.

Cattet (1990) estimated the nutritional condition of black bears *Ursus americanus* and polar bears *U. maritimus* by calculating a fat to nonfat (FNF) ratio (equalling body weight - nonfat body weight divided by nonfat body weight). Both nonfat body weight and body weight could be predicted accurately from morphological measurements (straight-line body length, axillary girth, and foreleg circumference). Total weight estimation from body measurements has been successfully used previously (Kolenosky *et al.*, 1989; Nagy *et al.*, 1984). The FNF ratio was independent of body size allowing it to be used to compare both between the sexes and among age classes, however, more accurate techniques are required as the FNF ratio was accurrate only over a limited range.

5.2.2.9 Problems with fat as an index of condition

Humphreys *et al.* (1984) point out that the use of a fat depot as the basis for a condition index could be misleading, especially when comparing different populations as: a) 'Different genetic stocks can vary considerably in the location of their fat depots' (Pond, 1978, p. 551); b) 'The allocation of production between growth and reproduction is responsive to changes in nutrition; c) Individual size is important because, due to the scaling of respiration with body size, a fat reserve of 10% of body weight will last an individual half the weight of another only 84 % as long' (Humphreys *et al.* 1984, p. 60), and d) Fat depots may be for purposes other than

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energy storage, such as for balance, social signals, and for insulation (Pond,1978). Further to this, the regulation of a fat reserve appears to be intrinsic, with deposition taking place prior to periods of potential food shortage or high energy demand, and is maintained low when food reserves are readily available (Mawhinney and Millar, 1990; Pond, 1978). Malpas (1977), in a study on elephants *Loxodonta africana* Blumenbach, found that if a population had a seasonally stable diet, fat reserves may not be built up by 'intrinsic anticipation'. Care must therefore be taken when comparing geographically isolated populations. Malpas (1977) mentioned also, that unless sampling takes place over several seasons, the use of fat depots can be unreliable, as elephant populations with a low KFI may have: 1. a seasonally stable diet, 2. been sampled when diet quality is high but before fat reserves have been laid down, or 3. been sampled when diet quality is low and fat reserves have been used up. The fat depot therefore reflects the amount of energy in reserve and not the quality of the diet at the time of sampling.

Variations between gender and within season may further complicate the use of fat as an indice of condition. Bamford (1970) found that during the breeding season the male possums *Trichosurus vulpecula* were more active, so severely depleting their fat reserves. To obtain comparable measurements of fat, and therefore a homogeneous population estimate, Bamford (1970) suggested sampling be confined to non-breeding times. Bear (1971), in a study on pronghorns *Antilocapra americana*, found seasonal and gender differences. Females had higher fat levels throughout most of year, reaching their minimum mean levels later in spring than males. Maximum fat levels for both sexes occurred in winter, corresponding to reproductive activity and general weather conditions. Kidney and visceral indices, and thoracic fat, showed similar seasonal trends, with fat reserves highest in early winter and declining during the most severe cold weather; the period of maximum snow accumulation and minimal food availability.

5.2.3 Physiological Criteria

These criteria need greater technological input than morphological criteria, but are capable of providing considerable information relevant to the assessment of condition. Various blood constituents can indicate nutritional status, short and long term stress, infections, disease and water balance (Humphreys *et al.*, 1984).

5.2.3.1 Hormone levels as indices of condition

Changes in hormonal concentrations can indicate the condition of an animal, as stress usually involves the pituitary-adrenal axis. Changes to this system can be detected by: 1. measuring plasma corticosteroid concentration, which is directly associated with adrenal activity; 2. examining the differential white cell count, or 3. examining the metabolites of glucogenesis such as liver glycogen, plasma glucose and protein concentrations (Humphreys *et al.* 1984). Problems that may occur with the analysis of hormonal activity is 1. their relative prevalence; i.e. their apportionment between blood and tissue; 2. the interdependency of various physiological systems, and 3. some diurnal and seasonal fluctuations occur (Humphreys *et al.*, 1984).

An example of a direct indicator of adrenal function is the measurement of cortisol, a major glucocorticoid in marsupials and other mammals. Changes in the relative concentration of corticosteroids (such as glucocorticoid) under conditions of stress may have detrimental effects (Miller *et al.*, 1991). For example, a population of snowshoe hares *Lepus americanus macfarlani* , during a 2 year decline from a peak population density period, displayed a relative neutrophilia, lymphopenia and eosinopenia, indicating a possible adrenal corticosteroid stress induced reaction (Dieterich and Feist, 1980). This is brought about when cortisol, a more potent glucocorticoid than corticosterone, becomes the major peripheral glucocorticoid (Humphreys *et al.*, 1984).

Approximately 80% of the glucocorticoid hormone in blood plasma is bound to high affinity corticosteroid binding globulin (CBG). Another 10% is bound to albumin, which occurs in high concentrations, binding to steroids of low affinity. The remaining unbound 10%, is thought to be biologically active. Increases in this portion can come about by increases in the corticosteroid production rate, and/or a decrease in its clearence rate. Experiments on cold stress in sheep *Ovis aries* suggest that the latter could occur following a reduction in hepatic and renal blood flow (Humphreys *et al.*, 1984).

The relative concentrations of glucocorticoid can also rise if there is a decrease in the concentration of steroid binding proteins, namely CBG and albumin. Post-mating mortality due to elevated concentrations of unbound corticosteroid hormone have been reported in the male dasyurid *Antechinus stuartii* (Bradley *et al.*, 1980), and the phascogale *Phascogale calura* (Bradley, 1987). In both situations, the rise in androgen occurring during the breeding season depressed the CBG concentration. The relative increase of unbound corticosteroids lead to immuno-supression, causing their death

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from gastrointestinal haemorrhage and/or by invasion by parasites and microorganisms (Bradley *et al.*, 1980). Immunological competence can be assessed with an antigen challenge (Humphreys *et al.*, 1984).

Watkins *et al.* (1991), in their study on *O. virginianus* fawns, noted that the thyroid hormone triiodothyronine (serum T3) had the highest correlation with body fat and gross energy; but little is known about factors affecting this hormone. Negative energy can cause a decline in T3, but decreases did not occur in the study, even though fawn growth rate was significantly reduced. Serum T4 (thyroxine) was even less related than T3, but as T4 is strongly influenced by season, the relationship with body composition may have been partially obscured. Bahnak *et al.* (1981), investigating the effects of nutrition and season on the thyroid hormones of *O. virginianus*, found that T4 and T3 were greater in late spring when body fat and energy were high (with does on high protein diets having greater T3 and T4 during winter and early spring than the does on low protein diets). Both T3 and T4 dropped sharply throughout winter in semi starved does. Contrary to both Watkins *et al.* (1991) and Kie *et al.* (1983), serum T3 was regarded by Bahnak *et al.* (1981) as providing a particularly valuable indicator of nutritional stress during winter.

5.2.3.2 Liver function

The liver has a major role to play in the relative concentrations of corticosteroids as it is involved in the production of high affinity steroid binding proteins, namely CBG and sex hormone binding protein (SBP). Therefore, it is associated with the steroid dynamics of both glucocorticoids and sex hormones. In addition to this, the liver also clears unbound steroid hormones from the blood. Consequently, a dysfunction of this organ may effect the production of CBG and/or SBP, as well as its function in clearing steroid hormones (Humphreys *et al.*, 1984). Such damage may be assessed by: 'a). a decrease in plasma albumin concentration (since the half life of albumin in circulation is 20 days in man, only chronic disease would be indicated; and/or b). measure liver specific enzymes, e.g. an increase in the concentration of liver amino-transferases, alanine aminotransferase (ALT), and aspartate amino- transferase (AST)' (Humphreys *et al.*, 1984, p. 61`).

The extrapolation of effects of changing concentrations of unbound corticosteroids from one species to another is cautioned as species may have different levels of resistance; for example, *T. vulpecula* has a low resistance to the nitrogen mobilizing activity of corticosteroids. Within the macropods, the red kangaroo, *Megaleia rufa* and the quokka *Setonix brachyurus* are highly resistant to these actions, while the

tammar wallaby, *Macropus eugenii* is more responsive (Humphreys *et al.*, 1984).

5.2.3.3 Blood constituents

DelGiudice *et al.* (1990), studying the effects of undernutrition on *O. virginianus*, found that between weeks 2 and 14 of reduced intake, fat reserves were depleted by 85% and differences in blood constituents occurred. These were: elevations in packed cell volume (PCV), serum calcium (Ca), cholesterol, triglycerides, cortisol, along with decreases in serum urea nitrogen and thyroxine (T4). Decreases in the ratios of urinary urea nitrogen: creatinine and potassium: creatinine were also associated with reduced food intake, mass loss, and a decrease in body water, fat, and protein.

Franzmann and Schwartz (1988), assessing the condition of black bears *Ursus americanus* using blood samples, also had positive results, finding that the most useful parameters for good condition in females were elevations in: haemoglobin (Hb), alpha 1 globulin (A1G), and calcium (Ca), while in males they were: globulin (G), packed cell volume (PCV), albumin/globulin ratio (A/G), sodium (Na), calcium/phosphorus ratio (Ca/P), and Hb. The results recommended using Hb and PCV to determine crude (good vs. poor) condition in the field.

5.2.3.4 Blood parameters: problems with their use

Like its morphological counterpart, the assessment of 'condition' by analysis of blood constituents has come under some contention. Watkins *et al.* (1991) concluded that as the reported effects of dietary protein and/or energy intake on haematological values of *O. virginianus* were conflicting, the use of haematological values for the assessment of condition were questionable. Kie *et al.* (1983), looking at both physiological and morphological parameters of *O. virginianus*, were of the same opinion, as highly significant changes in body weights and fat reserves among deer at high population density had relatively few differences in blood values. In summing up, they found that postmortem blood chemistry and haematological data were of limited additional value in assessing physical condition in field situations.

A problem with the use of blood is that seasonal variations occur in several blood parameters; for example in haemoglobin concentration, haematocrit and red blood cell count (Seal and Mech, 1983). These may be used to determine an animal's response to the seasonality of different environments (Humphreys *et al.*, 1984), but have to be accounted for if condition is being measured. For example, the rodent fauna of Nevada (USA) have a higher level of haemoglobin in winter than in summer, most

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probably due to variations in environmental temperature and body size, as greater metabolic expenditure occurs in winter to maintain homeothermy (Lee and Brown, 1970). In some species there are not only seasonal effects but also, as seen in *T. vulpecula*, variations in blood parameters between age and gender (Barnett *et al.* 1979; Presidente and Correa, 1981).

5.2.3.5 Effects of handling on blood sampling

A further problem with the use of blood samples is the effect of the trapping or handling procedures used. A stress induced reaction may occur, even though the animal may have undergone a standard period of acclimation. One effect which has been found in *O. virginianus*, is a delay interval between the stress event and when the blood constituent changes were observed. In this case, not until 24 hours after handling by physical restraint were marked changes noted. The changes were similar to those induced within a few minutes by handling together with the aid of the drugs phencyclidine or promazine. Decreases were observed in haemoglobin concentration, haematocrit, red blood cell count, fibrinogen, and total serum protein; while increases occurred in some serum enzymes associated with tissue damage (Humphreys *et al.*, 1984).

Franzmann (1972) measured the effect of handling induced stress in bighorns *Ovis c. canadensis* and found that rectal temperature, haematocrit, cholesterol, glucose, haemoglobin, and total plasma protein were influenced by the level of excitability, which he measured from the heart and respiratory rates during physical struggle. Barnett *et al.* (1979), could detect no differences in the blood of possums handled and trapped for the first time and that of handling and trap experienced possums (*T. caninus* and *T vulpecula*).

5.2.3.6 The use of urine as an index of condition

Miller *et al.* (1991), in a similar vein to Cattet (1990), advocates non-invasive techniques for studying stress in both the laboratory and in the wild, as problems occur. For example, the elevation of plasma cortisol concentrations in some species (as well as variations within the species), in both tame and wild animals, due to handling. The approach put forward was to measure cortisol in the excreta. The benefits of this method are that instead of getting a result that reflects the variability inherent at one point in time, the free cortisol is continually entering the bladder over a period of hours, so when the accumulated urine is voided it gives an average of the free cortisol that circulated between urinations. DelGiudice *et al.* (1987a), working on the effects

of fasting on *C. lupus*, noted elevations in haemoglobin, red blood cell counts and haematocrits; and declines in white blood cell counts, serum urea nitrogen and insulin concentration. The analysis of associated urine samples indicated decreases in the ratios of urinary urea:creatinine, potassium:creatinine, and sodium:creatinine. Mech *et al.* (1987) also working on *C. lupus*, analysed urine deposits in snow for the ratios mentioned above, and concluded that the relative nutritional state (how recently the animals had fed) could be reliably determined from these deposits.

5.2.3.7 Nutrition and condition

Obviously, from the above, there is an unavoidable overlap between nutrition and condition, as poor nutrition results in poor condition. There have been many studies to establish the nutritional status and the influence of nutrition on mammals, especially ungulates, through blood samples. These studies include: seasonal and nutritional effects on growth hormone and thyroid activity (Bahnak *et al.*, 1981); the influences of energy and protein on blood urea nitrogen (KirkPatrick *et al.*, 1975; Warren *et al.*, 1982); growth and health promotion (Verme and Ozoga, 1980); metabolic patterns and nutritional status with respect to dietary protein and energy (Seal *et al.*, 1978) and nutritional influences on nonesterified fatty acids, ketones, and cholesterol and feed/refeed experiments (DeCalesta *et al.*, 1975).

These studies highlight the effects of diet on several hematological characteristics, such as rises in haemoglobin concentration and packed cell volumes, and declines in total serum proteins and blood urea nitrogen in cases of progressive starvation (Bahnak *et al.*, 1979; DelGiudice *et al.*, 1987b). They can also indicate the catabolization of muscle proteins once fat reserves are depleted (mobilization of muscle protein to maintain required levels of energy metabolites results in a lowering of blood glucose, as the glucose-sparing effect of free fatty acid (FFA) is lost (DeCalesta *et al.*, 1975).

5.3 METHODS

5.3.1 General Condition

A superficial physical examination of the cats was made to ascertain the condition of the skin, coat and teeth. This consisted of a general inspection for pustules, scars, hair loss, scaly skin (dermatitis), abcesses and ear loss or damage. A check was also made for groin and umbilical hernias. Kinks in the tail (due to dislocation of tail vertebrae usually when the cat is young) and cats with red pigmentation on their noses were also noted. Cats with red pigmentation are more susceptible to nose

carcinomas.

Tooth condition was assessed simply by noting teeth that were missing or very blunt, i.e. more than half worn. As cat teeth vary in importance for dispatching and ingesting prey they were classified into two groups: I). Primary teeth, those used for killing and ingestion; these are the canines, 2nd. and 3rd. upper premolars, and the lower 2nd. premolar and molar. II). Secondary teeth; these are the incisors, the 1st. upper premolar and molar, and the 1st. lower premolar (Coman *et al.*, 1981). The dental formula for a cat is 3/3, 1/1, 3/2, 1/1.

Teeth were scored as follows: 1). All teeth complete or undamaged; 2). Three or more minor teeth missing or very blunt, or one canine missing or very blunt; 3). Two or more canines missing or very blunt; and 4). Major teeth missing or very blunt. The ability to catch or handle prey would be expected to decrease especially on the functional loss of major teeth.

5.3.2 Nutritional Condition

Three internal fat deposits were used to compare the nutritional stress of the cats. These were: subcutaneous fat, kidney fat and mesenteric fat. In addition to this, mean weight of the cats taken in autumn and winter were compared.

Subcutaneous fat is found between the dermis (skin) and the muscle tissue. An incision was made from the neck, along the ventral midline and down the right leg of each cat. This exposed the underlying subcutaneous fat. This fat depot was assessed visually and scored subjectively on the basis of fat cover on the ventral surface. Scoring was based on the following: no fat (0), thin all over (1), thin on chest but thick from belly to loin (2), thick from chest to loin (3) and very thick from neck to loin (4). Fat was scored as thin when the muscle wall could be seen underneath.

The abdominal muscle was then cut along the mid ventral line to expose the gut. Mesenteric fat is that which covers the gut on its ventral surface; it did not include fat connected to the intestines. The fat was obtained by lifting the fat deposit and dissecting out where it connected between the liver and the stomach. The fat was weighed. Kidney fat was assessed visually and scored subjectively on the basis of fat cover on the ventral surface of the kidney. Liver and kidney weight were also recorded.

As juveniles occurred in three distinct sizes, the weight and fat score for each of these was also compared. Age class Ia, consisted of cats estimated at 4-6 weeks of age.

Age class Ib were estimated at 13-16 weeks of age, and age class Ic were estimated at 6 months of age.

5.3.3 Gastro-Intestinal Parasites

The numbers of cats infected with conspicous (those ≥ 5 mm) gastro-intestinal parasites were also recorded. These parasites were obtained from the stomach and intestines concurrently with the dietary investigation (chapter 6).

Toxocara cati was identified by the presence of prominant cervical alae. *Taenia taeniaeformis* was identified by its box-like proglottids (segments), the abscence of a neck, and a large rostellum on the scolex. The spiruroids were identified as *Cylicospirura felineus* due to the absence of lateral alae. Also, in most cases, they were held firmly by the fibrous tissue of the nodule as noted by Gregory and Munday (1976).

5.4 RESULTS

5.4.1 General Condition

One 4.8 kg. male cat (age class IV) possessed a skin disorder consisting of three large patches of rubbed, dry skin on its back and at the base of the tail. This cat also had a scar from a cut on the right front pad. One 1.6 kg. female (age class II) had one scar on the left hind pad. The skin and coats of all other cats were in good condition. No pustules or abcesses were detected. No groin or umbilical hernias were detected. Two male cats (age classes II and III) had kinks in their tails. Torn ears usually consisted of no more than one to three rips. Some ears had small pieces missing from the outer edge. Only one cat was recorded as having lost ears, this was a 3 kg. male tabby. Torn ears and red noses were noted and tabled below (Table 5.1).

Male cats had a significantly higher percentage of torn ears than did females ($X^2 = 62.9$, 1.d.f., $P < 0.0001$). There was no significant percentage difference in the occurence of red noses between males and females. Of the sixteen cats with red noses, fifteen possessed an agouti or lighter than agouti coat colour. One possessed a dark coat.

The tooth condition of cats are tabled below (Table 5.2). Two female cats (age classes I and II) had an extra tooth in the lower mandible. This consisted of a smaller tooth, the size of an incisor, between canine and premolar. No cats had undershot or overshot jaws.

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Table 5.1. Torn Ears and Red Noses for the Feral Cats of Great Dog Island by Age Class and Sex

Age class	n	Male Torn Ears	Red Nose	n	Female Torn Ears	Red Nose
I	12	1	3 (a,a,b)	8	1	0
II	12	1	0	8	1	1 (c)
III	7	2	0	6	1	0
IV	6	3	2 (a,b)	2	0	1 (b)
V	2	2	1 (b)	5	0	0
VI	6	4	1(b)	4	0	2 (b,b)
VII	5	2	1(b)	2	0	1 (a)
VIII	1	1	0	1	0	1 (b)
IX	0	0	0	1	0	0
X	0	0	0	1	0	0
Unknown	2	0	2(a,b)	0	0	0
Total	53	16	10	38	3	6
Percentage of total		(30.2%)	(18.9%)		(7.9%)	(15.8%)

*Coat darkness of cats with red noses: a. pale coat. b. grey coat. c. dark coat.

Table 5.2. Tooth Condition of Feral Cats of Great Dog Island by Age Class and Sex.

Age class	n	MALES Tooth condition* 1 (n)	2 (n)	3 (n)	4 (n)	(N)	FEMALES Tooth condition 1 (n)	2 (n)	3 (n)	4 (n)
I	12	12	-	-	-	8	8	-	-	-
II	12	12	-	-	-	8	8	-	-	-
III	7	6	1	-	-	6	5	-	1	-
IV	6	5	1	-	-	2	1	1	-	-
V	2	2	-	-	-	5	4	1	-	-
VI	6	5	-	1	-	4	2	1	1	-
VII	5	2	1	2	-	2	2	-	-	-
VIII	1	1	-	-	-	1	1	-	-	-
IX	0	-	-	-	-	1	-	-	-	4
X	0	-	-	-	-	1	-	-	-	4
unknown	2	1	1	-	-	0	-	-	-	-
Total	53	46	4	3	0	38	31	3	2	2
Percentage		(86.8%)	(7.5%)	(5.7)	(0)		(81.5%)	(7.9%)	(5.3%)	(5.3%)

*1. All teeth complete or undamaged. 2. Three or more minor teeth missing or very blunt, or one major tooth missing or very blunt. 3. Two or more major teeth missing or very blunt. 4. All major teeth missing or very blunt (See methods for explanation of major and minor teeth).

Generally, the tooth condition of all cats was good. Tooth wear or loss only occurred in adult cats, and was present in 24.1% of adult males and 31.8% of adult females. Only two cats displayed a high degree of tooth loss or wear, these were the two oldest females.

5.4.2 Nutritional Condition

As juveniles occurred in three distinct sizes, the weight and fat score for each of these was compared. The fat scores and weights of the measured parameters are tabled below (Tables 5.3, 5.4, and 5.5). For pre-reproductive autumn cats fat deposits and weight generally increased with age for both sexes at the Ib. and Ic. stages (Tables 5.3and 5.4)

The juvenile cats (Ia-Ic) displayed some variation in weight and fat deposit scores. Females of the Ia group were 76.2% the weight of the Ia. males. This was mostly due to the greater length of the males. Mean mesogastric weight of females was 63.9% of the male weight. The standard deviation suggests that this is not significantly different, and so most likely occurred as a result of greater male length rather than a relatively greater fat deposit. Subcutaneous fat deposits were similar in both males and females. The males exhibited great dispersion in percentage of fat covering the kidney with a range of 10-60%. Females had much lower fat cover of the kidneys.

The group Ib. juveniles were similar in weight and length. The mean mesogastric weight and percent kidney cover was also similar, however, the standard deviations of these parameters indicate that within the sexes great variation occured. Subcutaneous fat deposits varied within and between the sexes with males generally having greater fat cover.

The male cat in Group Ic. was a similar length to, but 108.0% heavier than, the female. The mesogastric fat weight and percent fat cover of the kidneys was similar. However, the male had a larger deposit of subcutaneous fat.

The males of age class II cats (sub-adults) were slightly larger in size than the females of this age class. The mesogastric fat weight and percent fat cover of the kidneys was proportionately similar with males being slightly heavier. The males generally had a greater deposit of subcutaneous fat.

A comparison between the autumn and winter sub-adult females (Table 5.4 and 5.5) exhibits a great decline in weight. Most of this difference may be accounted for in the decrease of fat deposits. i.e. From autumn to winter, subcutaneous fat cover drops from generally good to thin, mesogastric fat weight is reduced by 86.9%, and fat cover of the kidneys falls from 82.9% to 0%.

Table 5.3. Fat Deposits, Age class, Length and Weight of Pre-Reproductive Male Feral Cats trapped in Late Autumn/Early Winter on Great Dog Island

Age class	n	Length (cm)	Weight (kg)	Sub. fat score (0-4)	Mesog. fat wt. (g)	% kidney fat cover
Ia.	4	24.475 (1.226)	0.525 (0.096)	1.5 (1-2)	3.675 (1.218)	25.0 (23.805)
Ib.	7	34.029 (1.602)	1.357 (0.113)	2.571 (2-3)	31.986 (8.735)	65.714 (25.071)
Ic.	1	42.200 (0)	2.700 (0)	2.0 (0)	89.200 (0)	90.000 (0)
II.	12	43.400 (2.777)	3.058 (0.326)	2.667 (2-4)	94.05 (19.944)	88.333 (10.941)

* Standard deviations in parenthesis

Table 5.4. Fat Deposits, Age class, Length and Weight of Pre-Reproductive Female Feral Cats Trapped in Late Autumn/Early Winter on Great Dog Island

Age class	n	Length (cm)	Weight (kg)	Sub. fat score (0-4)	Mesog. fat wt. (g)	% kid fat cover
Ia.	2	21.100 (0.707)	0.400 (0)	1.500 (1-2)	2.350 (0.495)	10.000 (0)
Ib.	5	34.040 (2.886)	1.340 (0.152)	2.200 (1-3)	32.280 (11.204)	58.000 (22.804)
Ic.	1	40.600 (0)	2.500 (0)	3.000 (0)	91.200 (0)	90.000 (0)
II.	7	42.171 (1.122)	2.600 (0.265)	2.429 (2-3)	75.464 (24.658)	82.857 (12.536)

* Standard deviations in parenthesis

Table 5.5. Fat Deposits, Age class, Length, and Weight of Pre-Reproducive Female Feral Cats Trapped in Late Winter/Early Spring on Great Dog Island

Age class	n	Length (cm)	Weight (kg)	Sub. fat score (0-4)	Mesog. fat wt. (g)	% kidney fat cover
II.	1	39.000	1.600	1	9.900	0
	(0)	(0)	(0)	(0)	(0)	0

N.B. No pre-reproductive males were obtained during winter.

The autumn adults had proportionately similar fat deposits (Table 5.6 and 5.7). The females weighed 67.8% of the mean male weight. Mean mesogastric weight of the females was 71.6% of the males. With the exception of one female, subcutaneous fat and percent fat cover of the kidneys was also similar.

The winter females generally had proportionally smaller fat deposits than did the males. The total weight of the females was 66.5% of the males, similar to the weight difference between autumn males and females. However, mean female mesogastric fat weight was 53.2% of males. The mean percent fat cover of the kidney and subcutaneous fat cover was 63.2% and 70 % of the males respectively.

Within the sexes, decreases were evident between autumn and winter. The mean weight of both males and females decreased significantly ($X^2 = 4.049$, 1.d.f., $0.01 < P < 0.05$) from autumn to winter. Male mesogastric fat (Table 5.6) weight fell to 48.7% of the mean autumn weight while fat cover of the kidneys was reduced to 27.1% of the mean autumn cover. The male mean subcutaneous fat cover fell to 67.6%. Decreases in fat deposits were relatively greater in the females (Table 5.7). Mesogastric fat weight fell to 36.2% of the mean autumn weight while fat cover of the kidneys was reduced to 17.5% of the mean autumn cover.

Female fat depots were proportionately more reduced than that of the males. Mesogastric fat weight fell to 36.2% of the mean autumn weight. Fat cover of the kidneys fell to 17.5% of mean autumn cover, while subcutaneous fat was reduced to 50.9% of mean autumn cover.

Table 5.6. Fat Deposits, Length and Weight of Adult Male Feral Cats Trapped on Great Dog Island for Autumn and Winter

	n	Length (cm)	Weight (kg)	Sub. fat score (0-4)	Mesog. fat wt. (g)	% kidney fat cover
AUTUMN	24	49.933 (3.646)	4.769 (0.961)	2.958 (2-4)	130.633 (39.531)	70.000 (15.604)
WINTER	5	49.400 (2.387)	3.940 (0.737)	2.000 (1-3)	63.600 (40.729)	19.000 (23.822)

* Standard deviations in parenthesis

Table 5.7. Fat Deposits, Length and Weight of Adult Female Feral Cats Trapped on Great Dog Island for Autumn and Winter

	n	Length (cm)	Weight (kg)	Sub. fat cover (0-4)	Mesog fat wt. (g)	% kidney fat cover
AUTUMN	12	43.850 (2.577)	3.233 (0.580)	2.750 (0.965)	93.535 (39.589)	68.750 (21.755)
WINTER	10	44.980 (2.649)	2.620 (0.397)	1.4 (0-4)	33.820 (12.960)	12.000 (24.175)

* Standard deviations in parenthesis

A comparison of body weight and fat depots by the winter killday (Tables 5.8 and 5.9) suggests that the subcutaneous fat of both sexes was being lost during this phase of the eradication scheme, with only a thin deposit generally being maintained. Kidney fat was generally low (between 0 and 10% cover) with three individuals having over 10% cover (two males and one female). Generally mesogastric fat weight fell to between 0.5% and 1.5% of total body weight and seemed to maintain this. Two cats (one male and one female) had mesogastric fat weights slightly greater than 2% and both of these also had good subcutaneous and kidney fat cover.

Table 5.8. Fat Deposits, Age class, Length and Weight by Killday (time from commencement of erdication programme) for Male Feral Cats Trapped in Late Winter/Early Spring

Trapday	Age class	Length (cm)	Weight (kg)	Sub. fat cover (0-4)	Mesog. fat wt. (g)	% kidney fat cover
67	VI	52.600	4.6	3	121.700	60
67	IV	51.200	4.6	2	76.500	5
70	VI	48.400	4.1	3	68.600	20
76	III	47.000	2.9	1	16.1	5
83	III	47.800	3.5	1	35.1	5

Table 5.9. Fat Deposits, Age, Length and Weight by Killday (time from commencement of erdication programme) for Female Feral Cats Trapped in Late Winter/Early Spring

Killday	Age class	Length (cm)	Weight (kg)	Sub. fat cover (0-4)	Mesog. fat wt. (g)	% kidney fat cover
67	III	42.600	2.200	3	48.200	80
67	IV	43.600	2.800	2	29.800	5
67	III	44.600	1.800	0	7.600	0
77	VII	45.600	3.000	2	40.800	5
87	IV	50.200	2.900	2	46.700	5
94	II	39.000	1.600	1	9.900	0
95	VI	42.000	2.400	1	17.300	0
105	IX	48.200	3.100	1	42.500	10
112	V	46.600	2.800	1	36.100	10
113	VI	43.200	2.600	1	30.600	5
115	V	43.000	2.600	1	38.600	0

5.4.3 Gastro-Intestinal Parasites

Species of gastro-intestinal parasite found in the gut of the Great dog Island cats were the cestode *Taenia taeniaeformis* and the nematode *Toxocara cati*. The stomach wall of some cats also had spiruroid nodules of the nematode *Cylicospirura felineus*. These ranged in size from approximately 5 mm to 10 mm in diameter. Each nodule contained between 11 and 20 spiruroid nematodes. The number of nematodes in each nodule did not appear to be related to the size of the nodule.

The three parasite species occurred both singularly and in groups of two or three. The presence of one species therefore did not totally exclude or inhibit the presence of another. Gastro-intestinal parasites occurred in 58 5% of the males and 76.3% of the females

T. taeniaeformis was found in 30 cats, 12 male (22.6% of males) and 18 female (47.4% of females). Of the males (Tables 5.10 and 5.12), this parasite infected 8.3% of the juveniles, no sub-adults, and 33.3% of the autumn adults. Infection increased to 60% in the winter males. The mean number of *T. taeniaeformis* per cat fell from 5 in juveniles to 1.38 in the autumn adults. This increased to 4.33 per cat during the winter.

Of the females (Tables 5.10, 5.11 and 5.12), this parasite infected 12.5% of juveniles, 28.6% of autumn sub-adults and 33.3% of the autumn adults. All females were infected by *T. taeniaeformis* during the winter. The mean number of *T. taeniaeformis* per cat fell from 4 in the juveniles to 1.5 in the autumn sub-adults. This increased to a mean number of 3 in the autumn adults. The single sub-adult female sampled in winter was also infected with 3 *T. taeniaeformis*, while the adults had a mean number of 5.7. The bias of *T. taeniaeformis* toward females may be due to the relatively high number of females in the winter sample.

Toxocara cati was found in 27 cats, 17 male (32.1% of males) and 10 female (26.3% of females). Of the males (Tables 5.10 and 5.12), this parasite infected 25.0% of the juveniles, 16.7% of sub-adults and 37.5% of the autumn adults. Infection increased to 60% in the winter males. The mean number of *T. cati* per cat increased from 3.33 in juveniles to 4 in the sub-adults. There was a mean number of 1.44 in the autumn adults. This increased to 2.67 per cat during the winter. Of the females (Tables 5.10, 5.11, and5.12), this parasite infected 12.5% of juveniles, 57.1% of autumn sub-adults and 25.0% of the autumn adults. None were present in the sub-adult winter female while 20% of the winter adults were infected. The mean number of *T. cati* per cat fell from 5 in the juveniles to 3 in the autumn sub-adults. A mean number of 2 occurred in both the autumn and winter adults.

Spiruroid nodules were found in 39 cats, 19 males (35.8% of males) and 20 females (52.6% of females). Of the males (Tables 5.10 and .5.12), this parasite infected 8.33% of the juveniles, 25.0% of sub-adults and 50.0% of the autumn adults. Infection increased to 60% in the winter males. The mean number of nodules per cat decreased from 3.0 in juveniles to 1.67 in the sub-adults. There was a mean number of 1.42 in the autumn adults. This increased to 2.33 per cat during the winter. Of the

females (Tables 5.10, 5.11, and 5.12), nodules infected 37.5% of juveniles, none of the autumn sub-adults and 75% of the autumn adults. One was present in the sub-adult winter female, while 70.0% of the winter adults were infected. The mean number of nodules per cat increased from 1 in the juveniles to 1.33 in the autumn adults. A mean number of 2.71 occurred in the winter adults. The bias of nodules toward females may be due to the relatively high number of females in the winter sample.

Table 5.10. Gastro-Intestinal Parasites Loads and Age of the Pre-Reproductive Male and Female Feral Cats of Great Dog Island Trapped in Late Autumn/Early Winter

Number of infected cats (mean number of parasite per infected cat in parentheses)

	Age class	n	Taenia	Toxocara	nodules
MALES	I	12	1	3	1
			(5)	(3.33)	(3)
	II.	12	0	2	3
			(0)	(4)	(1.67)
FEMALES	I	8	1	1	3
			(4)	(5)	(1)
	II.	7	2	4	0
			(1.5)	(3)	(0)

Table 5.11. Gastro-Intestinal Parasites Loads of the Pre-Reproductive Female Feral Cat of Great Dog Island Trapped in Late Winter/Early Spring

Number of infected cats (mean number of parasite per infected cat in parentheses)

	Age class	n	Taenia n	Toxocara n	Nodules n
	II.	1	1	0	1
			(3)	(0)	(1)

Table 5.12. Gastro-Intestinal Parasites Loads of Adult Male and Female Feral Cats Trapped over Two Seasons on Great Dog Island

Number of infected cats (mean number of parasites per infected cat in parentheses)

	n	Total Male Adults			n	Total Female Adults		
		Taenia n	Toxocara n	Nodule n		Taenia n	Toxocara n	Nodule n
AUTUMN	24	8 (1.38)	9 (1.44)	12 (1.42)	12	4 (3)	3 (2)	9 (1.33)
WINTER	5	3 (4.33)	3 (2.67)	3 (2.33)	10	10 (5.7)	2 (2)	7 (2.71)

5.5 DISCUSSION

5.5.1 General Condition of the Feral Cats of Great Dog Island

Generally, the coat and skin condition of cats on Great Dog Island was very good with only one cat displaying a skin disorder and none displaying lameness. The lack of pustules or abscesses suggests that conflict over resources (such as territory, food, mates), if it occurred at all, was not occurring at that time as any injuries had healed. The torn ears amongst the juveniles and sub-adults may be explained, for example, as occurring through accident during play. However, within the adult population, torn ears were only found in males. This strongly suggests that disputes between males do occur, as it would be expected that ear damage from accidents would be more equally distributed through the adult population. With the exception of one male, ears were not overtly damaged. This suggests that most conflicts were resolved before great injury was sustained. This has ecological merit as the chance to reproduce is not jeopardized. In cases such as this, conflicts may be resolved by bluff. Another explanation is that conflicts were infrequent. This may occur if a heirarchical social system was established in the island pouplation. As mentioned in chapter 3, young males establish a place in the heirarchy or dominance order system after initial fighting; little fighting occurs when this place is established (Liberg, 1980). The lack of torn ears in the adult female population may be due to higher tolerance of intruders into a territory and/or the establishment of female family groups.

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The tooth condition of cats was generally very good, with tooth wear or loss only occurring in adult cats. High degrees of tooth loss and wear were only present in the two oldest cats. This was assumed to be detrimental to these cats as their ability to catch and or handle prey could be severely reduced. Two female cats (age classes I and II) had an extra tooth in the lower mandible. This consisted of a smaller tooth, the size of an incisor, between the canine and premolar. Tooth wear, particularly in canine teeth, was often uneven. Some cats exhibited favouritism of one side (right handed vs. left handed eating habit) with both right or both left canines worn. Others had diagonally opposite canines worn.

The occurrance of pink noses was mostly associated with cats of the agouti or lighter than agouti coat colour. One red nosed cat was black therefore nose pigmentation may not be directly linked to coat pigment. Although cats with pink noses are said to be more susceptible to carcinomas, none were detected.

5.5.2 Nutritional Condition of Feral Cats on Great Dog Island.

The nutritional condition of cats, based on relative weight and extent of fat bodies, suggested that the autumn cats were generally in good condition. Of the juvenile cats, the males procured slightly greater amounts of fat. This was evident in both kidney cover and subcutaneous fat deposits. Sub-adult males also had a greater deposit of subcutaneous fat than their female counterparts. This may be due to the generally larger males being able to gain excess nutrition, enabling these deposits to be built up. If males achieve independance in their first year, obtaining greater amounts of fat would assist males through their first winter, as the thermoregulatory benefits of living in a family group would be lost.

The autumn adults had proportionately similar fat deposits suggesting that once adulthood was attained the ability to obtain energy reserves was equal. Only one adult cat in the autumn sample displayed relatively poor nutritional condition with only light deposits of fat. This was the oldest female. The tooth condition of this cat was also poor, with all teeth either very worn or missing. However, she was still able to obtain some food as her gut was more than half full. As fat deposits are a reflection of past, not present dietary success, it is suggested that she was relatively unsuccessful in acquiring food over the summer period.

The general nutritional condition of the winter cats was poor with females generally having proportionally smaller fat reserves than males. The presence of larger fat reserves in the males is most probably a result of sampling bias due firstly to the small sample size of the males, and secondly, to males being taken earlier in the season than most of the females. The low fat levels during winter may encourage grouping as an aid in thermoregulation.

Both males and females underwent a large decline in fat reserves from autumn to winter and reserves were further depleted as winter progressed. This signifies that cats were unable to maintain nutritional condition from prey alone and fat reserves needed to be metabolized to meet energy demands. It is likely, therefore, that nutritional stress was a major factor limiting the cat population on Great Dog Island, particularly in juveniles and sub-adults that failed to acquire adequate fat reserves. A high winter mortality of young cats explains the low number of cats reaching adulthood noted in chapter 3. Population Structure and Dynamics

The physical condition of adult feral cats on Macquarie Island, judged by general appearance and subcutaneous and perivisceral fat deposits, were reported as being good with no noticeable differences between summer and winter (Jones, 1977). Contrary to this, differences in the nutritional condition of adult cats on Great Dog Island were quite noticeable. With the exception of the old female, the subcutaneous fat deposits in autumn cats gave ribs and backbone thick coverings so that these bones could not be felt during inspection of the coat and skin. Deposits of fat on the chest, belly and loin could also be easily felt. The old female in the autumn sample and most adults in the winter sample had little or no subcutaneous fat. This was picked up immediately during coat and skin inspection as ribs and backbones could be easily felt. However, the coat condition of both autumn and summer cats were similar. A simple method to determine or score the nutritional condition of live cats in the field (for example, during radio-tracking work) could be based on body roundness or fat cover of ribs, backbone and belly as ascertained by hand. This could only be used as a guide due to the subjectivity of the approach, but may be adequate.

The determination of a condition indice based on a weight/length relationship is beyond the scope of this study as an independant measure of condition is required for validation. Validation ensures that all animals used to ascertain the indice were in the same general condition. Failure to do this would result in the slope of a regression line being erroneous and thus perpetuating the mistake in all subsequent measurements (Bakker and Main, 1980). One method of validation is to determine the total body

water (TBW) of cats using tritiated water (HTO). Studies on sheep (Searle, 1970) and Quakka *Setonix brachyurus* (Bakker and Main, 1980) indicate that animals in better condition can be expected to have higher percentages of fat and energy, and lower precentages of TBW. Condition indices therefore vary inversely with the percentage of TBW (Bakker and Main, 1980).

5.5.3 Gastro-Intestinal Parasites of the Feral Cats of Great Dog Island

The range of gastro-intestinal parasites in the feral cats of Great Dog Island is low (3 species) compared to that of Australian mainland studies (6 to 9 species). The range more closely resembles that of Macquarie Island (2 species). This may be due to only conspicuous species being selected. However, some species found in surveys from mainland Australia, Tasmania and King Island (for example, the cestodes *Spirometra erinacei* and *Dipylidium caninum*) are are quite conspicuous but were not detected. It is possible that the intermediate hosts for these species are absent from Great Dog Island or that the cats introduced to the island were free of these parasites.

Surveys of gastro-intestinal parasites in feral cats on mainland Australia and Macquarie Island suggest that prevalence of *T.taeniaeformis*, *T. cati* and *C.felineus* vary greatly, and are summarized in Table 5.15.

Table 5.13 Incidence of Selected Gastro-Intestinal Parasite Infection in Feral Cat Populations in Australia

	T. taeniaeformis	*T. cati*	*C. felineus*	Author(s)
Great Dog Island	33.0%	29.7%	42.9%	
Tasmanian midlands	2.3%	86.0%	57.0%	Gregory and Munday, 1976
King Island	42.9%	90.5%	42.9%	Gregory and Munday, 1976
Macquarie Island	32%	9%	-	Jones, 1977
Victoria	78.0%	78.0%	45.7%	Coman, 1972
N.S.W.	21.9%	21.9%	0.7%	Ryan, 1976

The numbers of cats on Great Dog Island infected with parasites was expected to be higher than those of the mainland as the high density of cats on the island suggest that intra-specific contact would be higher, therefore increasing the chances of transmission. There was, however, a large difference between the percentage of males and the percentage of females infested with parasites with the males displaying a much lower degree of infestation. This may be due to male contact being less frequent than that of female contact, which once again supports the notion that females may tend to group.

It is possible that a loss of condition may result in a reduction in the immune response mechanism, thus increasing the susceptibility of cats to parasite infestation. The percentage of male and female cats infested with the cestode *T. taeniaeformis* increased with age, between seasons and increased further during winter. This supports the notion that the parasites may be responding to a loss of condition. Differences in parasite numbers per infected cat between juveniles and adults could be explained by the poorer nutritional condition of the juveniles and/or by the juveniles having yet to build up immunity to this parasite.

T. cati exhibited a varied response as differences in infestation occurred between both gender and season. Infestation of males showed a response similar to that of *T. taeniaeformis*. Despite this, the female response was almost the reverse with lower infestations in the adults and a decrease occurring between autumn and winter. The number of cats infected with spiruroid nodules generally increased with age. However, while the percentage of adult males increased in infestation during winter, the females decreased.

This varied response of both *T. cati* and *C. felineus* refutes the notion that loss of condition results to an increased susceptibility to parasite infestation. This was found to be true of feral cats sampled in Victoria and western New South Wales (Coman *et al.*, 1981). The results of parasite prevalence on Great Dog Island, together with variations in parasite infestations from other studies, suggests that changes in parasite infestation may therefore be in response to other factors, such as changes in diet or to natural fluctuations in the life cycle of these parasites.

Rabbits and small rodents can act as intermediate hosts for *T. taeniaeformis* and *T. cati* (Coman *et al.*, 1981). The high prevalence of *T. taeniaeformis* in Victorian feral cats has been used to explain the high occurrence of mice in the diet (Coman, 1972; Ryan, 1976). As rabbits are absent from Great Dog Island, this indicates that mice are a prey item of the cats. The much higher infestations of this parasite during the winter suggests that either the importance of mice in the diet is greater at this time or the parasites a responding to increased nutritional stress.

Surveys usually report high incidences of *T. cati*. Coman (1972) mentions that in intermediate stages, the egg of this parasite is very resistant and its larvae will live for long periods in paratenic hosts thus offering a greater chance of survival. On the Australian mainland this parasite seemed better adapted to the cooler climates of the Eastern Highlands and Western Districts of Victoria rather than N.S.W. (Ryan,

1976). Accordingly, in Tasmania the parasite had a very high prevalence in the Midlands and on King Island. However, the incidence of *T. cati* on Macquarie island was small. This could be due to a natural fluctuation in the life cycle of *T. cati* or a response to the climate of Macquarie island. The relatively low incidence of *T. cati* on the Great Dog Island, in comparison to that of King Island, may also be a natural fluctuation in the life cycle of *T. cati* or in response to climate. For example, the average yearly rainfall on Flinders Island is 776 mm. This is dryer than King Island with an average yearly rainfall of 906 mm.

Spiruroids related to those found on Great Dog Island use coprophagous beetles as an intermediate host. Infestation of feral cats in both the Tasmanian Midlands and on King Island were thereby considered as coming from insects in the diet (Gregory and Munday, 1976). The presence of spiruroid nodules in the stomach of the Great Dog Island cats may therefore indicate that coprophagous and/or saprophagous insects are frequent in the cats diet. If the ingestion of these insects is accidental it suggests that cats are scavenging on carcasses. The decline in *C. felineus* in females during winter suggests that these insects may have become less available, therefore, scavenging may be reduced at this time.

The prevalence of gastro-intestinal parasites in the feral cats of Great Dog Island is therefore possibly due to responses to climate and the dietary habits of cats and not to fluctuations in nutritional condition. This will be tested in the next chapter.

5.6 SUMMARY

1. The general coat and skin condition of cats on Great Dog Island was very good. Pustules or abscesses were absent. Within the adult population, torn ears were only found in males.
2. The tooth condition of cats was generally very good. High degrees of tooth loss and wear were only present in the two oldest cats.
3. The occurrance of pink noses was mostly associated with cats of the agouti or lighter than agouti coat colour. One red nosed cat was black therefore nose pigmentation may not be directly linked to coat pigment. Although cats with pink noses are said to be more susceptible to carcinomas, none were detected.
4. The nutritional condition of cats, based on relative weight and extent of fat bodies, suggested that generally, the autumn cats were in good condition. Of the juvenile cats, the males procured slightly greater amounts of fat.
5. The autumn adults had proportionately similar fat deposits suggesting the ability to obtain these energy reserves was equal. The oldest female displayed relatively poor

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nutritional condition.

6. The general nutritional condition of the winter cats was poor. The low fat levels during winter may encourage grouping as an aid in thermoregulation.

7. Both males and females underwent a large decline in fat reserves from autumn to winter and reserves were further depleted as winter progressed. It is likely that nutritional stress was a major factor limiting the cat population on Great Dog Island, particularly in juveniles and sub-adults that failed to acquire adequate fat reserves.

8. The determination of a condition indice based on a weight/length relationship is beyond the scope of this study as an independant measure of condition is required for validation.

9. The range of gastro-intestinal parasites in Great Dog Island cats (3 species)was low compared to that of Australian mainland studies (6 to 9 species), and more closely resembled that of Macquarie Island (2 species). The species present were: *T.taeniaeformis*, 33.0% of cats; *Toxocara cati*, 29.7% of cats and *C. felineus* 42.9% of cats. Parasites were present in 58 5% of the males and 76.3% of the females.

10. The numbers of cats on Great Dog Island infected with parasites was expected to be higher than those of the mainland as the high density of cats on the island suggested that intra-specific contact would be higher therefore increasing chances of transmission.This was not the case.

11. The results of parasite prevalence on Great Dog Island together with variations in parasite infestations from other studies suggests that changes in parasite infestation are not due to variations in the nutritional condition of cats may therefore be in response to other factors such as changes in diet, climate or to natural fluctuations in the life cycle of these parasites.

6 DIETARY ANALYSIS

6.1 INTRODUCTION

The aim of this chapter is to determine the diet of the feral cats on Great Dog Island and address the following questions:

1). What is the diet of the feral cat on Great Dog Island, and what hunting strategies are evident?

2). Does age, sex, body size or coat colour confer an advantage in obtaining prey species?

3). Are there any seasonal variations in the diet of feral cats?

6.2 PHYSIOLOGICAL AND ANATOMICAL CONSIDERATIONS OF THE CAT AS A PREDATOR

The domestic cat, like most members of the felid family, is a strict flesh eater as it is unable to tolerate low levels of nitrogen (protein) in its diet (Rogers and Morris, 1980). This requirement for high protein is due to the high activity of the nitrogen catabolizing enzyme alinine aminotransferase in the cat's liver, which is designed to handle medium to high levels of dietary protein. This unalterable rate of activity results in high nitrogen loss. Cats are therefore prevented from exploiting carbohydrate foods, such as fruit, in the way that some canids do. In the dog, enzyme activity changes in response to dietary conditions including starvation. As a result of this, dogs are omnivorous and are able to adapt to variable protein intakes. In the cat nutritionally induced blindness owing to low protein diet have been recorded (Rogers and Morris, 1980). The food source for a cat must be at least 20% protein (Rogers and Morris, 1980). Cats do however ingest grass, perhaps as an aid to regurgitate fur balls and undigested bone or a lactic acid supplement in a precaution against anemia. Grass may also be a laxative or a source of vitamin C (Bayly, 1976). The grass, however, is not chewed.

The jaws of a cat displays features consistant with that of a strict flesh eater. The number of teeth in the cats jaw are reduced to 30, compared to 42 in the dog, *Canis familiaris*. This has resulted in the comparatively short face of the cat. The only functions of the remaining teeth are killing and grasping (the canines and to some extent the incisors) and cutting (the premolars and lower molar). The incisors of the

cat are unusual in that they straight and not gently curved like other mammals. The carnassial teeth, those that are modified for shearing flesh, are the main cheek teeth remaining. Unlike dogs, cats have no crushing teeth that in omnivores act to grind plant material. In fact, the grinding or chewing is impossible as the jaw operates in one plane, preventing side to side movement.

The length of the intestine is also consistant with that of a strict flesh eater. Vertebrates adapted to a carnivorous diet generally have a simpler stomach, colon and intestine than those in omnivores and herbivores. As a result the ratio of intestine length to body length in carnivores is much smaller. For example, the ratio of intestine length to body length in dogs is 6:1, in rabbits, 10:1 and in pigs, 14:1. The cat has a ratio of 4:1 (Rogers and Morris, 1980).

Like many predators which ambush and or stalk, the cats ability to detect prey is enhanced by having a short face and forward facing eyes giving it the stereoscopic vision required to judge distance and position. The cat also possesses some thirty muscles that control ear movement, enhancing its ability to detect prey by providing greater directionality and sensitivity. The cat is also unlike many mammals in that it has almost lost internal most branch of carotid artery, which in other mammals enters the skull next to the middle ear (bulla). This would reduce background noise caused by the circulatory system, further enhancing hearing ability.

The morphology and behaviour of cats are best adapted to taking small mammals, in particular small rodents and young rabbits (Fitzgerald and Karl, 1979), but they are probably capable of taking prey as large as themselves (Turner and Meister, 1988). The size of prey is probably selected on the basis of body size (Childs, 1986) and aggressiveness, as a predator needs to determine the risk to themselves before a predator-prey encounter.

To maintain energy levels, an adult cat requires 360 kJ/kg/day. A pregnant female requires 400 kJ/kg/day while a lactating female requires 1000 kJ/kg/day. Newborn cats require 1520 kJ/kg/day, while 10 week and 30 week old cats require 800 and 400 kJ/kg/day respectively (Rogers and Morris, 1980). To put this into perspective, an average sized mouse of 26g has an energy content of approximately 140 kJ (Rogers and Morris, 1980). Thus a 3.5 kg cat requires 1260 kJ/day. This could be met from nine 26 g mice/day. Fat is a beneficial foodstuff as it is a concentrated source of energy and contains essential fatty acids and fat soluble vitamins (Rogers and Morris, 1980).

In terms of protein weight per day an adult cat needs to consume roughly 5-8% of body weight. Females feeding kittens consume up to 20% and sub-adults 9.5% of body weight per day (Jones, 1977). For an indication of biomass required to meet daily energy demands of adult cats on Great Dog Island, it is useful to conceptualize daily volumes required in terms of numbers of prey. (This does not take into account any differential digestibilities or differences in energy content per gram of these prey species, and is purely hypothetical). The average weight of adult male and adult female cat on Great Dog Island is 4.626kg and 2.955kg respectively. Assuming that an adult cat will require 6% of its own body weight per day, males will require 278g/day, and females (assuming not pregnant or lactating) will require 177g/day. A male cat would require approximately; half a muttonbird, or 70% of a 1 metre tiger snake (snout-vent length), or 55 adult skinks, or 9 whip snakes, or 10 mice. A non-pregnant, non-lactating female would require approximately; 30% of a muttonbird, or 50% of a 1 metre tiger snake (snout-vent length), or 36 skinks (of about 10 cm nose to tail, or 6 whip snakes, or 7 mice.

The cat lacks a cyclical feeding pattern, tending to distribute meals evenly over a 24 hour period (Rogers and Morris, 1980). In the Galapagos Islands the greatest activity occurred at sunrise and sunset, and the least activity occurred at midday when temperatures were highest. (Konecny, 1987). In south-eastern Australia, cats also displayed greater activity at sunrise and sunset, and during the night (Jones and Coman, 1982).

The tendency of cats to reduce or cease activity during the day, especially around midday, has the advantage of reducing water loss. Additionally, their ability to produce concentrated urine and obtain both tissue fluid and metabolic water from their prey enables a positive water balance to be maintained in the absence of free water. This ability to survive without water is a major factor in their successful colonization of most of the semi-arid and arid zones of inland Australia (Jones, 1989).

6.3 THE DIET OF CATS

"It appears that feral cats are opportunistic predators and scavengers, and that the level of predation on any one prey type will depend largely on its relative availability". (Coman and Brunner, 1972, p. 848).

6.3.1 Feral Cat Diet on Islands

Once introduced to islands, feral cats generally become the main terrestrial predator of that ecosystem. These ecosystems are usually dominated by avifauna, with native mammals usually few or absent (Fitzgerald, 1988). In most cases, island avifauna have not evolved with a mammalian predator, therefore anti-predator strategies are not well developed. Those most at risk are species that nest on or near to the ground. The soft-plumaged petrel *Pterodroma mollis* on Marion Island (southern Indian Ocean) is a good example. This seabird is monogamous with a lifelong pair bond. Breeding commences when they reach 5-6 years old with one egg being layed every second year (van Rensburg, 1986). This life strategy is not one adapted to recovery from predation. Nesting period and habits can also affect the vulnerability of the chick to predation. Diving petrel chicks are fed by both parents each night, and incubation is changed nightly. This leaves the chick more vulnerable to predation. Conversely, fairy prions *Pachyptila turtur* change incubation every 6-7 days and the chicks are not fed on 15% of the nights. (Fitzgerald and Veitch, 1985). These chicks therefore benefit from greater parental protection.

The inability to resist the predation pressure brought about by cats has seen the demise or extinction of island bird species. On Little Barrier Island, New Zealand, the breeding success of the black petrel *Procellaria parkinsoni* has been seriously effected. On Raoul Island cats are thought to have exterminated the Kermadec parakeet *Cyanoramphus novaezelandiae cyanurus*. On Macquarie Island, cats and wekas *Gallirallus australis* were implicated in the extinction of the Macquarie Island parakeet *Cyanoramphus novaezelandiae erythrotis* and the Macquarie Island banded rail *Rallus philippensis macquariensis* (Karl and Best, 1982). On Herekopare Island, accounts indicate that a vast breeding population of diving petrels and thousands of broad-billed prions *Pachyptila vittata* were probably exterminated by cats, though fairy prions and sooty shearwaters *Puffinus griseus* persisted (Fitzgerald and Veitch, 1985). Among land birds, the yellow-crowned parakeet *Cyanoramphus auriceps,*, fern-bird *Bowdleria punctata*, brown creeper *Finschia novaeseelandiae*, Stewart Island robin, *Petroica australis rakiura*, Stewart Island snipe *Coenocorypha aucklandica iredalei* and the banded rail *Rallus philippensis* were exterminated (Fitzgerald and Veitch, 1985). Two other species, the red-crowned parakeet and tomtit, probably disappeared but subsequently recolonised the island. Although cats had the greatest influence on the bird life over this period, wekas, together with changes in the vegetation, may have effected some bird populations. Tree-dwelling species remain common (Fitzgerald

and Veitch, 1985). Cats on Marion Island posed a serious threat to avifauna as they fed on all species of burrowing petrel (Skinner*et al.*,1978).

Where man has introduced alternate prey species such as rabbits, rats and mice, the predation pressure on avifauna generally decreases, as prey selection is then biased toward these introduced mammals and/or scavenging. The reason for this is the hunting behaviour of cats is not adapted or has not been altered to taking birds that are fiercely defensive (Apps, 1986). On Macquarie Island, sea-birds were reported as able to drive away cats (Jones, 1977). However, increases in avifauna predation can occur for example during breeding seasons. Solitary chicks may be susceptible, as these do not display adequate defense. On Dassen Island, even though rabbits *Oryctolagus cuniculus* and house mice *Mus musculus* were present, feral cats ate primarily chicks of the jackass penguin *Spheniscus demersus*, listed as vulnerable. At least 9% of the penguin chicks produced annually were killed by cats. Sub-adult cats (less than 3 kg), ate a wide range of prey, but larger cats ate only penguins, rabbits and mice (Berruti, 1986).

The following dietary investigations indicate a preference for small mammals if available. An eradication programme carried out on Marion Island indicated the occurrance of a switch in prey selection corresponding with declining cat densities. The reduction in cat numbers was associated with a decreased proportion of burrowing petrels and an increased proportion of mice in the diet (van Rensburg, 1985).

On Macquarie Island rabbit remains were found in 82% of scats and 71% of gut samples. Of these, 81% weighed less than 600 g suggesting an age of about 10 weeks. Birds formed the second major component of the cats diet with Antarctic prion and white-headed petrel collectively occurring in 45% of the scats and 49% of the gut samples (Jones, 1977).

Rabbits were also the principal dietary item on Ténérife (Canary Islands), making up 53.8% of the dietary component. Reptiles, principally *Gallotia galloti*, an endemic lizard on the Western Canary Islands, was present in 74.2% of the scats (Nogales *et al.*, 1990).

New Zealand studies also indicate the importance of small mammals in the diet. On the New Zealand mainland, rat, rabbit, opossum, mouse and stoat were components of cat diet. Bird remains occurred in 12% of scats (Fitzgerald and Karl, 1979). On Stewart Island, rats occurred in 93% of the scats, birds in 12% and lizards in 24% (Karl and Best, 1982). The prey available to cats on Raoul Island included a great variety of nesting seabirds (few of which are present now), landbirds, Norway rats and kiore *Rattus exulans*. Rats were the main food, 90% of which were kiore. Land birds second in importance and seabirds were now a minor item (Fitzgerald, Karl and Veitch, 1991). Insects are also common in the diet of New Zealand cats, with wetas (Orthoptera), cicadas (Hemiptera) and beetles (Coleoptera) important seasonally. Although sometimes eaten in large numbers, insects contribute very little by weight to the diet (Fitzgerald and Karl, 1979; Karl and Best, 1982).

The introduced mice, *M. musculus* on Marion Island, were considered to be an important food source during winter when seals and many birds leave the island (Anderson and Condy, 1974). Scavenging also provides an important food source of food during winter. Similarly, scavenging on dead seals and penguins has been noted on Macquarie Island (Jones, 1977).

A small study found that birds were a major component of the diet of cats in western Tasmania, while small mammals were of secondary importance in the diet. (Taylor, 1986).

6.3.2 Feral Cat Diet on Mainland Australia

The diet of the feral cat on the Australian mainland is generally a reflection of the relative availability of prey. Small introduced mammals, in particular the rabbit and the house mouse, are the main dietary item of cats improved and semi-improved agricultural areas (Coman and Brunner, 1972). Habitat reduction associated with land clearing and grazing results in a great reduction of native species and the establishment of large numbers of introduced species (Jones and Coman, 1981). This is reflected in diets from the Victorian Mallee, where introduced mammals comprised 85% by weight of the diet, of which rabbit contributed 74% by volume to the total diet. Native mammals comprised only 2% by weight of the diet and included brushtail possums, planigales and bats. Birds comprised 9% by volume of the diet (Jones and Coman, 1981).

The number of native species exploited by feral cats increases as the relative abundance of rabbits and mice decreases. This can be seen in areas of reduced human activity such as in the eastern highlands of Victoria. The percentage by weight of introduced mammals was 45% of which rabbit contributed 43% to the total diet. Native mammals made up 40% by weight of the diet, with 11 species represented including the southern bush rat, common ringtail possum, common brushtail and/or mountain brushtail possum, brown antechinus and sugar glider. Birds comprised 13% by volume of the diet. In both areas, reptiles, amphibians, and arthropods were taken but only made up a very small proportion of the diet. Also plant material was present and there were indications of cannabalism (Jones and Coman, 1981).

In arid areas, Bayly (1976) noted that feral cats had a predominantly reptilian diet supplemented by invertebrates. Mouse and rabbit were present in 28.6% of the cats and birds consisted only a minor part of diet. In 1978, Bayly compared the foods of the feral cat and the fox and found that the fox exhibiting a much higher incidence of scavenged food than the cat. The diet of the fox consisted of rabbit, sheep (mainly as carrion), and various marsupials. Birds, reptiles, invertebrates, rodents and plant material were also present but made up a smaller proportion of the diet. The main cat foods were rabbit, native rodent, small marsupial and house mouse. Less significant dietary items were birds, reptiles, invertebrates and plant material. The ability of the fox and cat to co-existence in semi-arid environments is due to utilizing different age groups of the same staple prey and to some extent different supplementary prey. Foxes eat mainly adult rabbits while cats eat the young (Catling, 1988).

A study in south-eastern Victoria indicated that mammals were the main food source for cats, notably the ringtail possum *Psuedocheirus peregrinus* (56%), *Antechinus* spp. (15%), *Rattus* spp. (19%), and *Tachyglossus aculeatus* (2%). Non-mammalian prey were birds(27%), reptiles (23%), insects (17%), and plant material (19%). The proportion of birds and reptiles was greater during summer (Triggs *et al.*, 1984).

A single report of predation on macropods relates to the the rock-wallaby *Petrogale assimilis* involving a cat being seen eating juvenile rock-wallabies on two occassions. Six others were also found consisting of 3 juveniles, 1 sub-adult, and 2 adults (4kg. males). From results of post mortems and comparison to other victims, they were assumed to be victims of the cat. Other wallabies were also suspected as having been eaten by the cat, particularly young animals (Spencer, 1991).

It is worth noting that generally, birds are only a minor part of the diet of feral cats on the Australian mainland. The cat is not the threat to birds that common belief suggests (Coman and Brunner, 1972).

6.4 BACKGROUND TO THE DIETARY ANALYSIS OF CARNIVORES

Many methods for the dietary analysis of mammals exist in the literature. These include examination of faeces, examination of gut content, inferrence of diet from prey remains, observational studies and from anecdotal reports.

6.4.1 Dietary Analysis From Faeces

The study of faeces (scats) can be an important tool to the ecologist as much information can be gained from its analysis, such as the estimation of population size (including age-structure and biomass), habitat use, range, and dietary determination (Putman,1984). Faeces can also be used to supplement trapping and direct observation in the detection of shy or elusive species, by the presence of self-ingested hair in the faeces of the target species or by the presence of hair in the faeces of predators, and at the same time be of low cost, easily collected and stored (Brunner et al., 1976).

The use of faeces to determine diet enables ecologists access to data without causing disturbance or detriment to the animal under observation. This is important when rare or endangered species are being studied. As mentioned previously, the method allows diets to be determined in the absence of the species if a species is difficult to find (providing the creator of the scats can be identified).

6.4.2 Problems with Faecal Analysis

Inherent difficulies with faecal analysis lie in the differences in, 1. digestibility, and 2. the probabilities of persistence of plant and some animal materials as they pass through the gut. Additionally, the digested portion of a food-stuff increases with increased travel time through the gut. Thus, the recovery of equal numbers of fragments of two different foodstuffs in faeces, may reflect markedly different proportions of

the two species ingested (Putman, 1984). The use of faecal analysis, especially in herbivores with their relatively long gut, may be impeded sometimes to the extent that the error margin is so great that the technique becomes worthless (Putman, 1984).

The problem of differential prey digestibility has been noted by a few authors (Greenwood, 1979; Meriwether and Johnson, 1980; and Johnson and Aldred, 1982). Bones of small prey were not always detected in coyote *Canis latrans* faeces, while body parts from larger prey escaped digestion (Meriwether and Johnson 1980). Also, single prey items may be found in a number of droppings. Thus an individual prey item could be counted more than once, therefore overestimating the relative importance and numbers of that species in the diet. Consequently, 'the relative occurrence of different prey in droppings is not a reliable estimator for relative amounts eaten' (Meriwether and Johnson, 1980, p. 775). Johnson and Aldred (1982), also found that *C. latrans* may totally assimilate smaller prey, which therefore may go undetected in faeces. Bobcats *Felis rufus* assimilate an even greater proportion of ingested material. Whereas *C. latrans* normally assimilated approximately 91% of bones and 55% hair of prey, *F. rufus* assimilated 99% of bones including the teeth, and 90% of the hair.

It may be preferable instead to consider the relationship between biomass ingested to that recovered in faeces.

6.4.3 Methods of Faecal Analysis

An important question is how many prey items are represented by a particular set of various sized fragments in faecal material. Most analyses of dietary composition rely on counting number of fragments only, and thus, treat as equivalent, particles of different size (Putman, 1984). To add another complication, it must also be remembered that smaller animals are covered with relatively more hair per weight of flesh (i.e. a high surface area to volume ratio) and thus may be over represented in diet (Floyd *et al.*, 1978; Corbett, 1989).

One method of tackling this problem is to set up feeding trials to establish correction factors to correct for residues lost through fragmentation and digestion (Floyd *et al.*, 1978; Ackerman *et al.*, 1984). Floyd *et al.* (1978), for example, established trials to relate wolf *Canis lupus* scat content to prey consumed. Captive *C. lupus* were fed known numbers of various prey, from hares *Lepus americanus* to adult white tailed

deer *Odocoileus virginianus*. Examination of scats found that the remains of smaller prey occurred in greater proportion relative to the preys weight, and in lesser proportion relative to prey numbers, than did the remains of larger prey (Floyd *et al.*, 1978). In both studies, regression analysis were conducted between the prey biomass consumed per scat produced and live body weight of the prey animals. A relationship was determined, and a regression equation was derived to estimate the weight of prey eaten per scat (Ackerman *et al.*, 1984, $r^2 = 0.77$; Floyd *et al.*, 1978, $r^2 = 0.97$). This regression equation together with the average weight of the prey, also allows the relative numbers of prey eaten to be calculated (Putman, 1984; Corbett, 1989). Objective adjustments need to be applied however, to account for differences in size between juvenile and adult prey species, and for differences in the proportion of each age class eaten (Corbett, 1989). The use of average adult weight is acceptable in small mammals, birds and insects, but not fish as these grow through life (Putman, 1984).

Andelt *et al.* (1987) tackled the problem of overestimation of small prey in the diet of coyotes by only tabulating items that comprised greater than 40% of each scat. Prime and Hammond (1990), in their work on seals *Halichoerus grypus* used fish otoliths for both identification and size estimation of prey. Through feeding trials on captive animals, species specific digestion coefficients were obtained, enabling reduction in otolith size from digestion processes to be accounted for. A calculation of dietary efficiency, although crude, indicated no major item of the diet had been overlooked.

The use of stock references to establish the size of prey species is possible in many predators if they possess a limited food range for example, the use of femur length in birds and mammals. The precision of stock references on a fundamentally polyphagous carnivore would be severely hampered if not impractical as the size of the collection would need to be great (Putman, 1984). It is also important to note that the estimation of ingested biomass or volume is to determine the relative importance or contribution of any prey item in the diet for a population of scats only, it is not used to determine the actual proportional composition of different prey items in the ingesta of individual animals (Putman, 1984).

Where approximate estimation of dietary value is required, most workers use prey-units system. This takes, for example, a 20 g rodent as standard and estimates the value of other prey in terms of their relationship to this. However, this conversion factor system does not take into account the difference in the relative nutritive values of different prey (although this difference may only be small, as the energy content of a whole range of vertebrate and invertebrate materials vary over only a relatively restricted range (Putman, 1984).

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Not only is digestibility influenced by the type of food consumed, but also on the feeding behaviour of individuals. Raccoons *Procyon lotor* were fed adult American coot *Fulica americana* and their behaviour noted. One individual ate 'only a small portion of flesh and the feathers, another ate all soft parts but left skeletal frame intact with wings attached, and a third animal ate the entire coot except for a trace of feathers' (Greenwood, 1979, p. 193). This range of preference within a species, together with the variety of foods consumed, calls into question the value of deriving digestibility coefficients to adjust the quantitative estimates of faecal residues or to predict biomass ingested (Greenwood, 1979). 'Despite the theoretically greater accuracy provided, correction factors are not widely used, presumably because methods are time-consuming, prey data are unavailable, and it is often assumed that use of correction factors would not alter the conclusions of general diet studies' (Corbett, 1989, p. 343).

Many authors dispense with estimating biomass of prey or trying to calculate nutritive requirements, and use faeces instead to gather data on the range and relative amounts of foodstuffs making up the diet of a predator by simple presence/absence analysis (Brunner *et al.*, 1975; Seebeck, 1978; Green and Osborne, 1981; Garrott *et al.* 1983; Hargis and McCullough, 1984. Harrison and Harrison, 1984; MacCracken and Uresk, 1984, Stuart and Shaughnessy, 1984; Apps, 1986; Leopold and Krausman, 1986; Taylor, 1986; Brown and Triggs, 1989; Iriarte *et al.*, 1989; Lunney *et al.*, 1990). This method is simple to apply, the least time consuming and results can be compared directly with most other studies of the same or different carnivore species (Corbett, 1989). These discriptive studies are usually conducted over time to examine any seasonal variation in diet, and also give an indication on the dietary habits of the animal, for example whether or not they are opportunistic or selective. The usual method is to collect scats and store each scat individually rather than together. In the laboratory, the scats are soaked and manually separated in warm water and then dried. The hard parts (hair, bones feathers etc.) of prey are then identified by comparison to keys or reference collections.

Results are often expressed by calculating the percentage occurance of prey items i.e., the number of times a specific item was found as percentage of all items found (Brunner *et al.*, 1975; Litvaitis and Shaw, 1980; Green and Osborne, 1981; Karl and Best, 1982; Newsome *et al.*, 1983; Harrison and Harrison, 1984; MacCracken and Uresk, 1984; Triggs *et al.*, 1984; Leopold and Krausman, 1986; Wallis and Brunner, 1986; Brown and Triggs, 1989; Iriarte *et al.*, 1989; Lunney *et al.*, 1990).

Frequency of occurrence i.e., the percentage of total scats in which an item was

found (FitzGerald and Karl, 1979), is less seldom used as although frequency of occurrence indicates how common an item is in the diet, percent occurrence provides a better indication of the relative frequency with which each item is consumed, because it accounts for more than one of a given item being found in a scat (Ackerman *et al.*, 1984). However, because faecal samples often contain remains of more than one small mammal or other group, the percentage occurrence of a prey group can exceed 100% (Newsome *et al.*, 1983, Corbett, 1989).

Other methods of expressing results of faecal analysis are to calculate percentage volume, (for example, by water displacement, Doncaster *et al.*, 1990), or to use combinations of analyses, such as percentage occurance and percentage volume (Blackhall, 1980; Hargis and McCullough, 1984). Also used, is percentage by weight, defined as the number of individuals of each prey species multiplied by the mean weight of the species, and then divided by the total weight of all prey identified in the scats (FitzGerald and Karl, 1979), with the mean weights calculated and presented in table form. For statistical comparisons, non-parametric tests such as Chi-square analysis or Student's t-tests are sometimes used (Garrott *et al.*, 1983; Hargis and McCullough, 1984).

6.4.4 Identification of Faeces

The identification of the faeces of target species is most often carried out by comparison of size, shape and odour to known samples or the presence of grooming hairs (Brunner *et al.*, 1975; Cohen *et al.*, 1978; Brown and Triggs, 1989; Lunney *et al.*, 1990). The behaviour of a species may also assist in the identification of its faeces, for example, the dhole or Asiatic wild dog *Cuon alpinus* defecate collectively in a 'dung pile', a behaviour not reported in sympatric domestic dogs *Canis familiaris* or Asiatic jackals *Canis aureus* (Cohen *et al.*, 1978).

Another method of scat identification, where field evidence is lacking or of poor quality, may be by the use of bile acids (Major *et al.*, 1980; Johnson *et al.*, 1984). This method compares the patterns (or relative concentrations) of bile acids (such as cholic acid, hyocholic acid and lithocholic acid) in unknown samples with those from known samples by the use of thin-layer and/or gas chromatography (Major *et al.*, 1980). Basically, this process seperates out compounds depending on their chemical make-up, and identifies them by Rf (ratio of the distance the solute moved to the distance travelled by the solvent front) and/ or colour reactions. The relative concentration of a steroid is proportional to the size of a spot and/or to the intensity of a coloured spot on a chromatography plate. The use of bile acids are useful as they are stable

over time ('little variation exists in bile acids from modern human faeces and 2,000-year-old coprolites') and differences in relative concentrations occur among species (Major *et al.*, 1980, p. 290).

However, some problems with this method of faeces identification occur. Firstly, as bile acids are soluble in water, the relative concentrations of bile acids may be diluted during precipitation. The method may therefore be unreliable for identifying target species (Johnson *et al.*, 1984), unless relatively fresh scat is used. Secondly, as variables "such as humidity and temperature influence Rf and colour values, standard bile acids or standard solutions prepared from known faecal samples should be used for reference in each experiment. In addition, steroids in mixtures seem to interfere with each other and do not always run at the same rate as standards on TLC plates" (Major *et al.*, 1980, p. 291).

6.4.5 Identification of Ingesta

The identification of remains in faeces can be accomplished both macroscopically, as in the case of tooth patterns, bone shape and structure, or microscopically, as in the case of hair or feather patterning (Putman, 1984). The identification of mammal hair in south-eastern Australia has been facilitated by the work of Brunner and Coman (1974), and furthered in Tasmania by Taylor (1985), by the publishing of keys and reference photographs. Mechanical problems of agglutinisation and non-translucence of matter in faeces may impede or even make impossible, the identification of an animals diet (Putman, 1984).

To reduce time and effort involved in the hand separation of scats, a method of point frame analysis has been adopted by some authors. Originally a method of analysis used by botanists, it consists of the random or systematic placement of a frame holding pins, spaced at equal intervals in the vegetation to be sampled. The species hit by the pins are recorded. The method gives a fairly accurate picture of the species present and their relative densities. The method was adopted initially to sample the rumen of herbivores after trials were conducted on artificially constructed populations of plant fragments (Chamrad and Box, 1964). The study indicated that the results were reliable, 1.' if the rumen sample was adequately mixed, and 2. if there were no large items with unusual surface texture in the mixture'(Chamrad and Box, 1964, p. 476). The method was tested for accuracy and used to quantify *C. latran* diet by Johnson and Hansen (1977). The test for accuracy compared the results between hand separation and point frame analysis. No significant differences were found apart from point frame analysis enabling the researcher to obtain the same amount of

information, and to process 8 times as many samples in the given time.

6.4.6 Dietary Analysis From Gut Contents

Problems involved with identifying the scats of target species, and with the assimilation and fragmentation of prey etc., can be overcome somewhat, if gut contents are analysed. The use of the gut to analyse the diet of predatory species is common, especially if the animal 1. is a pest (for example feral cats *Felis catus*), 2. is exploited by trappers or fur dealers (for example, bobcats *Felis rufus*, wolverines *Gulo gulo*, and foxes *Vulpes vulpes,* or 3. is road killed. The benefits of gut analyses are 1. prey items are in larger pieces, and therefore, are able to be identified more easily; 2. the estimation of biomass ingested is made relatively easier; and 3. the possession of the carcass allows other data to be collected, such as relative condition and reproductive status.

The most popular method of gut analysis is by the investigation of stomach contents. The results of stomach analysis are usually expressed by frequency of occurrence and measurements of volumetric displacement (Coman, 1973; Ryan and Croft, 1974; Myhre and Myrberget, 1975; Whitehouse, 1977; Croft and Hone, 1978; Fritts and Sealander, 1978; Newsome *et al.*, 1983; Maehr and Brady, 1986; Stuart and Murie, 1986). Both of which reflect the proportion of samples containing a particular food item, while not considering the importance of other species.

Coman and Brunner (1972), Bayly (1976), and Bayly (1978), arranged their data on percentage occurrence and volume basis. (Thus, percentage of occurrence refers to the ratio between the number of times a particular food item was found in the stomachs and the total number of stomachs containing food, while percentage volume represents the ratio between total volume and the total volume of all food items). Catling (1988), tabled his data using percentage occurrence and percentage weight, while Toweill (1977), analysed the diet of cougers on a presence/absence basis only, mentioning how data from large mammal predators was difficult to obtain due to low population densities, remote habits and great mobility.

Other studies combine methods of dietary analysis to complement or reinforce findings. Van Rensberg (1985), determined the diet of feral *F. catus* by the investigation of stomach contents and by remains of prey found in the study area. In this case, the only other predators were bird species, so determination of those prey items utilised by cats was by field evidence such as tracks and puncture marks. The results were expressed as frequency of occurrence.

Jones (1977), investigated intestinal tracts and scats of feral *F. catus* using percentage frequencies to express results. Nellis *et al.* (1972) took the analysis of data from the intestinal tracts and scats of lynx *Lynx canadensis* a step further, by determining the volume (by water diplacement) and the number of individuals of each prey species. The biomass of prey consumed was then calculated from the total number of individuals of a species found in all sources of food habits data, and from weights of prey species, as determined from specimens taken near the study site.

Stomach contents and faeces have been analysed by some authors, and once again the expression of results have been varied. Reynolds (1979), used percentage occurrence on the diet of foxes *Vulpes vulpes* , Berruti (1986), used percentage number, percentage mass, and percentage frequency of occurrence, while FitzGerald and Veitch (1985), tabled the dietary items by frequency only. Jaksic *et al.* (1983) compared the diets of three species of foxes in Chile, *Dusicyon griseus, D. culpaeus and D. fulvipes*, by calculating the food-niche breadth (dietary diversity):

$$B = 1/(\Sigma p_i)^2,$$

where p_i is the relative occurrence of prey taxon 'i' in the diet of a given population. The index generates values ranging from 1 to n (for n equally used resources). To compare populations, the food-niche breadth was standardized:

$$B_{sta} = (B_{obs} - B_{min})/(B_{max} - B_{min}),$$

where B_{obs} is the observed niche breadth, B_{min} is the minimum niche breadth possible (=1), and B_{max} is the maximum breadth possible (=n), which is the number of prey taxa actually taken by a given population. B_{sta} ranges between 0 and 1, i.e., between very narrow and very broad food-niche breadth. Food-niche overlap (dietary similarity) between fox populations was then computed:

$$a = \Sigma p_i q_i/(\Sigma p_i^2 \Sigma q_i^2)^{1/2},$$

where p_i is the relative occurrence of taxon 'i' in one fox population diet, and q_i is its relative occurrence in the second population diet. This index generates values ranging from 0 to 1, representing complete dissimilarity and complete similarity, respectively.

Litvaitis *et al.* (1984) working on *F. rufus*, and Marsack and Campbell (1990), working on dingoes *Canis familiaris dingo* both used frequency of occurrence to analyse food items in gastro-intestinal tracts. Toweill (1974), in addition to frequency of occurrence, calculated the percentage volume. He found the method less reliable, due to the effects of differential digestion and the difficulty of seperating flesh and bones of various food items present in a single otter *Lutra canadensis* digestive tract. Jones and Coman (1981), in their analysis of the intestinal tracts of feral cats, used frequencies of occurrence and the weight contribution of food. The latter was calculated

by multiplying the number of occurrences of each item in tract by its mean weight eaten. The result was expressed as a percentage of the total weight of food eaten. Where considerable digestion had taken place, total weights eaten were calculated: 1. the mean maximum weight eaten was used for prey heavier than this value; 2. for lighter prey, mean adult weights were used; and 3. mean weights eaten determined for one or two localities were used to calculate total weights eaten for cats from another locality. Although the maximum weight eaten, should be constant for all localities, mean weights eaten of particular items could vary. The use of mean adult weights of small mammals in place of mean weights eaten could also cause errors, because the numbers of individuals eaten per meal (and therefore the total weights eaten) were unknown. For species eaten less frequently, it was likely that each occurrence represented a single individual; for species eaten frequently it was likely that, for many occurrences, more than one individual was represented (Jones and Coman, 1981).

6.4.7 Alternate Methods of Dietary Analysis

6.4.7.1 Fatty acid composition

An indirect approach to analysing the diet of an animal is to use the fatty acid composition of its adipose tissue (Reidinger *et al.*, 1985). Two experiments using this method attempted to identify vertebrate pests in agroecosystems and their food-web associates. In the first experiment, male norway rats *Rattus norvegicus* were supplied diets of varying oil composition, from 20% corn oil (and no coconut oil) to 20% coconut oil (and no corn oil). After five weeks, samples of adipose tissue were taken from four rats on each of the diets. The analysis revealed that oleic and linoleic acids (combined) made up the greatest proportion of fatty acids in the samples (mean 53.5%), whereas palmitoleic (mean 3.1%) and stearic acids (mean 3.2%), were relatively less abundant. Lauric and myristic acids, (more of which are found in coconut oil than in corn oil), were strongly (r^2 = 0.83 and 0.88, respectively) and directly associated with the percentage of dietary coconut oil. (Reidinger *et al.*, 1985). The second experiment consisted of three mongoose *Herpestes auropunctatus* being fed rats that had been collected in a macadamia grove, and another three mongoose being fed rats that were collected in a sugar cane field. After 38 days, the three former mongoose had proportions of fatty acids that were strongly associated (r^2= 0.84-0.99), with the proportions of fatty acids in the macadamia nuts (Reidinger *et al.*, 1985).

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6.4.7.2 Starch-gel electrophoresis

The starch-gel electrophoresis technique was initially developed as an aid for law-enforcers in the identification of game meats. Dilworth and McKenzie (1970), compared the composition of skeletal muscle from three domestic species; cow *Bos taurus*, pig *Sus scrofa*, and sheep *Ovis aries*, and three game species; moose *Alces alces*, deer *O. virginianus*, and caribou *Rangifer tarandus*. An analysis of total protein, esterase, and lactic dehydrogenase of muscle myogens, found that the electrophoretic patterns were genus specific. No intraspecific variations in patterns were found although some interpopulation differences may exist. This technique would be of value in the gut analyses of carnivores if no hard parts (for example, bones and hair) could be found. However, a large reference collection would be required.

6.4.7.3 Fallout radiocesium

Holleman and Stephenson (1981) determined the diet and consumption of prey by the Alaskan wolf *Canis lupus pambasileus* by the use of the fallout radiocesium method. This method relies upon the build-up of fallout radiocesium, cesium-137, in the potential prey species and its subsequent transfer to *C. lupus*. The radiocesium concentration in wolf prey is a result of dietary preference. Lichens and mosses, which are a major part of the diet of caribou *Rangifer tarandus* possess relatively high radiocesium concentrations. Grasses and shrub leaves, which are relatively low in radiocesium concentration, are the prefered diet of moose *A. alces*, sheep *O. aries* and hares *Lepus americanus* (non-lichen selectors). The radiocesium concentration in *C. lupus* was estimated from a sample of skeletal muscle. It was assumed that 43% of the body weight of a *C. lupus* was skeletal muscle, and that this was the site of 80% of the radiocesium in the body. One kilogram of this muscle was assayed using a spectrometer, and measured in pCi/kg. 'The radiocesium concentration in *C. lupus* muscle depends upon its intake, absorption, and its in vivo kinetics in the *C. lupus* ' (Holleman and Stephenson, 1981, p. 621). The method allows both quantitative and qualitative information to be acquired. The estimates of prey consumption was carried out by considering how much prey a *C. lupus* would need to consume to account for the observed average radiocesium concentration.

6.4.7.4 Intubation

Sampling stomach contents by intubation (Wrazen and Svendsen, 1979), is a relatively harmless means of assessing animal diet. The method entails using a syringe to withdraw food fragments from the stomach. The animal is firstly anesthetized, then

the head is tilted and a tube is passed through the mouth to the stomach. Water in a syringe is then expelled, and the plunger raised. Fewer items may be detected in the stomach than in faeces, as the stomach provides information on a single meal or foraging bout, while faeces may give a cumulative account of diet. As the stomach contents are not completely removed, and the largest food fragments likely to be too big to enter the tube, only qualitative data is provided. Also, some material is likely to pass out of the stomach into the small intestine between capture and intubation.

However, due to dietary items being relatively less fragmented and digested at this point, identification is facilitated and the probability of identification error is decreased. The method can provide data for population dietary analysis by item occurrence, and estimates of the number and character of food items eaten during the period immediately preceding capture are possible. Intubation samples can also provide suitable material for chemical analyses of stomach contents (Wrazen and Svendsen, 1979).

6.4.7.5 Radiotelemetry

Radiotelemetry and live-trapping to gather data on the ecology of feral dogs *Canis familiaris* in Alabama was used by Scott and Causey (1973). The investigation assumed that: 1). the dogs hunted large game in packs, and 2). that the dogs would return to, or stay near, a kill until it was consumed. Sites visited at least twice by the radiotracked pack were searched thoroughly for prey remains, also five scats from trapped dogs were analysed. The study found, contrary to popular opinion, that feral dogs were not as abundant as believed, and that they did not appear to be a significant predator on deer or livestock.

6.4.7.6 Observation

Direct observations and inference are another methods by which the diet of carnivores can be established. For example, Truett (1979), documents two observations of *C. latrans* attacks on mule deer *Odocoileus* spp. fawns in Arizona, one successful, the other not. He also infers an apparent attack from the presence of the tracks of *C. latrans* and fawn *Odocoileus* spp. in association with dried blood, tufts of hair, and sections of a herbivores intestine.

Behrend and Sage (1974), reported adult female snapping turtle *Chelydra serpentina* as prey of the black bear *Ursus americanus*. They initially saw a turtle laying eggs. Later, turtle fragments were found associated with black bear tracks. They also reported the predation of an adult *O. virginianus* confined in a cage. The certainty of

the event was indicated by *U.americanus* tracks, hair, claw marks and drag marks.

The predatory behaviour of puma *Felis concolor* (including stalking, method of attack and the killing bite) toward *O. virginianus* was observed directly and documented by Wilson (1984). The carcass information of prey (age, sex, condition) was also reported.

Similarly, Malcolm and Van Lawick (1975), reported observations on wild dogs *Lycaon pictus*, hunting zebra *Equus burchelli* on the Serengeti. Detailed behaviour of the *Lycaon pictus* when hunting, capturing and killing were documented.

The diet of feral *F. catus* by observation has been documented by Anderson and Condy (1974), Doucet (1973) and Spencer (1991).

6.5 METHODS

6.5.1 Laboratory Procedure

The diet of the cats of Great Dog Island captured as part of an eradication programme in 1991 was studied by analysis of gut contents. The gut of each cat was removed between the cardiac sphincter of the stomach to the inside of the pubis bone. The gut was opened and the contents removed, washed with warm running water, then seived and separated using a 500 micron seive. Fleshy prey remains and conspicuous gastro-intestinal parasites were removed, labelled and preserved in 70% alcohol. The remaining hard parts, (feathers, hair bones and scales), were washed in 70% alcohol, placed in aluminium foil quiche trays and dried at 60° C for 8-10 hours. After drying, bait remains were removed and discarded. The dried gut contents were then placed in snap-lock plastic bags, labelled and set aside for identification. Due to time and resource constraints, the contents of the stomach, small and large intestine were combined. Analysis of separate sections of the gut may have allowed the order of the last two or three meals of the cat to be determined.

Ten scats were collected on the 27 - 29 May 1992, one year after the commencement of the cat eradication programme. The scats were combined and treated in the same manner as described for the gut. No scats from the 1991 season were recovered.

6.5.2 Identification of Ingesta

Bird remains were identified from beaks, feathers and feet, by comparison with the reference collection held at the Tasmanian Museum and Art Gallery.

The identification of mammal hair was achieved by methods and keys described by Brunner and Coman (1974), involving the examination of medullar shape (from cross-sections of mammal hair) and cuticular scale casts.

Skulls of mammals were identified using keys (Green and Rainbird, 1983).

Reptiles were identified from either body sections (whole or part) or from scale pattern.

Invertebrates were initially sorted to order by remains of hard parts, such as wing cases, and limb structure. Further identification to genus and or species level was made by comparison to reference collections at both The Tasmanian Museum and Art Gallery and the Department of Primary Industry.

The gut contents of skinks was also examined to ensure that prey species regarded as dietary items of the cats were not present due to secondary ingestion.

6.5.3 Data Analysis

Dietary items in the gut were counted to yield frequency of occurrence. The data were separated into two groups reflecting the two periods over which the cats were samplred: Group I, late autumn to very early winter (25.05.91-04.06.91), involving 75 cats taken over 11 days (referred to as 'autumn cats'); and Group II, mid-winter to early spring (30.07.91-16.09.91), involving 16 cats taken over 48 days (referred to as 'winter cats').

Analysis of the weight and volume of prey species was not carried out because cages were checked only once per day. Since cats had spent unknown periods of time in the traps (minutes to hours), analysis may be misleading due to unknown digestibilities of prey items.

To ascertain if age, body length, weight, dominant coat colour, tooth condition or date of capture influenced prey species taken, the cat diet data were examined using global non-metric multidimensional scaling (GNMDS). The number of random starting configurations was 30, and the number of dimensions ranged from 1 to 4. The transformation applied to values of abundance was: $X = LOG(X+1)$. The dissimilarity coefficient used was Czekanowski (Bray-Curtis). The cat variables and trap date were fitted to the three dimensional ordination space produced by the diet data using a

vector-fitting procedure to find the maximum correlation for each variable. The significance of the maximum correlation values was tested by a Monte-Carlo approach using 999 random permutations.

6.6 RESULTS

A total of 26 species was found in the gut of cats (Table 6.1), comprising 2 bird, 1 mammal, 5 reptile and 18 arthropod species. Of the arthropods, 8 insect species were considered prey items while a further 7 species were assumed to be the result of accidental ingestion. Of the 3 arachnid species present, 1 was considered to be the result of accidental ingestion. The gut of 16 cats were either empty or contained only residual food stuffs. Most cats had soil and plant matter in the gut. Finely divided plant matter was found in the gut of a few cats due to secondary ingestion. This plant material was only found in association with mouse remains and was assumed to be mouse ingesta. No human refuse was found in the gut of cats.

The results from the vector fitting (GNMDS) indicated that age, body weight, dominant coat colour and tooth condition have no significant bearing on prey selection. There was however a strong correlation between day of capture and prey items selected, reflecting a seasonality in prey availability. Further analysis indicated that autumn cats selected similar prey, while within the winter cats, prey selection varied with time (Fig. 6.1) (see also Appendix 1)

P. tenuirostris was the major component of the autumn diet (Table 6.1), but was much less important during winter, occurring only early in the season (Table 6.2). The unidentified passerine only occurred in the winter diet.

The occurrence in the diet of *M. musculus* increased greatly during the winter (Table 6.1) especially during the latter part of the season (Table 6.2). Some cats had massive fur balls present in the gut. There was no indication of cannibalism, as the bulk of hair ingested matched that of the host cat. Also no hard parts resembling those of a cat were present.

Of the five species of reptile on the island, *N. metallicus* was by far the most commonly represented in the diet. It was the only reptile to occur in the winter diet. The frequency of this lizard in the diet increased during the winter, however it generally occurred earlier in the season (Table 6.2).

Table 6.1. The Percentage Occurrence and Mean Prey Number (including maximum prey number) of the Prey Species from Gut Samples of Feral Cats from Great Dog Island for Autumn and Winter.

Food item	n	AUTUMN (n=75) Percentage occurrence	Mean no. prey (max. no. in parenthesis)	n	WINTER (n=16) Percentage occurrence	Mean no. prey (Max. no. in parenthesis)
Birds						
Puffinus tenuirostris	68	90.7		3	18.8	
Unidentified passerine	0	0.0	0	1	6.3	1
Mammals						
Felis catus (own fur)	35	46.7		10	62.5	
Mus musculus	6	8.0	1.0	6	37.5	1
Reptiles						
Drysdalia coronoides	2	2.7	1.0	-	-	-
Lerista bougainvillii	1	1.3	1.0	-	-	-
Niveoscincus metallicus	32	42.7	1.4 (7)	10	62.5	1.6 (5)
N. ocelatus	1	1.3	1.0	-	-	-
Notechis ater	1	1.3	1.0	-	-	-
Arthropods						
Apotrechus ambulans	10	13.3	1.3 (3)	-	-	-
*Australomyia rostrata**	2	2.7	1.0	-	-	-
*C. stygia**	1	1.3	1.0	3	18.8	1
*Calliphora vicina**	2	2.7	1.0	1	6.3	1
Cercophanius squama	2	2.7	1.0	-	-	-
Chalcidoid wasp*	-	-	-	3	18.8	5.67 (9)
Gryllotalpa australis	39	52.0	3.7 (11)	3	18.8	3.33 (7)
Ichnuemonid wasp	1	1.3	1.0	-	-	-
*Labidura sp.**	1	1.3	1.0	-	-	-
Oxycanus fuscomaculatus	9	12.0	2.0 (5)	-	-	-
Persectania ewingii	-	-	-	10	62.5	42.5 (195)
Phaulacridium vittatum	25	33.3	7.1 (40)	-	-	-
Pimelopus nothus	3	4.0	1.0	2	12.5	1.5 (2)
*Saprinus sp.**	3	4.0	1.0	-	-	-
Stanwellia pexa	4	5.3	1.0	1	6.3	1
Tenodera australasiae	15	20.0	1.3 (5)	-	-	-
*Thalycrodes sp.**	1	1.3	1.0	-	-	-
shield tick*	2	2.7	1.0	-	-	-
Plant	54	72.0		10	62.5	
Soil	53	70.6		10	62.5	
Empty	13	17.3		3	18.8	
Lenses	10	13.3	3.7 (7)	6	37.5	2.83 (9)

* Assumed to be accidental ingestions
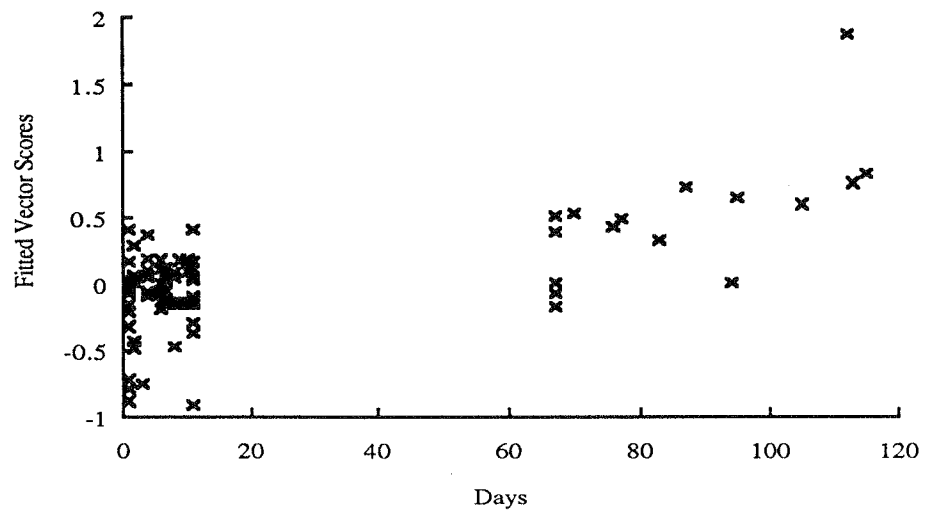
Fig. 6.1 Plot of fitted vector for the killdate vs. killdate

Table 6.2. The Total Numbers of the Common Winter Prey items by Capture Day in the Gut of the the Feral Cats of Great Dog Island.

Capture day	*P. tenuirostris*	*P. ewingii*	*N. metallica*	*Mus musculus*	lenses
67	2	20	4	-	2
70	-	-	5	-	3
76	-	1	1	-	1
77	1	1	2	1	9
83	-	-	1	-	-
87	-	195	1	1	10
94	-	-	-	-	-
95	-	29	-	1	-
105	-	111	2	1	-
112	-	24	-	-	-
113	-	31	-	1	-
115	-	13	-	1	-

Most arthropod species are assumed to be a result of accidental ingestion or of minor dietary importance. Ten species were considered to be the result of deliberate predation, seven of which were considered to be of greater importance due to either numbers ingested and/or size. These were *G. australis*, *P. vittalum*, *T. australasiae*, *A. ambulans*, *O. fuscomaculatus*, *P. nothus* and *P. ewingii*. All were present in the autumn diet

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except *P. ewingii*. During winter *G. australis*, *P. nothus* and *P. ewingii* were present. 2 of these species were exploited as larvae (*O. fuscomaculatus* and *P. ewingii.*) while a further species was exploited in both larvae and adult stages (*P. nothus*). The larval stage of these 3 species are not hairy and so are likely to be palatable.

Ten scats obtained one year after the commencement of the eradication programme consisted of only *M. musculus* remains. The hard parts (mandibles) of twelve mice were present. No bird, reptile or arthropod remains were present. Also no mouse ingesta was present.

Muttonbirds *Puffinus tenuirostris* are the most abundant Australian shearwater and possibly Australian bird. Birds arrive at Great Dog Island in the third week of September. After 're-courtship', burrow renovation and copulation, the island is vacated until egg laying begins 19-21 Nov. One egg is laid between 19th Nov. and the 1st of Dec. and incubated for 52-55 days. Chicks remain in the nest for 94 days. Parents migrate during the second week of April while chicks migrate late April to early May (Pizzey, 1983). Chicks are guarded in first week, then left up to a week from early to mid-March. The burrow is large enough for a cat to enter. Muttonbirds are harvested between the 27th of March and the 30th of April. As the muttonbird had commenced on its migration at the time of the eradication programme, the presence of muttonbird in the diet of cats indicated scavenging.

The house mouse *Mus musculus* is usually crepuscular or nocturnal, and is herbivorous.

The reptiles are diurnal. The tiger snake *Notechis ater* feeds on mice, reptiles and birds. The white-lip snake *Drysdalia coronoides* feeds on lizards and amphibians. Lizards feed on other lizards and invertebrates. It could not be determined if the tiger snake remains in the diet of one cat was due to predation or to scavenging.

Mole cricket *Gryllotalpa australis* 4cm. long. Subterranean burrower, in shallow horizontal tunnels where it feeds on roots. Rarely leaves burrows for dispersal flights. Males sing loudly just below surface, and therefore easy for a cat to locate by sound. Most likely exposed by excavation. Common in Tasmania in sandy soils.

Grasshopper *Phaulacridium vittatum* 1.5-2.0 cm. Feeds on green foliage especially annual dicotyledonous plants. They are polymorphic for wing length, but most are brachypterous. Adult grasshoppers are present from January to winter, but most die after Autumn. Diurnal. Easy for a cat to catch and very abundant in some years.

1. A forefoot from a skink *Niveoscincus metallicus*.

2. The upper beak and skull from a muttonbird *Puffinus tenuirostris*.

3. The skull of a mouse *Mus Musculus* with some fragments of mouse ingesta.

4. A section of the abdomen of a skink *Niveoscincus metallicus*.

5. The lower mandibe of a skink *Niveoscincus metallicus*.

Fig. 6.2 Examples of Fragments of Vertebrate Prey found in the Gut of Feral Cats from Great Dog Island
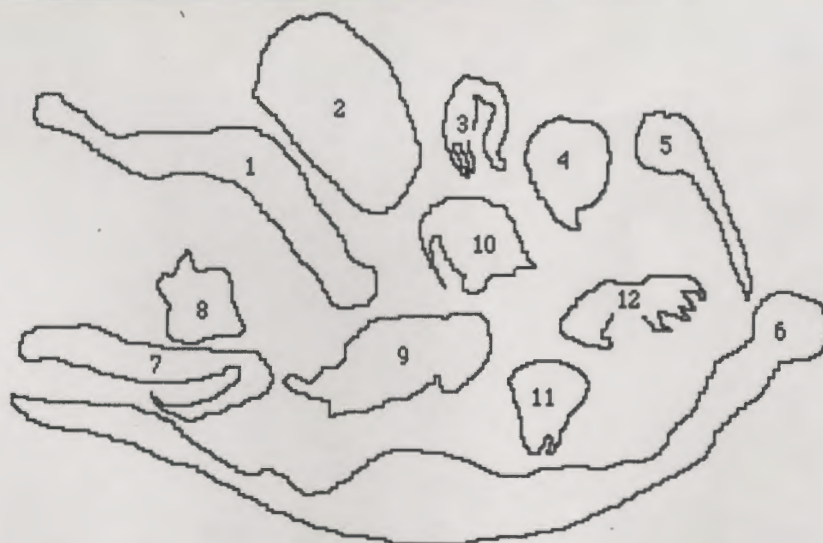
1. Dermis and head capsule of the Army worm (caterpillar) *Persectania ewingii*.
2. Half of a wing case from the beetle *Pimelopus nothus*.
3. Pedipalp of a scorpion *Cercophonius squama*.
4. The head of a cricket *Apotrechus ambulans*.
5. An ovipositor of a cricket *Apotrechus ambulans*.
6. Dermis and head capsule of a caterpillar *Oxycanus fuscomaculatus*.
7. The forelimb of a mantis *Tenodera australasiae*.
8. The head of a mantis *Tenodera australasiae*.
9. The head and thorax of a grasshopper *Phaulacridium vittatum*.
10. The Chelicerae (fangs) of a trapdoor spider *Stanwellia pexa*.
11. The head of a mole cricket *Gryllotalpa australis*.
12. The forelimb of a mole cricket *Gryllotalpa australis*.

Fig. 6.3 Examples of Fragments of Invertebrate Prey found in the Gut of Feral Cats from Great Dog Island

Mantis *Tenodera australasiae* 12.0 cm. A slow-moving ambush predator, which hunts amongst grass, tussocks or on shrubs for prey such as flies. Active by day and night.

Cricket *Apotrechus ambulans* 4.0 - 5.0cm. A nocturnal omnivorous cricket which spends daylight hours in a burrow. Emerges at night to forage for seeds, small insects and carrion. Common in sandy soils near the coast.

Caterpillar *Oxycanus fuscomaculatus* 9 - 10 cm. A large caterpillar often gregarious, which lives in a vertical tunnel in the soil from which it emerges at night to feed on grasses or prostrate plants. Has a 2 year life cycle. Turns into a large brown moth in May. Cats could predate these in the evenings.

Beetle and caterpillar *Pimelopus nothus* (adult, 4.0 cm.). A large scarab or cockchafer-type of beetle. Larvae is a subterannean grub which eats roots of grasses. The larvae never comes to the surface. The adult flies but only at night. Lives in sandy soils. Cats would need to excavate larvae.

Army worms *Persectania ewingii* 4.0-5.0cm. Often super-abundant on grasses at night feeding on the leaves. During the day they hide at the base of the grass tussocks. Probably 2 generations per year. The adult is a grey nocturnal moth.

Spider *Stanwellia pexa*. 5.0 cm. A trapdoor spider living on coastal sandy soil. Preys on slaters etc. Lives in a deep burrow but comes to near the surface at night. Males wander over the ground in autumn looking for females in their burrows. Long-lived.

Scorpion (*Cercophonius squama*) 4.0-5.0 cm. Only one species in Tasmania. Eats a wide range of small prey items. Nocturnal. Common in litter. Active all year round near sealevel. Has only a minor sting.

The remaining species were considered to be accidental ingestion, i.e. accidently ingested when the cats have been scavenging (e.g. dipterans) or grooming themselves (e.g ticks). No further discussion of those species will be made.

The prey of skinks bore no resemblance to those of the cats, differing both in size and species.

Also present in the gut of cats were yellow, glass-like, spherical objects ranging from 1.5 to 2.0mm. The origin of these are unknown but are thought to be eye lenses. Further investigation by comparative analysis is required to determine their origin.

Such an investigation was beyond the scope of this thesis.

6.7 DISCUSSION

The cats on Great Dog Island captured in 1991 exhibited an opportunistic hunting strategy shifting from hunting live prey to scavenging carcasses of the muttonbird (*P. tenuirostris*) as the need arose. This would be important to the cats on the island as the high densities of conspecifics and the inability to migrate to areas of higher prey avalability, together with presumed fluctuations in food availability exerts a pressure to exploit food resources as they arise. This exploitation extends to the predation of potentially lethal or harmful prey such as the tiger snake, the trapdoor spider, and the scorpion, and to invertebrates of relatively low energy content, including grasshoppers and ichnuemonid wasps. Despite their size these species must provide a net energy gain as a loss would be detrimental to the cat. It was concluded that arthropod species found in cats and classed as prey items were not present due to secondary ingestion via skinks. The incidence of cats with empty or residual amounts of food in the gut may be a result of time in the box trap rather than to lack of hunting success.

There was no advantage in age, body size or coat colour in obtaining prey species. Juveniles and sub-adults had already acquired skills enabling them to take more elusive prey such as mice, lizards, and white-lip snakes, even trapdoor spiders and scorpions.

The diet exhibited definite seasonality, most probably reflecting seasonal fluctuations in the availability of food. Scavenging on muttonbird carcasses formed the principal component of cat diet during the autumn with scavenging peaking at this time. The majority of cats had feathers in the gut that matched those feathers found on the breasts and abdomen of muttonbirds, suggesting that the cats were targeting these areas. However, one cat had the upper mandible and skull of a muttonbird, while two others each had one foot. The plumage for all but one bird, was adult. Hunting was apparently of secondary importance, but resulted in a wide number of species being exploited. Generally, cats trapped during autumn had very similar diets.

During the winter, scavenging was much reduced and hunting became more significant, with the skink *N. metallica*, mice and *P ewingii* becoming important in the diet. The numbers of reptile and arthropod species exploited at this time was lower than that of autumn. Variations in diet occurred during the 6.5 weeks over which the winter cats were captured. The exploitation of muttonbird carcasses and *N. metallicus* and the presence of lenses was predominantly in the first three weeks. In the second three

weeks, these items dropped out, while the frequency of mice and *P. ewingii* in the diets increased. As previously mentioned this is most probably a reflection of prey availability not preferential selection of certain prey items.

The prevalence of reptiles in the diet, especially the skink *N. metallicus*, is comparable only with studies undertaken in the arid and semi-arid areas of mainland Australia. This indicates both a high relative abundance of *N. metallicus* and the importance of reptiles in the diet of feral cats on Great Dog Island.

The diet of the cats indicates that cats procurfed food during both day and night. Muttonbird carcasses, when available, could be exploited at any time. It is assumed that the diurnal meals of the cat, when in season, consisted of muttonbird, reptiles, grasshoppers, mantis and *P. nothus* (adult). At dawn, dusk and during the night, meals consisted of mouse, crickets (*A. ambulans*), *O. fuscomaculatus*, *P. ewingii*, trapdoor spiders and scorpions. The presence of 195 *P. ewingii*, in the gut of one cat and 111 in another suggests that the importance and availability of this species, and probably arthropods in general. Although the energy content per individual is not known, *P. ewingii* are virtual bags of food as only the head capsule and part of the dermis is not digested. 195 individuals would be the same weight as 3 to 4 mice.

As the mole cricket rarely comes to the surface and *P. nothus* larvae are subterannean, it is most probable that these two species were excavated. However, the occurrence of *P. nothus* in the diet usually occurred with, or was preceded by one or two days of rainfall, each day having between 7 and 15 mm of rain falling (measured at Whitemark, capital of Flinders). It could be likely that this species had migrated closer to the surface at this time where it was more vulnerable to predation. The presence or absence of wet or dry weather did not seem to make any other species (vertebrate or invertebrate) more or less susceptible to predation. Even though some cats had large amounts of hair in the gut, there was no indication of cannabalism as was evident on Macquarie Island (Jones, 1977) or on the Australian mainland (Jones and Coman, 1981).

The soil in the gut of cats is most likely a result of excavation and ingestion subterannean invertebrates.he accidental ingestion of soil accumulted on and in muttonbird carcasses. Some cats had quite large quantities of soil (to 10 g).

Most of the vegetation ingested by cats were grasses both native and introduced. This indicated that prey was mostly obtained in the muttonbird rookery or in one of the areas under pasture. Only one cat had vegetation from the forested areas. This consisted

of a twig of *Casuarina stricta*. The large amounts of grass in the gut of some cats suggested that they were ingested deliberately. The reasons for this include grass aiding the regurgitation of fur balls and undigested bone or being a lactic acid supplement in a precaution against anemia. Grass may also be a laxative or a source of vitamin C (Bayly, 1976).

In the previous chapter, parasites in the gastro-intestinal tract suggested that an increase in the proportion of mice and a decrease in scavenging may occur in the winter cats. This was confirmed in this chapter. However the high prevalence of reptiles in the was not alluded to. This may be due to the absence of intermediate hosts on the island. For example, one parasite in found in cats and associated with reptiles is the cestode *Spirometra erinacae*. An intermediate host of the species is a copepod. As there are no water bodies on the island the copepod is not present to complete the life cycle of the parasite.

Ten scats obtained one year after the eradication programme (May 1992) indicated that hunting, not scavenging, was the main method of procurring food and mice were the only prey item. The prevalence of mice and lack of bird, reptiles or arthropods in the diet was a noticeable change from the previous year. As mouse numbers at this time were high, cats were probably responding to an increased frequency of encounters over that of muttonbird carcasses and skinks which were also abundant. As mice were not as prevalent in the diet as the previous year this suggests that the mouse population may have been kept low by, for example, predation pressure or a response to natural population cycles. It is hypothesized that the removal of most of the cats caused a reduction in predation pressure resulting in the growth of the mouse population to levels where they were the most available resource to predators. The effect of the increased mouse population on the island fauna is unknown. However, the lack of mouse digesta in the faeces of feral cats suggests that food reserves may be nearly depleted. This was also inferred by a post-mortem on two mice that indicated that the mice had no food in the intestinal tracts nor were they carrying any fat.

The impact of cats on the fauna of Great Dog Island is difficult to establish without further study. The diets of feral cats during spring and summer are unknown and population parameters of prey need to be determined. The feeding habits of cats and rates of predation also need to be ascertained. For example, due only to the relative availability of the muttonbird during the breeding season (an estimated 400,000), it is likely to be predated by feral cats. It is not known however, to what extent cats are predating on 'surplus' birds that may have died regardless. Another complicating factor is that it is not known how much a cat will eat before it kills again. For example

a muttonbird weighs around 580g The average weight of adult male and adult female cat on Great Dog Island is 4.626kg and 2.955kg respectively. Thus, assuming that a cat will require 6% of its own body weight per day, males will require 278g/day, approximately half the weight of a muttonbird, and females (assuming not pregnant or lactating) will require 177g/day, approximately a third the weight of a muttonbird per day. However, it is not known if a cat will eat all the bird in two (for males) or three (for females) days or will kill every day. Therefore in one week, the 54 adult male cats may kill between 189 and 378 muttonbirds, while the 56 adult female cats may kill from 131 to 392. Extrapolating hypothetically from this, for the approximate 22 weeks that the muttonbirds nest, and assuming muttonbirds were the primary source of food, adult males would kill between 4158 and 8316 birds, while females would kill between 2882 and 8624 birds, a total of between 7040 and 16940 birds. However, as Great Dog Island is a commercial muttonbird rookery the effect of man is far greater.

A further problem (albeit possibly a minor one) in assessing the impact of feral cats on Great Dog Island may be the incidence of 'surplus' killing. This behaviour has been noted in mammals such as the leopard *Panthera pardus*, caracal *Felis caracal*, (Stuart, 1986) and domestic cat *F. catus* (George, 1978) as well as small predatory bird species such as the American kestrel (*Falco sparverius*) and the loggerhead shrike (*Lanius ludovicianus*) (Oksanen et al., 1985). This behaviour has been defined as '... the killing by a predator of prey, without the killing individual or its offspring or members of the same social unit eating anything from the kill, although there is free access to the carcass, and usually the particular prey species would be eaten by the predator' (Stuart, 1986, p. 556). This phenomenon occurs as a response by smaller predators to the threat of larger predators entering their territory and capturing live prey. Prey from 'surplus' hunting is hidden and therefore is protected from these potential invaders and acts as a food store for when the relative availability of prey declines.

6.8 SUMMARY

1. A total of 26 prey species were found in the gut of cats. These consisted of 2 bird, 1 mammal, 5 reptile and 18 arthropod species. Of the arthropods, 8 insect species were considered prey items while 7 were assumed to be the result of accidental ingestion. Of the 3 arachnid species present, 1 was considered to be the result of accidental ingestion. The gut of 16 cats were either empty or contained residual food stuffs. Most cats had soil and plant matter in the gut.

2. The cats on Great dog Island captured in 1991 exhibited an opportunistic hunting strategy shifting from hunting live prey to scavenging carcasses of the muttonbird *P. tenuirostris* as the need arose.

3. There was no advantage in age, body size or coat colour in obtaining prey species.

4. The dietary analysis exhibited seasonality, most probably reflecting seasonal fluctuations in the availability of food. Scavenging formed the principal component of cat diet during the autumn. During the winter, scavenging was much reduced and hunting became dominant.

5. It is most probable that two species of arthropod were excavated. This also explains the frequency of soil in the diet.

6. Except for *P. nothus* the presence or absence of wet or dry weather did not seem to make any species (vertebrate or invertebrate) more or less susceptible to predation.

7. There was no indication of cannabalism.

8. In the previous chapter, parasites in the gastro-intestinal tract suggested that an increase in the proportion of mice and a decrease in scavenging may occur in the winter cats. This was confirmed. However the high prevalence of reptiles in the diet was not alluded to. This may be due to the absence of intermediate hosts on the island.

9. Ten scats obtained one year after the commencement of the eradication programme (May 1992) indicated that hunting, not scavenging, was the main method of procurfing food and mice were the only prey item. This was a significant change from the previous year.

10. The effect of feral cats on prey species on Great Dog Island is difficult to establish without further study as the diet of cats during spring and summer is unknown, and will probably fluctuate in response to prey availability. Also, it is not known to what extent cats are predating on 'surplus' animals that may have died regardless. Another complicating factor for large prey is that it is not known how much a cat will eat before it kills again.

7 CONCLUSIONS

7.1 CONCLUSIONS

In relation to the aims outlined in chapter one:

The 189 feral cats eradicated from Great Dog Island in 1991 displayed a male: female ratio of 1:1. The pre-eradication density was estimated to be at least 56.9 cats/km^2, which is comparatively high for a non-urban feral population. Juveniles and sub-adults made up 44.9% of the population, while the remaining 55.1% of cats were in either reproductive or post-reproductive phases. The ages of juveniles suggested that a breeding season occurred between November and mid to late April with a peak in February. Seasonality in breeding was also suggested by changes in the population structure as the autumn population consisted of juveniles, sub-adults and adults, with two females lactating and none pregnant; while the winter population consisted of adults and one sub-adult only; no females were lactating or pregnant. The approximate life expectancy of these cats was estimated to be 73-84 months for males and 85-96 months for females.

Counting cementum annuli in the teeth was shown to be an effective method of age determination. By comparison with two known-age samples and incorporating the findings of van Aarde (1983) 89 cats were assigned to estimated age classes. Complications in the use of cementum annuli include: 1. Limited access to known age material. 2. Variations in the structure of annuli, and 3. Over-decalcification.

Chapter 4 revealed that length and weight of male and female feral cats of Great Dog Island was comparable to that of populations on the Australian mainland. However, a decline in the weight of adult females between autumn (mean weight of 3.233 ± 0.580 kg) and winter (mean weight of 2.620 ± 0.397 kg) suggested the occurrence of seasonal nutritional stress on the island. Adult females displayed no significant relationship between age and length beyond their first year, suggesting that, in females, length offers no advantage to longevity. However, the relationship between age and length in adult males suggests that greater length is associated with longevity. Adult males were generally proportionately larger than females, however, the head width, mandible width and depth of males were noticeably larger than that of females.

The presence of seven mutant pelage-related genes, in addition to the wild type, indicated a comparatively high degree of genetic diversity within the feral cat population of Great Dog Island. Comparable numbers of pelage-related genes have only been recorded in urban and rural areas where domestic cats can provide a great diversity of genes to the feral population. The long hair allele is probably being selected against as juveniles suffer high mortality (an adult: juvenile ratio of 1: 2.75). The expression of the inhibitor allele is bias toward males (a ratio of 1: 0.5). No significant relationships were found to occur between coat colour and weight or length. However, for adult males and females, the darker phenotypes (blotched and non-agouti) were slightly, but not significantly, smaller than the light phenotypes.

The analysis of diet resulted in a total of 26 species being found in gut of cats. These consisted of 2 bird, 1 mammal, 5 reptile and 18 arthropod species. Of the arthropods, 8 insect species were considered prey items while 7 were assumed to be the result of accidental ingestion. Of the 3 arachnid species present, 1 was considered to be the result of accidental ingestion. The gut of 16 cats were either empty or contained only residual food stuffs. Most cats had soil and plant matter in the gut. In a few cases, the presence of finely cut plant matter in the gut of cats was due to secondary ingestion. This plant material was only found in association with mouse remains and was assumed to be mouse ingesta. As two subterannean species of arthropod were recovered, it is probable that the cats actively excavate in the soil. There was no evidence of cannabalism and no human refuse was present

The cats on Great Dog Island exhibited an opportunistic hunting strategy shifting from hunting live prey to scavenging as the need arose. Scavenging formed the principal component of cat feeding strategy during the autumn. During the winter, scavenging was much reduced and hunting became dominant.. Ten scats obtained one year after the eradication programme indicated that hunting, not scavenging, was the main method of procuring food, this was a noticeable change from the previous year. Food selection is generally a response to the relative availability of prey species

There was no advantage in age or body size in obtaining prey species. Juveniles and sub-adults had already acquired skills enabling them to take more elusive prey such as mice, lizards, and white-lip snakes, even trapdoor spiders and scorpions.

Generally, the coat and skin condition of cats on Great Dog Island was very good, with only one individual having a skin disorder. None displayed lameness, pustules or abscesses, and no carcinomas were detected. Tooth condition of cats was also generally very good, with tooth wear or loss only occurring in adult cats, and high degrees of tooth loss and wear only present in the two oldest cats.

The nutritional condition (fat deposits) of cats suggested that generally, the autumn cats were in good condition. The juvenile and sub-adult males procured slightly greater amounts of fat than their female counterparts. The autumn adults of both sexes generally had proportionately similar fat deposits suggesting that once adulthood was attained, the ability to obtain these energy reserves was equal. Only one adult cat in the autumn sample, the oldest female, displayed relatively poor nutritional condition with only light deposits of fat.

Both sexes underwent a large decline in fat reserves from autumn to winter and reserves were further depleted as winter progressed, leading to generally poor nutritional condition in winter cats. This signified that cats were unable to maintain nutritional condition from winter prey alone and fat reserves needed to be metabolized to meet energy demands. It is likely therefore, that nutritional stress was a major factor limiting the cat population on Great Dog Island, particularly in juveniles and sub-adults that failed to acquire adequate fat reserves.

The diversity of gastro-intestinal parasites in Great Dog Island cats (3 species) is low compared to that of Australian mainland studies (6 to 9 species), and more closely resembles that of Macquarie Island (2 species).The species present were *Taenia taeniaeformis*, *Toxocara cati* and *Cylicospirura felineus* . There was a large difference between the percentage of males and the percentage of females infested with parasites with the males displaying a much lower degree of infestation. It was found that loss of condition did not generally result in an increased susceptibility to parasite infestation. Changes in prevalence of gastro-intestinal parasites through time were instead better explained as a response to the diet of cats and to climate.

7.2 ARE MUTTONBIRDS THE KEY TO CAT SURVIVAL?

In spite of the absence of hard data, indirect evidence assembled suggests that muttonbirds are a key resource to the cats of Great Dog Island.

The high densities and 1: 1 sex ratio of feral cats on Great Dog Island suggests that food is readily available. However, although the cats were able to acquire food, fat

deposits were being depleted as winter progressed, suggesting that a decrease occurred in the quality and/or quantity of food. Keeping in mind that fat deposits are a reflection of past dietary success and that cats sampled in autumn had large deposits of fat, these fat reserves were likely to have been obtained during the summer when numbers of muttonbirds are very high (900,000 adults, 400,000 young). Since the diet of cats usually reflects the relative abundance of prey, it is probable that muttonbirds are being eaten.

The calculation of the energy content of muttonbirds was beyond the scope of this thesis, however, a similar sized sea-bird in the same family as muttonbirds, the great-winged petrel *Pterodroma macroptera* has an energy content of 4000kJ per individual (van Rensburg, 1985). Keeping in mind that such comparisons are problematical, if the energy content of muttonbirds are similar, an adult male cat consuming 278g (6% of cat body weight) of this bird would gain 2000kJ, which is 334kJ greater than the estimated daily requirement. An adult female (also assumed not to be pregnant or lactating) consuming 177g (6% of cat body weight) will gain 1333kJ. which is 269.2kJ greater than the estimated daily requirement. A lactating female (assumed to be the same weight as an average female) would require 2955kJ per day. This also could be met by one muttonbird.

This indicates that by exploiting muttonbirds there is potential to build fat reserves to assist in meeting energy demands during winter when prey availability is presumably depleted.

Another advantage from eating muttonbirds is that the high fat content of this bird results in greater production of metabolic water. As there is no free water on the island, this would be of benefit in the summer.

The only adult cat not to have a large deposit of fat was the oldest female. The tooth condition of this cat was also poor, with all teeth either very worn or missing, thereby reducing her ability to catch and/or handle prey. However, she was still able to obtain some food as her gut was more than half full with scavenged muttonbird, arthropods and one skink. It is assumed that this cat was unsuccessful in obtaining live birds which reinforces the probable importance of live mutton birds in building condition for the winter period.

7.3 SUGGESTIONS FOR FURTHER STUDY

Suggestions arising from chapter three, 'Population Structure and Dynamics', are:

1). A study of the spacing patterns of a high density feral cat population on an island, would answer some questions raised in this chapter. The field work should be carried out over one year at least to account for any seasonal variations. Questions to be addressed are:

i). Is the social system heirarchical, territorial or non-existant? What is the effect on territory size?

ii). Is this system plastic? Does the structure change depending on seasonal changes in cat densities and the relative abundance of resources over the course of the year?

iii). In which age group do young cats become independant, and what is their nutritional status at this point? Do the young females remain associated in a maternal group or do they disperse?

2). Follow up work is required to verify the estimated age of cats, especially those in the older age classes (3 years and older). There is also a need to compare sexes further to verify that no differences occur. Some persistance is required in obtaining known age teeth from vetinarians. During this study, only two known-age samples were obtained even after continued approaches. This does not indicate a reluctance on the part of the vetinarian to provide these samples, but is probably due to dental work resulting in teeth being too damaged to be of use, or to clients taking the intact dearly departed to be buried under the rose bush in the corner of the garden.

3). Follow up work is required on the use of adhesion or growth lines occurring in the periosteal region of cat mandibles. Being thicker than cementum lines in teeth, these structues lend themselves to age determination. However, known age samples may prove harder to acquire than samples of teeth.

4). It is recommended that other metachromatic stains be tested for their ability to stain for annuli and/or adhesion lines.

5). Age determination by the methods described may also be of use in estimating the ages of native mammals. This could be of use, for example, in assessing the ages of road kills to see what age group, if any, are more vulnerable.

A suggestion arising from chapter four, 'Morphology and Phenotypes':
A study comparing the mutant-allele frequencies of the Great Dog Island cats to feral and domestic cat populations on Flinders and nearby islands would be useful. Such a study may help explain the pelage-related genetic diversity on Great Dog Island and offer further insights into interactions between coat colour and environment.

A suggestion arising from chapter five, 'Condition', is:

A condition indice based on a weight length relationship would be of great use in assessing the nutritional condition of feral cats. Such an indice would be of great practicle application as it is fast, efficient and removes the subjectivity of visual scoring. The application of a condition index is only feasible if validated by comparison to an independent measure of condition.

Suggestions arising from chapter six, Dietary analysis, are:

1.) As an aid to further research, the energy content of both invertebrate and vertebrate prey species should be determined.

2). In addition to suggestion #1, and in particular reference in this case to cats, the differential digestibility of prey needs to be determined. This could be accomplished by establishing feeding trials. This enables a researcher to estimate what percentage of a prey item is actually digested. This, together with information regarding the energy content of the prey, will aid in generating much information on the quantities/prey required by predators.

3). If further eradication programmes are commenced the opportunity there for predator removal experiments to be established. Such work would indicate what effect the removal of a top order carnivore would have on other predators and prey.

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APPENDIX 1

Arthropods obtained from Great Dog Island between 25-27 May 1992

ORDER	FAMILY	GENUS/SPECIES
Diptera	Calliphoridae	*Calliphora sp.*
	Chloropidae	undetermined species
	Muscidae	undetermined species
	Chironomidae	undetermined species
	Mycetophilidae	undetermined species
Lepidoptera	Noctuidae	*Persectainia ewingii.*
	Arctiidae	*Luecania uda.*
		Phaeophlebosia sp.
Coleoptera	Byrrhidae	*Microchaetes sp.*
	Scarabaeidae	*Pimelopus nothus.*
	Scarabaeidae	*Aphodius sp.*
	Tenebrionidae	*Saragus sp.*
	Carabidae	*Hypharpax sp.*
	Anthicidae	*Anthians sp.*
	Nitidulidae	undetermined species
	Ptinidae	undetermined species
	Staphylinidae	undetermined species
Hymenoptera	Formicidae	*Iridomyrmex sp.*
		Pheidole sp.
		Rhytidoponera sp.
Homoptera	cicadellidae	undetermined species
Psocoptera	Psocidae	undetermined species
	Curculionidae	*Timareta sp.*
Blattodea	Blattellidae	undetermined species
Dermaptera	Labiduridae	*Anisolabis sp.*
Acarina	Erythraeidae	undetermined species
	Penthaleidae	undetermined species
Pseudoscorpinida		undetermined species
Araeinida	Theridiidae	undetermined species
		Lampona cylindrata.
		Nicodamus bicolor.
	Lycosidae	*Lycosa sp.*
Amphipoda		undetermined species
Isopoda		undetermined species
Collembola		undetermined species
Archaeognatha		undetermined species

APPENDIX 2   Table of diet by killday demonstrating a shift in prey as the season progresses.

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                           Autumn Cats                        | Winter Cats
              1111111111122222222223333333333444444444455555555556666666666777777777788888888889999
              12345789012345678901234678901234567890123456789012345678901234567890123456789012345 78901

Tigersnake    -1-------------------------------------------------------------------------------|-------
mantis        ---1-1-----1---5----1--------1111--1--1-1-1-1-------------------------------1-----|-------
Scorpion      --------------1----------------1-------------------------1------------------------|-------
Bougainvilli  ----------------------------------------1----------------------------------------|-------
Ocelatus      ------------------------------------1--------------------1------------------------|-------
grasshopper   ---113---41----1--*------*---------*1*-231141-3-11-------42--51--*-----------------|-------
Oxycanus      ---15------------------------------------1-----------4-1---11---31----------------|-------
Apotrechus    1---2--------1----1------1-----1--3-1--1------------------------------------------|-------
mutton bird   11-1111111111111111-1111111-111-11111111111111iii1111-11111111-1-1--1-------------|-------
Whitelip snake -----1-------------------------------------1--------------------------------------|-------
mole/cricket  92-*-46-**231971-1-35-112---1-3-3-632-12-53-3-1--1-1-58-11----3---1-2----7--------|-------
Soil material ---11----1111-111-111-1-1111111----1111111111111111111-1111-11--11111-111111------|-------
Plant material 11-11-1-11-1111----11111111-1111-1111111-1-1111111-1111--1-11111--111-111-111-11--|-------
Cat hair      -111----11-1--11-1--1111-111-1-1----1-11-111-1--11-1---11--1--111-1111111--1------|-------
Metallicus    ----12-1--111---1-1417-1-1-1-1-1--3112---111111----1-1-1------1----11115121 1-2---|-------
Stanwellia    --------------------------1-----------1---------------11-------1----1--------------|-------
Lens          ---74--2---7-----------------1-----------------5------4--4--2-1--11319-2-----------|-------
Pimelopus     -----------------------------------------------------1-1--1------2-1--------------|-------
Mouse         --------1-------------------1-----11--------1-1----------------------1-111-11------|-------
passserine    ----------------------------------------------------------------1-----------------|-------
Army worms    -----------------------------------------------------------*3-11-******------------|-------
```