THE HEALTH, HAEMATOLOGY AND BLOOD BIOCHEMISTRY OF FREE-RANGING FARM CATS IN RELATION TO SOCIAL STATUS

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Abstract *Animal Welfare 1998, 7:* 243-256

*In order to test the hypothesis that social parameters within carnivore societies are correlated with health status, a profile is presented of the general health, haematology and blood biochemistry of a colony of free-living feral farm cats (*Felis silvestris catus*). Samples and biochemical data were collected between late November and early December 1989. A higher proportion of adult males than females was found to be clinically abnormal. Social status (Central or Peripheral) had a significant effect on female mouth condition, but not on male mouth condition. Eosinophilia (34.6% of individuals), high fibrinogen levels (19.2%) and low haemoglobin levels (28.8%) were significantly more likely to occur in clinically abnormal than in clinically normal cats. Blood biochemistry varied with age and, among adults only, varied between the sexes. Haematological measurements varied significantly with age and sex. There were no haematological effects of social status in males, but in females social status affected reticulocyte, neutrophil, eosinophil and white blood cell (WBC) counts. We interpret variation in health and haematology in terms of the differences in social status and reproductive tactics.*

Keywords: *animal welfare, blood biochemistry, feral cat, general health, haematology, social status*

Introduction

Feral cat (*Felis silvestris catus*) colonies are common throughout the world, and often occur in close proximity to man or livestock on farms and in cities (UFAW 1981). Their health is important for several practical and scientific reasons, in addition to considerations of welfare. First, it is important to monitor the health of these free-living populations because cats can carry and transmit numerous diseases which affect humans, livestock and wild animals. The health status of free-ranging cats is important for the conservation of endangered wild felids because feral domestic cats may represent a significant health hazard to rare wild felids (Yamaguchi *et al* 1996). Nevertheless, though there have been studies of the health, haematology and blood biochemistry of pet or laboratory cats (Jain 1986; Parry 1987; Earle *et al* 1990; Evans 1994), few have focused on free-living feral cats (Yamaguchi *et al* 1996).

Over and above the foregoing reasons for evaluating the health of feral cats is the opportunity which they offer to test an hypothesis of general importance in mammalian

populations. Because members of farm cat colonies can readily be assigned to straightforward categories of sex, age and social status, they provide an excellent model for testing the hypothesis that poor health is associated with low status. The elusive nature of many wild felids largely precludes such study.

Feral cat colonies are organized into matrilineal feeding groups (Macdonald *et al* 1987; Liberg & Sandell 1988). Two classes of cat can readily be identified: 'Central' individuals which are spatially clustered at centralized feeding and denning resources and tend to live in groups; and 'Peripheral' individuals which tend to live alone on the margins of a resource centre, and which, especially in the case of males, may move between colonies (Kerby & Macdonald 1988). Central females have higher breeding success than Peripheral females (Kerby & Macdonald 1988). Central or Peripheral status, and other social factors, may hitherto have been overlooked as elements which might affect an animal's physiological condition and health (Evans 1994). Sex, age, season, diet, capture method and handling also influence blood biochemistry and haematology (Beltrán *et al* 1991; Knick *et al* 1993). We selected a large colony of cats so as to be able to sample all age-sex classes under similar environmental and resource conditions.

For these reasons, our aim in this paper is to report baseline values for haematology and blood biochemistry of exclusive free-living feral cats, and to investigate the relationship between status (Central or Peripheral) and health of free-living feral cats with special reference to blood biochemistry and haematology.

Materials and methods

All procedures were conducted under the Home Office Personal Licence PIL 30/02172, and Project Licence PPL 30/00043.

Study colony

We studied a colony of 50 to 80 feral cats living at Barley Park Farm, Ducklington, Oxfordshire, United Kingdom (51°45'45"N,1°30'20"W). The farmer provided cats with fresh milk and dry cat food daily, placed at three sites around the outbuildings. Cats were neither culled, nor given general veterinary care.

Cats were classified into the following age groups: adult (known to be older than 12 months of age, or had been observed copulating with another sexually mature individual); juvenile (6-12 months old and had not been observed copulating); or kitten (less than 6 months old). Juveniles and kittens were grouped together as subadults.

To determine the social category (Central or Peripheral) of adult cats we observed them at feeding sites for 2 years, following the methodology of Kerby (1987). During observation periods, feeding sites were scanned every 30min and all cats present were individually identified. Cats which were present for less than the average calculated for their sex, in terms of number of visits, were considered to be Peripheral, while cats present more often than average for their sex were considered to be Central (Kerby & Macdonald 1988). Three Central matrilines, each comprising a different feeding group, were identified. In early November 1989, the sex, age and current status (Central versus Peripheral) of the 55 cats then present on the farm were abstracted from routine data on patterns of attendance at the feeding sites, and used as the basis for exploring health parameters.

Trapping, handling and sampling procedures

Cats were trapped in box-traps baited with cat food and set for seven nights between late November and early December 1989. Traps were set at dusk and checked at or before dawn. A total of 52 individuals were caught: 36 adults (15 males and 21 females, consisting of 8 Central males, 5 Peripheral males and 2 males of unknown status, plus 18 Central females and 3 Peripheral females); 10 juveniles (8 males and 2 females); and 6 kittens (5 males and a female). Only three individuals known to belong to the colony (an adult male, an adult female and a juvenile male) eluded capture.

Captured cats were immobilized with an intramuscular injection of 22mg kg-1 ketamine hydrochloride (Vetalar™, Parke, Davis and Co, Pontypool, Gwent, UK). The following measurements were then taken: head-body length (between the tip of the nose and the sacro-coccygeal joint); tail length (between the bottom of the tail and the tip of the tail, excluding hair); hind foot length (from the end of the calcaneus to the bony tip of the longest digit – digit 3); neck circumference; skull width (the maximum zygomatic width of upper skull); canine length (the longest dimension on buccal surface of the upper right canine, or the left canine if the right one was damaged or missing); number of upper and lower incisors; and weight.

While immobilized, and under veterinary supervision, a blood sample(of < 10ml for adults and < 4ml for subadults) was taken from a jugular vein and put into two evacuated glass tubes, one containing dipotassium salt of ethylenediaminetetracetic acid (EDTA) and the other containing lithium heparin (Becton Dickinson Vacutainer Systems UK, Oxford, UK). Blood in EDTA tubes was cooled with ice and sent to the laboratory for haematological analyses. Blood collected into heparinized tubes was centrifuged at approximately 2000g for 10min, within 15min of sampling. The supernatant plasma was immediately frozen on dry ice, and stored at -70°C within 6h of the sampling, for subsequent analyses of blood biochemistry.

Cats were classed as clinically normal or clinically abnormal on the basis of a thorough veterinary examination which assessed each of the following parameters:

i) ectoparasites (present or absent);

ii) skin lesions (present or absent);

iii) mucus discharges from the eyes and nose (0 = none, 1 =slight, 2 = serous, 3 = purulent);

iv) ear wax (0 = none, 1 = slight, 2 = mild, 3 = severe);

v) clinical signs of gingivitis, tartar and ulcerations on the upper palate and tongue (0 = none, 1 = slight, 2 = mild, 3 = severe, 4 = chronic gingivitis or stomatitis);

vi) coat condition (1 = coarse, 2 = medium, 3 = soft/good); and

vii) thinness (the ease with which the dorsal spinous process vertebrae could be palpated: 1 = easily palpable/very thin, 2 = palpable with moderate pressure/thin, 3 = palpable with strong pressure/good condition). See Caro *et al* 1987.

Cats showing severe clinical abnormality in more than two of these areas were classified as clinically abnormal. All animals were assessed by the same observer. Thirty-three cats were classified as normal and 19 as abnormal.

Haematology and blood biochemistry

Practical haematology was carried out according to standard methods suitable for comparative studies (Hawkey 1975; Bennett *et al* 1991).

The following measurements were taken from each blood sample:

i) blood haemoglobin (Hb), spectrophotometrically as cyanmethaemoglobin;
ii) red blood cell count (RBC) using a Coulter Counter, Model ZF;
iii) packed cell volume (PCV), following centrifugation for 5min at 10 000g;
iv) number of reticulocytes and Heinz bodies, counted in whole blood stained supravitally with new methylene blue;
v) total white blood cells (WBC) counted by phase-contrast microscopy using an improved Neubauer haemocytometer;
vi) neutrophils, lymphocytes, monocytes, eosinophils and basophils – as the percentage of total WBC on blood film stained with May-Grunewald stain;
vii) fibrinogen, measured as protein precipitated at 56°C (Millar *et al* 1971);
viii) mean cell volume (MCV), mean cell haemoglobin content (MCH) and mean cell haemoglobin concentration (MCHC), all calculated using standard formulae (Jain 1986).

An haematological disorder (eg eosinophilia)was defined as when a cat recorded values of any haematological parameter which fell outside the average value (± 2 standard deviations) for normal domestic cats, using the LYNX haematology and biochemistry reference program (Bennett *et al* 1991).

Plasma samples were used to measure concentrations of urea, creatinine, bicarbonate, sodium, potassium, total protein, albumin, calcium, magnesium, inorganic phosphate, alkaline phosphatase, total bilirubin, aspartate transaminase and iron. Each measurement was made using standard methods (Bennett *et al* 1991) by using a Techcom-SMAC instrument (Bayer plc, Bayer House, Newbury, Berkshire, UK) and an American Monitor Corporation Perspective clinical analyzer (Bayer plc, Bayer House, Newbury, Berkshire, UK).

Statistical analyses

The goodness of fit of variables to a normal distribution was assessed using either the Shapiro-Wilk test (when $n < 50$) or the Kolmogorov D test (when $n \geq 50$; SAS Institute 1985). Where possible, comparisons between two categories of cat were made using unpaired *t*-tests (Campbell 1989). Otherwise, Mann-Whitney *U*-tests (Zar 1984) or Chi-squared tests (Campbell 1989) were used to assess the differences. All tests are two-tailed unless otherwise stated.

Results

Body measurements and general health

Mean head-body length, hind foot length, neck circumference, skull width, canine length and body weight were significantly greater for adults than for subadults (Table 1). Within sexes, differences between adults and subadults in mean head-body length, hind foot length, neck circumference, skull width and body weight were also significant (one-tailed $P < 0.05$). In addition, adult males had longer tails than subadult males (one-tailed $P < 0.05$) and longer canines (one-tailed $P < 0.01$).

Males were significantly larger than females for every body measurement (one-tailed $P < 0.05$), and this remained true when only adults were considered (Table 2). However, there

Table 1 **Mean and standard error (SEM) for body measurements of adults and subadults. Differences were assessed with unpaired *t*-tests or one-tailed Mann-Whitney *U*-tests. **P* < 0.05. ***P* < 0.01.**

Body Measurement	Adults (n = 36)		Subadults (n = 16)		
	Mean	SEM	Mean	SEM	*P*
Head-body length (mm)	569.5	7.44	498.3	20.07	**
Tail length (mm)	251.6	3.32	240.6	5.64	
Hind foot length (mm)	114.8	1.28	108.0	3.35	*
Neck circumference (mm)	180.0	3.40	143.1	6.77	**
Skull width (mm)	68.5	0.93	61.1	1.26	**
Canine length (mm)	10.5	0.30	8.0	0.53	**
Upper incisor (number)	1.6	0.38	5.43	0.38	**
Lower incisor (number)	3.0	0.37	5.2	0.34	**
Weight (kg)	3.5	0.12	2.2	0.22	**

Table 2 **Mean and standard error (SEM) for body measurements of adult males and adult females. Differences were assessed with unpaired *t*-tests or one-tailed Mann-Whitney *U*-tests. ***P* < 0.01.**

Body Measurement	Adult males (n = 36)		Adult females (n = 21)		
	Mean	SEM	Mean	SEM	*P*
Head-body length (mm)	604.9	7.23	544.2	7.95	**
Tail length (mm)	263.2	5.31	243.3	3.27	**
Hind foot length (mm)	119.6	1.79	111.3	1.37	**
Neck circumference (mm)	198.3	3.80	166.9	2.62	**
Skull width (mm)	73.8	1.00	64.8	0.59	**
Canine length (mm)	11.7	0.50	9.7	0.25	**
Upper incisor (number)	1.9	0.64	1.5	0.47	
Lower incisor (number)	3.3	0.61	2.9	0.48	
Weight (kg)	4.1	0.14	3.0	0.10	**

were no significant differences in body measurements between male and female subadults, nor were there significant differences between Central or Peripheral males and females.

Adults had significantly fewer upper and lower incisors than did subadults (Table 1). On average, adult males had significantly fewer upper and lower incisors (one-tailed $P < 0.01$ in both cases) than subadult males. Adult females had significantly fewer upper incisors than subadult females (one-tailed $P < 0.01$).

A significantly greater proportion of adult females (81%) than adult males (47%) were clinically normal (chi-square = 4.63, $df = 1$, $P < 0.05$). The mouths of Central females were significantly healthier than those of Peripheral females: Central females had significantly less gingivitis ($P < 0.01$) and ulceration ($P < 0.05$) than did Peripheral females. There were no significant differences in general health between Central males and Peripheral males.

Haematology

No basophils were detected in any of the blood samples analyzed.

Common haematological disorders (see, *Methods* for definition) of the 52 individuals examined included eosinophilia (34.6% of individuals), neutrophilia (32.6%), high fibrinogen levels (19.2%) and low haemoglobin levels (28.8%). These were significantly more likely to occur in clinically abnormal than in clinically normal cats (chi-square = 7.68 for eosinophilia, chi-square = 10.09 for high fibrinogen levels and chi-square = 7.10 for low haemoglobin levels respectively; all $P < 0.01$ and all $df = 1$), although the difference was not significant for neutrophilia (chi-square = 2.93, $df = 1$, $P = 0.06$).

Hb levels and PCVs, which are not independent of Hb levels, were significantly greater in the blood of adults than subadults($t = 2.24$, $df = 49$, $P < 0.05$ for Hb; and $t = 2.09$, $df = 50$, $P < 0.05$ for PCVs). Adult males had significantly greater MCVs and MCHs than did subadult males ($t = 2.62$, $df = 25$, $P < 0.05$ and $t = 2.47$, $df = 25$, $P < 0.05$ respectively); and subadult males had significantly greater lymphocyte counts than adult males ($t = 2.77$, $df = 24$, $P < 0.05$). Total WBC counts and fibrinogen levels were significantly greater in subadults than in adults (Table 3). Subadult females had significantly greater monocyte counts than adult females ($P < 0.05$).

If subadults are divided into juveniles and kittens, both adults and juveniles had significantly higher Hb levels and PCVs than did kittens. (For Hb: adult-kitten $t = 3.1$, $df = 39$, $P < 0.01$ and juvenile-kitten $t = 2.73$, $df = 14$, $P < 0.05$; for PCVs adult-kitten $t = 2.61$, $df = 40$, $P < 0.05$ and juvenile-kitten $t = 2.15$, $df = 14$, $P < 0.05$.) However, there were no such differences between adults and juveniles. Similarly, among male cats, adults had higher fibrinogen levels ($t = 3.01$, $df = 17$, $P < 0.01$), MCVs ($t = 2.3$, $df = 17$, $P < 0.05$) and MCHs ($t = 2.87$, $df = 17$, $P < 0.05$) than kittens; and juveniles had higher levels of fibrinogen ($t = 2.65$, $df = 11$, $P < 0.05$) and MCHs ($t = 2.4$, $df = 11$, $P < 0.05$) than kittens – although there were no such differences between adults and juveniles.

Among male cats, lymphocyte number also differed significantly between juvenile and adult males (JM > AM; $t = 2.95$, $df = 19$, $P < 0.05$), but not between kittens and adults, or kittens and juveniles. Females had significantly higher numbers of lymphocytes than did males ($t = 2.06$, $df = 48$, $P < 0.05$). This difference remained significant when only adults were considered ($t = 2.51$, $df = 33$, $P < 0.05$; Table 4), but there were no significant differences between male and female subadults.

There were no significant haematological differences between Central and Peripheral adult males. Central females had significantly higher reticulocyte counts than Peripheral females ($P < 0.05$), and Peripheral females had significantly higher numbers of neutrophils ($t = 2.3$, $df = 19$, $P < 0.05$), eosinophils ($t = 2.73$, $df = 19$, $P < 0.05$) and total WBC ($t = 2.71$, $df = 19$, $P < 0.05$) than Central females (Table 5).

Table 3 **Mean, standard error (SEM) and range of haematological values for adults and subadults. *$P < 0.05$.**

Haematological parameter	Adults ($34 \leq n \leq 36$)			Subadults ($15 \leq n \leq 16$)			
	Mean	SEM	Range	Mean	SEM	Range	*P*
Hb (g dl^{-1})	11.4	0.28	8.8-15.0	10.3	0.38	7.1-12.8	*
RBC (10^{12} l^{-1})	7.8	0.19	5.4-9.9	7.4	0.31	5.2-9.3	
PCV (%)	33.1	0.8	26.0-42.0	30.4	1.0	23.0-36.0	*
MCV (fl)	42.7	0.5	36.7-47.9	41.5	0.7	36.3-47.7	
MCH (pg)	14.7	0.2	12.6-17.1	14.1	0.3	12.3-15.9	
MCHC (g dl^{-1})	34.5	0.2	32.1-38.0	34.0	0.3	31.6-36.4	
Reticulocytes	3.0	0.8	0.0-18.0	2.6	0.8	0.0-11.0	
Heinz bodies (%RBC x 10)	2.8	1.1	0.0-35.0	1.6	0.8	0.0-10.0	
WBC (10^{9} l^{-1})	12.9	0.7	5.7-19.2	15.6	1.1	10.6-23.1	*
Neutrophils (10^{9} l^{-1})	8.5	0.6	2.7-15.5	10.5	1.1	5.2-18.3	
Lymphocytes(10^{9} l^{-1})	3.1	0.2	0.4-7.4	3.5	0.3	1.8-5.1	
Monocytes (10^{9} l^{-1})	0.3	0.1	0.0-1.3	0.5	0.1	0.0-1.6	
Eosinophils (10^{9} l^{-1})	1.0	0.1	0.0-2.9	1.1	0.3	0.0-5.4	
Fibrinogen (g l^{-1})	2.1	0.1	0.9-3.6	2.7	0.3	1.2-6.4	*

Blood biochemistry

Mean creatinine concentrations were significantly higher in adults than in subadults ($t = 3.19$, $df = 42$, $P < 0.01$), but subadults had significantly higher mean inorganic phosphate concentrations than adults ($t = 2.69$, $df = 43$, $P < 0.01$; Table 6). Adult males had significantly higher concentrations of creatinine than subadult males ($t = 3.32$, $df = 20$, $P < 0.01$), and this difference was also found between adult and subadult females ($t = 2.66$, $df = 20$, $P < 0.05$). Subadult females also had significantly higher concentrations of inorganic phosphate than adult females ($P < 0.05$). Males had significantly higher concentrations of calcium ($t = 2.3$, $df = 43$, $P < 0.05$) and alkaline phosphatase ($P < 0.01$) than females. Concentrations of creatinine, calcium and alkaline phosphatase in adult males were significantly higher than in adult females ($t = 4.08$, $df = 31$, $P < 0.01$; $t = 2.6$, $df = 32$, $P < 0.05$ and $t = 3.4$, $df = 31$, $P < 0.01$ respectively; see Table 7). Among subadults there were no significant differences between the sexes in any blood biochemistry measurements, nor were there significant differences between Central and Peripheral adults of either sex.

Discussion

Body condition and haematology

Not surprisingly, there were significant differences in body size between adults and subadults, and between males and females. Adults had fewer incisors than subadults, but there were no other age-related differences in general health. However, as with wild cheetahs (*Acinonyx jubatus*) in the Serengeti (Caro *et al* 1987), adult females tended to be in better condition than adult males. This may be due to sexual differences in immunity and susceptibility to parasites (Alexander & Stimson 1988) as well as in behavioural patterns.

Table 4 **Mean, standard error (SEM) and range of haematological values for adult males and adult females. *$P < 0.05$.**

Haematological parameter	Adult males ($14 \leq n \leq 15$)			Adult females ($20 \leq n \leq 21$)			
	Mean	SEM	Range	Mean	SEM	Range	*P*
Hb (g dl^{-1})	11.4	0.5	8.8-15.0	11.48	0.3	9.6-14.6	
RBC (10^{12} l^{-1})	7.7	0.4	5.4-9.9	7.9	0.2	5.9-9.7	
PCV (%)	33.0	1.4	26.0-42.0	33.2	0.9	27.0-41.0	
MCV (fl)	43.2	0.8	38.3-47.9	42.4	0.6	36.7-47.5	
MCH (pg)	14.9	0.3	12.8-17.1	14.6	0.2	12.6-16.3	
MCHC (g dl^{-1})	34.5	0.4	32.4-38.0	34.5	0.2	32.1-36.3	
Reticulocytes	3.4	1.3	0.0-1.7	2.8	1.0	0.0-1.8	
Heinz bodies (%RBC x 10)	1.9	0.9	0.0-10.0	3.5	1.7	0.0-35.0	
WBC (10^{9} l^{-1})	12.7	0.9	9.1-16.9	13.0	1.0	5.7-19.2	
Neutrophils (10^{9} l^{-1})	9.0	0.8	5.0-13.6	8.1	0.8	2.7-15.5	
Lymphocytes (10^{9} l^{-1})	2.4	0.2	0.4-3.5	3.6	0.3	0.9-7.4	*
Monocytes (10^{9} l^{-1})	0.3	0.1	0.0-0.8	0.3	0.1	0.0-1.3	
Eosinophils (10^{9} l^{-1})	1.0	0.2	0.3-2.8	1.0	0.2	0.0-2.9	
Fibrinogen (g l^{-1})	2.2	0.2	1.4-3.3	2.1	0.2	0.9-3.6	

Table 5 **Mean, standard error (SEM) and range of haematological values for Central and Peripheral females. *$P < 0.05$.**

Haematological parameter	Central females ($17 \leq n \leq 18$)			Peripheral females ($n = 3$)			
	Mean	SEM	Range	Mean	SEM	Range	*P*
Hb (g dl^{-1})	11.3	0.3	9.6-14.6	12.6	0.7	11.5-13.8	
RBC (10^{12} l^{-1})	7.8	0.2	5.9-9.7	8.4	0.6	7.4-9.4	
PCV (%)	32.8	1.0	27.0-41.0	35.7	1.2	34.0-38.0	
MCV (fl)	42.3	0.7	36.7-47.5	43.0	1.6	40.4-45.8	
MCH (pg)	14.5	0.2	12.6-16.3	15.0	0.2	14.7-15.5	
MCHC (g dl^{-1})	34.4	0.2	32.1-36.2	35.0	0.7	33.8-36.3	
Reticulocytes	3.2	1.0	0.0-18.0	0.3	0.3	0.0-1.0	*
Heinz bodies (%RBC x 10)	4.0	2.0	0.0-35.0	0.3	0.3	0.0-1.0	
WBC (10^{9} l^{-1})	12.0	1.0	5.7-19.1	18.7	0.3	18.4-19.2	*
Neutrophils (10^{9} l^{-1})	7.4	0.8	2.7-15.5	12.2	0.6	11.0-13.3	*
Lymphocytes (10^{9} l^{-1})	3.5	0.4	0.9-7.4	4.2	0.2	3.9-4.6	
Monocytes (10^{9} l^{-1})	0.3	0.1	0.0-1.3	0.3	0.2	0.0-0.6	
Eosinophils (10^{9} l^{-1})	0.8	0.2	0.0-2.2	2.0	0.7	0.7-2.9	*
Fibrinogen (g l^{-1})	2.1	0.2	0.9-3.6	2.1	0.2	1.7-2.5	

Table 6 **Mean, standard error (SEM) and range for blood biochemistry parameters for adults and subadults. **$P < 0.01$.**

Blood parameter	Adults ($15 \leq n \leq 34$)			Subadults ($6 \leq n \leq 11$)			
	Mean	SEM	Range	Mean	SEM	Range	*P*
Urea (mmol l^{-1})	8.7	0.4	5.6-16.0	8.5	0.4	6.4-10.6	
Creatinine (mmol l^{-1})	97.3	3.0	70-137	76.8	6.6	54-106	**
Bicarbonate (mmol l^{-1})	19.9	0.5	13-26	19.4	0.7	15-23	
Sodium (mmol l^{-1})	153.5	0.6	146-164	153.6	0.9	150-159	
Potassium (mmol l^{-1})	3.9	0.1	2.7-4.9	3.6	0.2	3.0-4.9	
Total Protein (g l^{-1})	81.0	1.9	42-94	79.0	4.1	65-9.3	
Albumin (g l^{-1})	27.8	0.9	15-35	26.0	1.8	20-31	
Calcium (mmol l^{-1})	2.2	0.03	1.9-2.6	2.3	0.05	2.1-2.7	
Magnesium (mmol l^{-1})	0.9	0..02	0.7-1.1	0.8	0.02	0.8-0.9	
Inorganic phosphate (mmol l^{-1})	1.4	0.1	0.3-2.2	1.7	0.1	1.4-2.4	**
Alkaline phospatase (IU l^{-1})	45.4	4.0	16-103	74.1	26.6	17-241	
Bilirubin (mmol l^{-1})	2.1	0.1	1-3	2.1	0.2	1-3	
Aspartate transaminase (IU l^{-1})	44.7	2.8	16-96	34.9	3.8	9-48	
Iron (mmol l^{-1})	11.9	1.1	5-19	11.8	2.0	4-18	

Table 7 **Mean, standard error (SEM) and range for blood biochemistry parameters for adult males and females. *$P < 0.05$; **$P < 0.01$.**

Blood parameter	Adult males ($9 \leq n \leq 14$)			Adult females ($6 \leq n \leq 20$)			
	Mean	SEM	Range	Mean	SEM	Range	*P*
Urea (mmol l^{-1})	9.1	0.8	5.8-16.0	8.5	0.5	5.6-14.0	
Creatinine (mmol l^{-1})	108.9	4.8	85-137	88.7	2.4	70-105	**
Bicarbonate (mmol l^{-1})	19.2	0.6	16-23	20.3	0.6	13-26	
Sodium (mmol l^{-1})	153.6	1.1	149-164	153.3	1.1	146-159	
Potassium (mmol l^{-1})	4.0	0.1	3.1-4.7	3.8	0.1	2.7-4.9	
Total Protein (g l^{-1})	81.7	1.8	71-89	80.6	2.9	42-94	
Albumin (g l^{-1})	29.8	1.3	25-35	26.6	1.2	15-31	
Calcium (mmol l^{-1})	2.3	0.04	2.2-2.6	2.1	0.03	1.9-2.5	*
Magnesium (mmol l^{-1})	0.9	0.004	0.7-1.1	0.8	0.02	0.7-1.1	
Inorganic phosphate (mmol l^{-1})	1.5	0.1	0.6-2.2	1.3	0.1	0.3-1.8	
Alkaline phosphatase (IU l^{-1})	60.2	6.8	19-103	35.9	3.7	16-88	**
Bilirubin (mmol l^{-1})	2.0	0.1	1-3	2.2	0.1	2-3	
Aspartate transaminase (IU l^{-1})	52.4	5.1	16-96	39.4	2.5	16-65	
Iron (mmol l^{-1})	10.9	1.6	5-19	13.5	1.2	10-18	

In general, the range of values for the haematological variables of free-living feral cats in this study agree with values from other studies among domestic cats (Jain 1986; Parry 1987; Earle *et al* 1990; Evans 1994). Reference ranges for haematological parameters in the cat, however, are wide, perhaps due to failure to recognize the effects of breed variation, physiological variation and subclinical diseases (Evans 1994).

At approximately 3-4 months, kittens attain adult levels of PCV, while they attain adult Hb levels at approximately 5-6 months (Jain 1986). Our study included six kittens under 6 months old in the subadult category, and the significant difference between adults and subadults in Hb and PCV levels, which are not independent of each other, was the result of low Hb levels in these kittens. The significant difference between adult and subadult males in fibrinogen levels, MCVs and MCHs was also an effect of the inclusion of kittens in the subadult category. Haematological differences between adults, juveniles and kittens have been noted in other studies (Jain 1986; Earle *et al* 1990) and should be taken into consideration when using haematology to assess the health of feral cats and wild felids whose age may be difficult to determine.

Leucocytosis may have either a physiological or a pathological basis in cats (Jain 1986; Evans 1994) and in Iberian lynx, *Lynx pardina* (Beltrán *et al* 1991). Females in our study tended to have higher lymphocyte counts than males. Since lymphocyte counts in cats are increased by stresses such as capture (Jain 1986), the higher levels in our females might indicate that they were more susceptible than males to these stresses. Peripheral females had relatively high numbers of neutrophils and eosinophils compared to Central females. This eosinophilia might be related to a greater incidence of intestinal nematode infestation (Hawkey & Hart 1986): *Toxocara cati* and *Toxascaris leonina* were highly prevalent in our cat colony (Yamaguchi *et al* 1996).

Blood biochemistry

Adults had higher plasma levels of creatinine than juveniles in our study colony and than those reported for Iberian lynxes (Beltrán *et al* 1991). Creatinine concentration is associated with age and body weight in some carnivores, because it is affected by muscle mass (Brannon 1985). Male cheetahs are not significantly heavier than females, and among free-living adult cheetahs there were no significant differences in serum creatinine levels between the sexes (Caro *et al* 1987). Among feral cats, adults were heavier than subadults and adult males were heavier than adult females. These differences in muscle mass might underlie differences between the sexes in creatinine concentrations, although higher plasma creatinine levels may reflect kidney disease (Gaskell 1994). Feline immunodeficiency virus (FIV) is well known to be involved in renal disease/failure (Hopper *et al* 1994), and thus the higher plasma creatinine levels of adult males compared to adult females might be related to renal disease/failure which is in turn related to FIV infection. In this colony, however, there was no significant difference in FIV prevalence between adult males and females (Yamaguchi *et al* 1996).

Calcium and alkaline phosphatase concentrations differed significantly between males and females, and between adult males and adult females. Given that the concentration of alkaline phosphatase increases in association with diseases of the bile ducts such as cholangiohepatitis (Rutgers 1994), this may suggest that males tend to suffer from such diseases more than females. Furthermore, this may be one reason why adult females tended to be in better body condition than adult males. Alternatively, these differences may be due to differences in osteoblast activity, as males have a greater skeletal mass than females (Brannon 1985). However, in spite of their lesser skeletal mass, subadults did not differ from adults in levels

of calcium and alkaline phosphatase, perhaps because of the higher osteoblast activity associated with skeletal growth (Weaver & Johnson 1995). Subadults had significantly greater concentrations of inorganic phosphate than adults, and this may be related to bone development in the young animals which is associated with high levels of serum calcium and phosphorous (Smith & Rongstad 1980).

Health and status

Our hypothesis was that membership of each social class is associated with different health costs and benefits. Differences in haematological findings between Central and Peripheral females, as well as the difference in clinical condition, may more plausibly be explained by their sociobiology rather than their age. However, age could be a confounding effect where it affects both prevalence or severity of a disorder and adult female status (Central and Peripheral). Because most cats were already adult at the start of our study we had an insufficient sample to analyse that variable. Nonetheless, all the published evidence suggests no link between adult female age and Central versus Peripheral status (Kerby 1987; Macdonald *et al* 1987; Kerby & Macdonald 1988). We conclude, therefore, that the significant differences in health that were discovered between Central and Peripheral adult females are corollaries of social status.

Sociobiologically, a female's most important resources are food and shelter. In large outdoor enclosures, most females relocated their nests closer to a food source as litters approached weaning (Feldman 1993). The importance of easy access to resources for a female's reproductive success and survival is clear. Therefore, when resources are concentrated in a central area, Central status close to the resource centre is likely to be more advantageous than Peripheral status, and probably associated with better health. Indeed, Central females have higher reproductive success than Peripheral females (Kerby & Macdonald 1988). Unfortunately, we do not have the longitudinal data to distinguish cause and effect in this relationship between status and health.

On the other hand, females are an important resource to males. During the mating period, high energy expenditure and social tension could make males less resistant to pathogens and more susceptible to infection (Khansari *et al* 1990).

Peripheral status has different implications for males and females. Among females, Peripheral individuals are essentially subordinate outcasts, whereas Peripheral males are arguably the most reproductively active and dominant individuals. Peripheral males roam between groups in search of oestrous females. This tactic is likely to be energetically more costly than that of Central males which remain with a single female in a feeding group throughout most of her oestrous period (Kerby & Macdonald 1988). Peripheral males may be more susceptible to pathogens than Central males because of their higher energy expenditure, wandering habits and exposure to stress. On the other hand, and in contrast to the situation in adult females, Central males tend to be younger than Peripheral males (Kerby 1987; Liberg 1988). Wild young adult male lions (3.3-4.5 years old) had significantly lower levels of serum testosterone than did old (6.1-9.8 years old) adult males (Brown *et al* 1991), even though lions can become sexually mature at 2 years old (Schaller 1972). In feral cat colonies, younger Central males may similarly differ from older Peripheral males in testosterone titres and therefore in aggression (Sapolsky 1987). Any differential in reproductive success between Central and Peripheral males is unknown and, despite their different tactics, these categories did not show significant differences in either clinical or haematological condition.

Carnivores, including felids, have complicated and flexible social systems (Macdonald 1983). Our data indicate that within these societies physiological, haematological and biochemical parameters may vary with sex, age and social status. In particular, Peripheral females (those excluded from the social units that congregate at food resources and known to have low reproductive success), are in significantly poorer health than Central females.

Infectious diseases

Individual cats differ in their likelihood of interacting with wildlife. Our results show that those individuals whose status made them most likely to encounter wildlife were also those in generally poor health. The cats most likely to traverse large home ranges are Peripheral males, while Peripheral females are confined to the edges of the colony. In so far as the biochemical and haematological poorer health of these categories of cat are reflected in a higher incidence of infectious pathogens, their spatial organization is likely to exacerbate the threat they pose to wildlife. In our study colony, all Peripheral males were FIV positive compared with just 50 per cent of Central males (Yamaguchi *et al* 1996). However, age, sex and social status had no significant effects on the prevalence of any infectious parasites tested for in the colony, which included: FIV, feline leukaemia virus, feline calicivirus, feline herpesvirus1, rotavirus, feline parvovirus, feline coronavirus, cowpox virus, *Haemobartonella felis*, *Chlamydia psittaci*, *Toxoplasma gondii*, *Toxocara cati* and *Toxascaris leonina* (Yamaguchi *et al* 1996). This may suggest that once an infectious pathogen is introduced into a high-density, group-living feral cat colony where there is a high interaction rate, every cat, regardless of age, sex or status, will become vulnerable to infection through within-group transmission.

Animal welfare implications

Concerns commonly raised about free-ranging cats include the disquieting sight of sick or dead individuals, along with risks of disease transmission, fouling and general nuisance (Passanisi & Macdonald 1990). Control regimes to combat the nuisance can involve neutering and release, and post-neutering management. Our results show that Peripheral females are likely to be in poor health. The consequences of 'neutering and returning' for Peripheral females merit investigation: their low status and poor health raise the possibility that euthanasia may be a better welfare option for this class of cat.

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