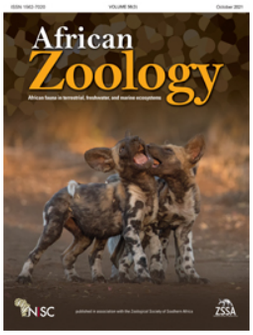

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Aspects of the blood chemistry of wild lions, *Panthera leo*

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Serum chemical data are presented for forty-five lions, *Panthera leo*, living in the Etosha National Park, Namibia. Most results are similar to those for captive lions. The effects on blood assays of twenty-one environmental, physiological and behavioural variables are investigated. Age and immobilization-related effects were the main variables operating within the normal range. The major finding related to behavioural variables associated nomadic individuals with poor condition. None of the blood parameters measured was related significantly to either season or cub survival.

Serum-chemiese data word voorgelê vir vyf-en-veertig leeus, *Panthera leo*, woonagtig in die Etosha Nasionale Park, Namibia. Die meeste van die resultate stem ooreen met dié vir leeus in gevangenskap. Die uitwerking op bloedtoetse van een-en-twintig omgewings-, fisiologiese en gedragsveranderlikes word ondersoek. Ouderdoms- en immobiliserings-verwante effekte was die hoofveranderlikes wat binne die normale perke 'n uitwerking gehad het. Die hoofbevindings aangaande gedragsveranderlikes toon 'n assosiasie tussen nomadiese individue en swak kondisie. Geeneen van die bloedparameters gemeet het 'n betekenisvolle verband getoon met òf seisoene òf oorlewing van kleintjies nie.

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Blood chemistry is used in human and veterinary medicine to help diagnose diseases, to establish disease processes and to monitor the progress of diseases. To do this there must be adequate information on blood values from clinically healthy subjects so that abnormality can be detected and its significance evaluated. The development of sophisticated capture techniques over the last 20 years has meant that biologists studying large mammals in the wild have often been able to routinely collect blood from a sample of animals. Although there is still an interest in separating out individuals with abnormal profiles, often more subtle questions are asked concerning what blood data can tell us about overall population condition (Hanks 1981). In particular the emphasis concerns trying to use these data to index the nutritional well-being of a group of animals in a particular environment (Franzmann 1972; Melton & Melton 1982). To do this not only must the normal range be defined, but there also needs to be an understanding of how values vary within the normal range in response to various physiological, environmental and behavioural factors. It is only with this knowledge that an attempt can be made to separate dietary induced effects from other causal processes.

The main purpose of this paper is to present aspects of the blood chemistry of wild lions (*Panthera leo*) to help define normal values for this species feeding on a natural diet. A second objective is to examine the effects of various variables or boundary conditions on blood assays. It is probable that food and social behaviour regulate lion abundance (Bertram 1973). In particular the survival of nomadic animals and cubs has been found to be considerably lower during times of food shortage (Schaller 1972; Starfield, Furniss & Smuts 1981). There is, therefore, an interest in identifying links between aspects of population structure and indices of nutritional status.

Methods

The majority of lions sampled belonged to one of five prides in a main study area in the Etosha National Park of northern Namibia (18°S/16°E). The remainder were incidental animals found temporarily in the study area. The population has been declining in recent years probably because of drought-related mortality, including lions being destroyed on nearby farmland. Fifty-six animals were immobilized between April 1981 and April 1983 using a capture-release technique developed by Van Wyk and Berry (pers. comm.). Fifty-three animals were immobilized using ketamine hydrochloride (Vetalar; Park-Davis, USA) in combination with xylazine hydrochloride (Rompun; Bayer, West Germany). Three lions were immobilized with phencyclidine hydrochloride (Sernylan; Bio-Ceutic Laboratories Inc., USA). A 10-ml sample of blood was taken from the jugular vein using an evacuated serum separation tube (Vacutainer no. 6510; Becton-Dickinson, USA) in conjunction with a 20-gauge needle. The sample was allowed to clot before cooling it to 0°C. Serum was obtained by centrifugation at 3000 rpm for 15 min within 4 h of sampling and then stored at −20°C prior to analyses. The sex of the individual was noted and age determined using the dental criteria of Smuts, Anderson & Austin (1978). The animal was weighed to the nearest kilogram using a sling suspended from a 500 kg spring balance. Information on the social and reproductive status of animals came from ongoing studies of the lion population (H. Berry pers. obs., J. Orford pers. comm.). Ten adult females were sexually inactive owing to contraceptive implants.

Serum chemical analyses for urea nitrogen, glucose, total protein, albumin, calcium and phosphorus were carried out using standard Auto Analyser techniques. Serum cholesterol, serum glutamic-oxaloacetic transaminase (SGOT) and serum glutamic-pyruvic transaminase (SGPT) were measured using a Centrifugal Analyzer (Centrifichem).

A list of variables examined for their effects on blood assays is given in Table 1. The Statistical Package for the Social Sciences (SPSSX) program Regression (Draper & Smith 1966)

Table 1 Variables examined for their effects on blood assays

Variable	Code name	Continuous or discontinuous	Units
Season			
Dry hot	DHOT	Dis.	yes or no
Dry cold	DCOLD	Dis.	yes or no
Wet hot	WETHOT	Dis.	yes or no
Year			
1981 – 1983	1981 – 1983	Dis.	yes or no
Age			
Age	AGE	Cont.	year
Weight	WATE	Cont.	kg
Immobilizing drugs			
Elapsed time from darting to sampling	ELAPSTM	Cont.	min
Ketamine dose	KETAMINE	Cont.	mg/kg
Rompun dose	ROMPUN	Cont.	mg/kg
Reproduction			
Sex	SEX	Dis.	male or female
Sexually inactive	INACTIV	Dis.	yes or no
Sexually active	ACTIVE	Dis.	yes or no
Female pregnant	PREGNANT	Dis.	yes or no
Female lactating	LACTATE	Dis.	yes or no
Social status			
Prides 1 – 5	PRIDE 1 – 5	Dis.	yes or no
Home range	HRANG	Cont.	km^2
Single male nomad	NOM	Dis.	yes or no
Nomadic group	NOMS	Dis.	yes or no
Family group	FAMILY	Dis.	yes or no
No. of cubs in group	CUBS	Cont.	$1-n$
Group size	GPSIZE	Cont.	$1-n$

was used to examine possible relationships between variables and blood values.

Results and discussion

Mean values for serum chemicals

Eighteen males were sampled that ranged between 2 years and 13 years of age and from 100 kg to 260 kg in weight. The 38 females sampled were between 2 years and 9 years of age and from 69 kg to 165 kg in weight. These totals include nine individuals which were sampled more than once. The mean values, standard deviations and ranges of the serum chemicals measured are given in Table 2 for all animals. Serum chemistry data for captive lions are given for comparison in Table 3; the normal ranges for the domestic cat are included where lion data are unavailable (Chemassay undated). All mean values for Etosha lions are similar to means reported for captive animals (Morse & Follis 1974; Fowler 1978). However, the upper range appears extended in wild lions for blood urea nitrogen (BUN), glutamic-oxaloacetic transaminase (SGOT) and glutamic-pyruvic transaminase (SGPT).

Searcy (1969) uses no fixed statistical method to define a normal range, but bases limits on what is known of the role of a chemical in normal physiological and disease states. Others have cited individual values which lie greater than two or three standard deviations (*S.D.*) from the mean as abnormal (Henry 1964; Seal, Mech & Van Ballenberghe 1975). Here results are separated out as possibly abnormal after considering the range within 2 *S.D.* of the mean, although a completely rigid system is not adhered to. Sixteen profiles included results which are believed to be abnormal (Table 4); these will be discussed further after quantification of the effects of boundary conditions on blood values.

Table 2 Mean values, standard deviations and ranges for some serum chemicals for 56 blood samples from lions in the Etosha National Park

Blood parameter	Mean	Standard deviation	Range
Blood urea nitrogen (mmol/l)	41,1	15,5	14,8 – 72,9
Glucose (mmol/l)	7,5	3,6	2,4 – 17,8
Calcium (mmol/l)	2,5	0,3	1,7 – 3,3
Cholesterol (mmol/l)	4,3	1,0	2,1 – 7,2
Total protein (g/l)	79,0	9,0	50,0 – 100,0
Albumin (g/l)	24,0	5,0	10,0 – 35,0
Phosphorus (mmol/l)	1,9	0,5	0,9 – 2,9
Glutamic-oxaloacetic transaminase (IU/l)	39,8	27,5	6,0 – 158,0
Glutamic-pyruvic transaminase (IU/l)	29,3	18,0	1,0 – 80,0

Table 3 Serum chemistry data for captive lions as reported by Morse & Follis[a] (1974) and Fowler (1978)

Blood parameter	Mean	Standard deviation
Blood urea nitrogen (mmol/l)	47,1	6,4
	20,0	3,6
	12,5[a]	–
	9,9[a]	–
Glucose (mmol/l)	6,6	1,4
Calcium (mmol/l)	2,4	0,1
	1,9[a]	–
	2,5[a]	–
Cholesterol (mmol/l)	3,6	1,1
Total protein (g/l)	66,0[a]	–
	72,0[a]	–
Albumin (g/l)	(26,0 – 42,0)[b]	
Phosphorus (mmol/l)	1,6	0,4
Glutamic-oxaloacetic transaminase (IU/l)	39,0	9,0
Glutamic-pyruvic transaminase (IU/l)	(1,0 – 59,0)[b]	

[b]Normal range for the domestic cat (Chemassay undated)

Effects of physiological, environmental and behavioural variables on blood assays

Multiple regression analyses were run using the complete data set (Table 5) and with the abnormal values removed (Table 6). In the following discussion all reference to significance refers to at least $P < 0,05$ and full details of statistics are given in the appropriate table.

When all data were considered BUN was significantly affected by three variables; the main association was for nomadic animals to have elevated levels. The removal of abnormal values, however, resulted in no significant variables being identified. This finding emphasizes the need to attempt to separate abnormal values as results for all data could have been interpreted as suggesting that nomads receive a higher protein diet than other animals, when in fact they are likely to be in a stressed condition. BUN levels will rise within a normal range as the quality or quantity of protein ingested increases, however abnormal elevation can occur if protein

Table 4 Individual test results believed to be abnormal for lions in the Etosha National Park

Animal number	Sex	Age (years)	Abnormal results
8	F	5	Glucose↑ (17,8 mmol/l)
10A	M	7	Blood urea nitrogen↑ (66,9 mmol/l)
11	M	6	Blood urea nitrogen↑ (66,2 mmol/l)
20	M	2½	Phosphorus↑ (2,9 mmol/l)
23	F	2	Glucose↑ (16,9 mmol/l)
24	M	7	SGOT[a]↑ (158 IU/l)
26	M	10	Blood urea nitrogen↑ (67,6 mmol/l)
30	M	2	Phosphorus↑ (2,9 mmol/l), Calcium↑ (3,3 mmol/l), Blood urea nitrogen↑ (72,9 mmol/l), Total protein↑ (>100,0 g/l)
32B	F	4½	Calcium↑ (3,3 mmol/l), Total protein↑ (>100,0 g/l)
34A	F	5	SGOT[a]↑ (89 IU/l)
36	F	3½	SGOT[a]↑ (78 IU/l)
38A	F	9	SGOT[a]↑ (96 IU/l)
38B	F	9	Albumin↓ (10,0 g/l)
40	F	2½	SGOT[a]↑ (82 IU/l), SGPT[b]↑ (78 IU/l)
44	M	3½	SGOT[a]↑ (84 IU/l), SGPT[b]↑ (80 IU/l)
45	F	3½	Blood urea nitrogen↑ (67,9 mmol/l), SGOT[a]↑ (75 IU/l)

[a]Glutamic-oxaloacetic transaminase ↑ high value
[b]Glutamic-pyruvic transaminase ↓ low value

Table 5 Regression formulae for nine blood parameters using data from all lions sampled

Regression[a]	*df* regression	*df* residual	*F*	Overall sig.
BUN(mmol/l) = 60,2 + 36,6(NOMS)*** − 14,0(1982)* − 0,3(ELAPSTM)*	3	23	7,0	*P*<0,01
CHOL(mmol/l) = 5,9 − 0,3(AGE)**	1	25	11,5	*P*<0,01
GLUC(mmol/l) = 5,7 + 0,3(GPSIZE)*	1	25	5,4	*P*<0,05
CALC(mmol/l) = 2,7 − 0,1(AGE)** + 0,3(INACTIV)*	2	24	6,6	*P*<0,01
PROT(g/l) = 79,0[b]	no significant variables			
ALB(g/l) = 28,0 − 1,0(AGE)** + 4,0(PRIDE 1)* + 4,0(1983)*	3	23	6,3	*P*<0,01
PHOS(mmol/l) = 1,8 + 0,8(PRIDE 4)**	1	25	7,9	*P*<0,01
SGOT(IU/l) = 30,8 + 59,2(NOM)** + 35,8(PRIDE 5)*	2	24	7,1	*P*<0,01
SGPT(IU/l) = 21,4 + 29,6(1983)***	1	25	36,3	*P*<0,001

[a]See Table 1 for code name explanations
[b]Mean value given
*P<0,05; **P<0,01; ***P<0,001.

is catabolized during food shortage or owing to renal dysfunction (Searcy 1969). Five animals exhibited abnormal BUN values (Table 4). Animal 30 was a 2-year-old pride male with abnormally high readings for three other chemicals as well. This pattern suggests haemoconcentration owing to dehydration or renal damage. Animals 10A, 11 and 26 only showed abnormal readings for BUN. All three lions were males with worn or broken teeth, two were nomadic and one was old.

Table 6 Regression formulae for seven blood parameters after abnormal results have been removed

Regression[a]	*df* regression	*df* residual	*F*	Overall sig.
BUN(mmol/l) = 38,5[b]	no significant variables			
CHOL(mmol/l) = 5,9 − 0,3(AGE)**	1	25	11,5	*P*<0,01
GLUC(mmol/l) = 7,1[b]	no significant variables			
CALC(mmol/l) = 2,8 − 0,01(ELAPSTM)* − 0,22(1982)*	2	19	6,9	*P*<0,01
PROT(g/l) = 79,0 − 2,0(ELAPSTM)*** + 7,0(MALE)**	2	19	17,5	*P*<0,001
ALB(g/l) = 28,0 − 1,0(AGE)** + 4,0(PRIDE 1)* + 4,0(1983)*	3	22	6,3	*P*<0,01
PHOS(mmol/l) = 1,8[b]	no significant variables			

[a]See Table 1 for code name explanations
[b]Mean value given
*P<0,05; **P<0,01; ***P<0,001.

It is likely that the results reflect protein catabolism following an inadequate diet. Although not quantified on a regular basis we have noted that lions over 8 years of age tend to lose condition as judged by external appearance and it is possible that broken teeth may often play a part in this. However, contrary to the findings here we believed that older females would be more disadvantaged than males, as males maintain dominance at carcasses.

Lion 45 had a raised SGOT value in addition to BUN which suggests tissue damage related to a disease state or perhaps trauma during capture.

No abnormal results were identified for cholesterol assays. Cholesterol levels declined significantly with age. Cholesteremia is observed in very young mammals including man, but a more significant trend is for higher cholesterol values in later life (Van Zyl & Kerrich 1955; Baeder 1965; Searcy 1969). Levels for this chemical are also affected by diet in a number of ways and chronic malnutrition would be expected to promote hypocholesteremia (Searcy 1969). It is possible that the result given here reflects such a nutritional relationship. Seal *et al.* (1975) equated lower cholesterol levels with a lower intake of animal flesh in wild wolves (*Canis lupus*).

Serum glucose levels were positively related to increasing group size when all data were analysed. However, the removal of two abnormally high values resulted in no significant variables being identified. Both females 8 and 23 come from groups larger than the mean (7,6; *S.D.* = 4,5), their group sizes being 11 and 14 respectively. It is possible that these young animals were subject to more social stress in these larger groups, which is a relationship seen in other species (Steyn, Hamilton-Bruce, Zuurmond & Pharo 1975). In addition animal 8 was observed copulating prior to capture which could account for her higher level. A number of disease states such as diabetes mellitus will also result in hyperglycemia.

The associations found for calcium when all data were analysed mainly reflect the fact that two animals with abnormally high levels were young and sexually inactive. A different set of associations is suggested when these abnormal values are removed (Table 6). The inclusion of a year effect suggests that associations at the 5% level need to be viewed with particular caution as year differences are unlikely to have biological significance. The decline in calcium values found with increasing elapsed time between darting and taking blood

is a trend reported for other species and is probably connected with haemodilution proceeding for some time after drug administration (Seal, Ozoga, Erickson & Verme 1972; Steyn 1975).

The removal of the two abnormally high total protein values resulted in two variables being found to affect this blood parameter, whereas none was found using the whole data set. Increasing elapsed time was again associated with lower values and a sex effect was quantified for higher values in males. This latter relationship may be related to diet, but under standard conditions males of other species have also shown higher readings for a range of chemicals (Searcy 1969; Steyn *et al.* 1975).

The negative effect of age on albumin values may be related to diet. The abnormally low value of animal 38B was accompanied by quite low vaues for calcium, cholesterol and total protein, these being 1,7 mmol/ℓ, 2,1 mmol/ℓ and 50 g/ℓ respectively. This 9-year-old female had broken teeth and could have been suffering from a number of disorders including parasitism at the end of winter when this sample was taken (Searcy 1969). The other two variables identified as affecting albumin at the 5% level should be viewed with caution. Pride 1 constantly broke up into small groupings and had a poor record of cub survival that was believed to be related to a seasonal shortage of food in their pride area and an ongoing drought. The association of higher albumin levels with this pride is therefore contrary to that expected. Likewise the year effect probably has no biological significance.

The association of a higher phosphorus level with pride 4 was related to the inclusion of animal 20 with an abnormally high reading in that pride. Like lion 30 this animal could have been dehydrated as its calcium and protein values were quite high at 2,9 mmol/ℓ and 87,0 g/ℓ.

SGOT and SGPT were only considered using all data, as the objective was to examine trends with abnormally high values of these indicators of tissue damage. Seven animals showed elevation in one or both of these enzymes. It is possible that single nomadic animals often have disease states that cause SGOT elevation, but the significance of a pride effect and a year effect are not known (Table 5).

As mentioned above a main behavioural observation was that pride 1 stood out as an unstable grouping with a poor record of cub survival. It was suggested that this had a nutritional basis although socially induced mortality cannot be ruled out. Contrary to expectations the regression analyses did not emphasize any pride differences that could be easily related to nutritional status. An analysis of variance supported this finding with only phosphorus (F = 4,68; dfs = 4,45; $P < 0{,}01$) and SGPT (F = 2,85; dfs = 4,45; $P < 0{,}05$) showing significant between-pride differences (Snedecor & Cochran 1967). For SGPT this result is explained by pride 5 having a number of high values giving a mean of 49,3 IU/ℓ, well above the overall mean of 29,3 IU/ℓ (*S.D.* = 18,0). For phosphorus some of this variation results from pride 4 having some high readings, however pride 1 did have the lowest value of 1,7 mmol/ℓ.

Again contrary to predictions no seasonal effects were found. It is believed that the dry hot season is a period of stress for lions at Etosha, because preferred prey tend to vacate certain lion territories and concentrate at areas of better grazing and the most potable water sources. Conversely the wet/hot season is a period of food abundance in the area occupied by the study prides.

Lastly, the number of cubs in a pride did not correlate with any potential index of nutritional status.

Conclusion

The blood values presented here were generally similar to data for captive lions. Differences were mainly for an increased range above the mean which usually reflected the presence of individuals with abnormal readings in the wild.

Analyses to evaluate the effects of various boundary conditions on blood parameters often produced different results when abnormal values were removed. Both types of analysis were useful, but their interpretation was different. Only six variables showed significant effects within the normal range, with age and elapsed time between darting and sampling being the most important. Variables reflecting social behaviour had little effect apart from the association of nomadic animals with abnormal values, which were probably related to poor nutrition, a higher incidence of disease or dehydration.

Additional data on physiologic normals such as have been presented here will assist in evaluating the nutritional status of mammals in the wild and in captivity. Further studies are needed to see whether the lack of significant trends to support tentative hypotheses from behavioural observations means that the hypotheses are falsified or whether blood chemical variation within the normal range is subject to too many subtle effects for those connected with nutritional status to be easily identified. It is possible that demographic information for lions such as cub mortality may be a better indicator of population condition than physiologic indices.

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