

BLOOD CHEMISTRY, HEMATOLOGY, AND CONDITION EVALUATION OF BLACK BEARS IN NORTHCOASTAL CALIFORNIA

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Abstract: I used blood chemistry and hematology to evaluate the physical condition of black bears (*Ursus americanus*). Analyses were performed on 70 blood samples taken from 55 live-captured black bears in the redwood (*Sequoia sempervirens*) region in northcoastal California. Blood parameters analyzed included calcium, inorganic phosphorus, total protein, albumin, creatinine, blood urea nitrogen (BUN), glucose, cholesterol, triglycerides, uric acid, total bilirubin, direct bilirubin, alkaline phosphatase, GGT, SGOT, SGPT, LDH, sodium, potassium, chloride, ferrous, total globulins, WBC, RBC, HGB, HCT, MVC, MCH, and MCHC. Bears captured in Aldrich foot-snares, chased up trees with trained dogs, or immobilized with sedative darts while free-roaming had significantly greater ($P < 0.01$) WBC and serum levels of uric acid, SGOT, SGPT, and LDH, and lower levels of inorganic phosphorus than bears captured in culvert traps. Male bears had significantly ($P < 0.01$) less MCH than female bears. Additional significantly different ($P < 0.05$) blood values between sexes suggest a differential stress response of females to immobilization and handling procedures. Adult bears had significantly ($P < 0.01$) higher MCV, MCH, and serum levels of triglycerides and lower levels of alkaline phosphatase than subadults or cubs. Seasonal differences were observed for inorganic phosphorus, total protein, creatinine, total globulins, MCH, and MCHC. These latter differences were probably a result of adult male capture bias in spring and subadult capture bias in fall. Six indices of physical condition were developed. Each bear was assigned a condition evaluation index (CEI) value based on subjective assessment of body fat deposits, number and types of parasites, and pelage condition. Five physical condition ratio (PCR) values were calculated by dividing body weight by each of 5 somatic measurements (total length, girth, height at shoulder, head circumference, and head length). The CEI did not reflect physical condition as well as the PCR values. The ratio body weight/total length (PCR-A) permitted objective physical condition comparisons between sex and age classes. These comparisons suggest relationships between and within sex and age classes based on intraspecific competition for available resources. Blood parameters significantly correlated ($P < 0.005$) with PCR-A (total protein, albumin, total globulins, triglyceride, glucose, RBC, HGB, HCT, MCH, and MCHC) may be used to monitor the nutritional status of black bear populations under a variety of conditions.

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A variety of methods have been used to assess the physical condition of wild mammals (Hanks 1978). Bailey (1968) used weight and total length to index the relative condition of individual cottontail rabbits (*Sylvilagus floridanus*); Klein (1968) used body weight measurements as an index of condition for reindeer (*Rangifer tarandus*); and Austin (1984) used subcutaneous fat to index mule deer (*Odocoileus hemionus*) condition. An analysis of an animal's growth in weight and length can provide objective criteria for assessing condition, based on the concept that changes in weight, growth rates, or subcutaneous fat deposition can be correlated with changes in condition (Hanks 1978).

Annual variation in food resources leads to fluctuations in an animal's condition through time. These changes in food availability contribute to physiological changes. LeResche et al. (1974) reported that blood chemistry and hematology variables may reflect the physiological condition of an animal and be useful in assessing its relative plane of nutrition.

Although several blood parameters have been identified as possible biochemical indicators of condition, it is often difficult to evaluate condition because of the influence of sex, age, capture stress, or season

(Hanks 1978). For wild populations, sex and age may be the determining variable in physiological condition evaluation because certain sex or age classes outcompete others for limited resources, resulting in better nutritional condition. This intraspecific competition can lead to a range of condition states within a population at any 1 time.

It is unrealistic to correlate biochemical parameters with a subjectively assigned condition index. Blood chemistry parameters must be related to some form of objective condition evaluation technique before they will be recognized as acceptable indicators of habitat quality. Seal (1978) described how some biochemical indicators of the nutritional status of free-ranging populations may be used to assess habitat condition. In this study, condition indices were considered a measure of the physiological condition of the population and were related to the individual animal's chances of living or dying (Hanks 1978).

Preliminary observations of black bears captured in Redwood National Park (RNP) in northcoastal California indicated variation in relative body mass, fat deposits, ectoparasite load, and pelage condition among bears of similar sex and age class. I further examined blood chemistry and hematology. Two types of condition indices were developed to assess and compare the relative physical condition of individual bears. These results were used to assess the ability of selected blood parameters to reflect corresponding differences in physical condition.

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STUDY AREA

The primary study area is the Redwood Creek drainage, most of which is within RNP (Fig. 1). The Redwood Creek drainage is composed of about 72,000 ha of rugged terrain within the north coast range of California. Redwood Creek flows into the Pacific Ocean about 28 km south of the mouth of the Klamath River and 60 km north of the mouth of Humboldt Bay. Redwood Creek is strongly elongated in a northwesterly direction and is characterized by high relief, steep slopes, and narrow valley bottoms (Janda et al. 1975).

The area is characterized by mild, wet winters and cool summers with frequent coastal fog. Annual precipitation ranges from 185 to 256 cm; daily mean minimum temperature is 6.0 C and a daily mean maximum is 16.1 C (Janda et al. 1975). The elevation ranges from sea level to 850 m at Rodgers Peak.

Before the study area was incorporated into RNP, logging was the dominant land use (Muldavin et al. 1981). Because of the temporal progression of timber harvests, numerous stages of vegetative succession are represented. Several discontinuous stands of old-growth redwood remain. Stands at higher elevations also contain Douglas-fir (*Pseudotsuga menziesii*) and tanoak (*Lithocarpus densiflora*). Borders of logging roads and trails and numerous small openings are dominated by stands of red alder (*Alnus rubra*). Major shrub species include salal (*Gaultheria shallon*), evergreen huckleberry (*Vaccinium ovatum*), and coyotebrush (*Ceanothus thyrsiflorus*). Vegetation analysis is reported by Muldavin et al. (1981).

Secondary study areas include parts of Humboldt County, California, near towns where bears damaged orchards, beehives, and livestock. These areas are generally near 2nd-growth redwood stands, but bears were trapped only in urban areas.

METHODS AND MATERIALS

Capture and Handling Techniques

Black bears were captured with Aldrich spring-activated snares or culvert traps, or were chased up trees with trained dogs ("treeing" technique). Culvert traps and Aldrich snares were equipped with radiotransmitters modified to transmit when an animal was captured, or had disturbed, a trap. Transmitters were monitored at least twice daily to minimize the time an animal spent in a trap.

Seven bears had been captured and fitted with radiotransmitters in RNP before this study. Four radio-instrumented bears were captured during winter dormancy so that researchers could change or adjust radiocollars, record measurements and weight, and obtain blood samples. These bears evacuated their dens when researchers were closer than approximately 30 m. Trained hounds were used to pursue bears leaving dens and force them up a tree. Treed bears were darted with a projectile syringe fired from a CO₂ pistol. After injection, bears were permitted to leave the tree and move away until they became immobilized. Prior immobilization experience with dormant bears indicated that no bears, except females with newborn cubs, would return to their original dens after handling. Therefore, winter-captured bears were monitored until they were considered able to defend themselves and were not returned to the original den after handling. Free-ranging and treeing techniques were treated as snare captures in analyses (based on similar levels of physical activity observed as bears attempted to escape).

In 1982 a syringe mounted on a fiberglass dowel (jabstick) was used to immobilize trapped bears. Jabstick use was limited to culvert-trapped or partly immobilized bears after 1982. In 1983 and 1984, projectile syringes were used to administer drugs to snared or free-ranging bears.

All bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride at a concentration of 200 mg ketamine per ml. The drugs were administered at 0.91 mg ketamine/kg of estimated body weight (Addison and Kolenosky 1979). Black bears were trapped 10 May 1982–25 July 1984 in RNP. Bears trapped or killed within 70 km of RNP by Calif. Dep. of Fish and Game (CDFG) personnel were also included in the analyses.

Bears were marked with aluminum ear tags and lip tattoos for permanent identification (Graber 1982); lower 1st premolars were extracted and cementum annuli were counted to estimate age (Stoneberg and Jonkel 1966) and blood samples were taken.

Bear ages were also estimated by tooth wear and head and body size (Graber 1982). Age estimates generally agreed with cementum annuli counts; however, in cases where annuli were difficult to interpret, annuli-based estimates were amended according to other age parameters measured during capture. Ages were reported as estimated age at last birthday. Yearly age classes were combined as cubs (0–12

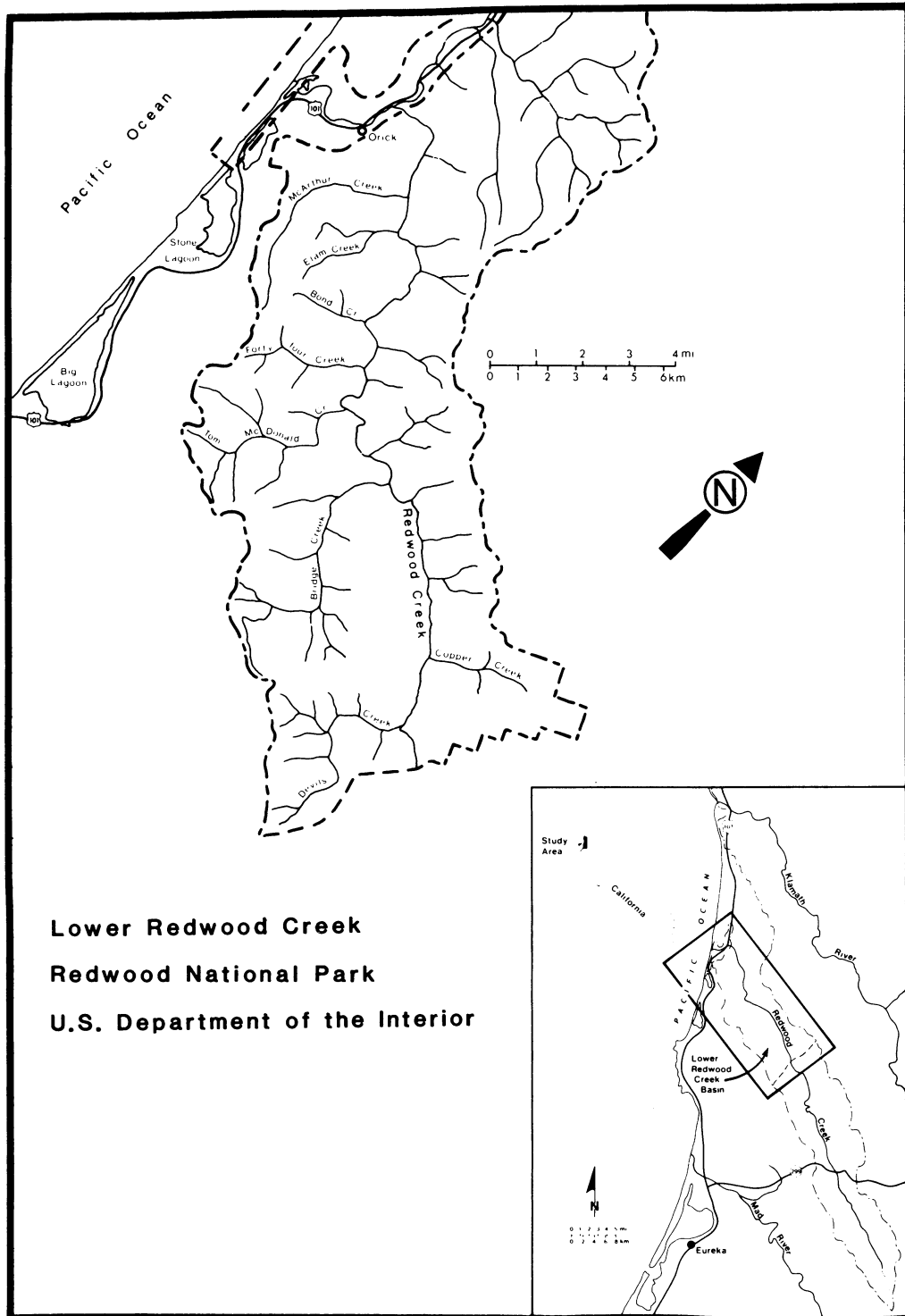


Fig. 1. Study area for blood chemistry, hematology, and condition evaluation of 55 black bears captured (70 total captures) from 10 May 1982 to 25 July 1984. Primary study area was Redwood National Park; 9 bears were captured in secondary areas within nearby towns in Humboldt County.

months), subadults (13–47 months), and adults (≥ 48 months).

A condition evaluation index (CEI), with values from 6.0 to 10.0, was developed to compare the relative health status of each bear. The coded rating was based on an assessment of body fat deposits, pelage condition, and numbers and types of ectoparasites. Body fat deposition was the major factor contributing to the CEI. Bears that appeared to have large fat deposits initially received high condition codes (9 or 10). Bears that appeared lean, had an angular outline, or had bony prominences received lower condition codes (6 or 7). Parasite and pelage evaluation worked as negative factors on the condition code. Thus, the condition of all bears was evaluated with an index based solely on external characteristics. The evaluations were the consensus of 2 trained individuals, who generally agreed on CEI assessments before indexing as a team.

An ectoparasite classification, with values ranging from 0 to 4, was assigned based on the number and types of ectoparasites observed during a careful examination of each bear. The most frequent ectoparasites were ticks (*Ixodes* spp.), which formed the basis of the classification; lice (*Trichodectes* spp.) infestation was a secondary factor. This classification code was increased by 1 integer if lice were detected. The coding sequence was a relative comparison of ectoparasite load; each coding criteria was approximately 25% of the range of tick numbers encountered. The coding sequence was based on a whole body examination: code 0, no ectoparasites; code 1, 1–5 ticks or only lice; code 2, 6–10 ticks or 1–5 ticks plus lice; code 3, 11 or more ticks or 6–11 ticks plus lice; code 4, 11 or more ticks plus lice. Representative samples of ectoparasites collected from each bear were preserved in 70% ethyl alcohol with 5% glycerin.

A pelage code was assigned to each bear during capture. This code rated the relative luster or sheen of the fur and was classified as 1 = excellent; 2 = good; 3 = fair.

Standard weights and lengths were recorded at each capture (Graber 1982). All measurements were recorded to the nearest 0.1 cm. Bears were weighed to the nearest pound using a spring scale. Weights were later converted to kilograms. Live weight was divided by each of 5 body measurements (total length, height at shoulder, girth, head circumference, and head length) to develop 5 additional condition indices (Physical Condition Ratios; PCR-A through E). Depredation bears were handled similarly to RNP bears.

Each bear was released at its capture site, except CDFG bears which were relocated or destroyed.

Whole Blood and Serum Preparation

Blood samples were collected from the femoral vein into evacuated glass tubes inserted into a vacutainer multisample holder attached to a 20-gauge needle. Blood was obtained 10–40 min after immobilization. Whole blood was collected into vacutainer tubes containing EDTA. To obtain sera, blood was also collected in silicon-lined tubes and allowed to clot for 1 hour. The silicon-lined tubes were centrifuged at 3,200 rpm for 15 min in a centrifuge powered by a portable generator in the field. Serum was then removed and stored in plastic tubes.

Sera samples were also obtained from 2 bears killed for depredations in Humboldt County. These samples were collected by cardiac puncture immediately after death. Whole blood samples were not collected from these bears.

Blood samples were transported in small styrofoam coolers with refrigerant or ice to Central Pathology Laboratory in Santa Rosa, Calif.; most samples were analyzed within 30 hours after collection.

Laboratory Analyses

Blood samples were immediately refrigerated on arrival at Central Pathology Laboratory. Blood was analyzed in a Boehringer Mannheim Diagnostics 8700 series analyzer (Boehringer Mannheim Diagnostics, Inc., Indianapolis, Ind.); measured parameters included glucose, creatinine, creatinine/urea, blood urea nitrogen (BUN), uric acid, total protein, albumin, cholesterol, total globulins, albumin/globulin, triglyceride, sodium, potassium, chloride, calcium, phosphorus, iron, total bilirubin, direct bilirubin, lactic dehydrogenase (LDH), alkaline phosphatase, gamma-glutamyltransferase (GGT), serum glutamic-oxalacetic-transaminase (SGOT), and serum glutamic-pyruvic-transaminase (SGPT).

Whole blood samples were gently mixed for at least 5 min and subsamples analyzed for leukocyte count (WBC), erythrocyte count (RBC), and mean corpuscular hemoglobin (MCH) using a Coulter Model S analyzer (Coulter Diagnostics, Inc., Hialeah, Fla.). Packed cell volume (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and hemoglobin (HGB) were calculated from RBC and MCH values.

Statistical Analyses

Descriptive statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975) on the Humboldt State Univ. computer. Arcsine transformations were performed on all ratio or percentage data before statistical analyses. Transformed variables included HCT, MCHC, albumin/globulin, BUN/creatinine, and all PCR values.

Data were evaluated with the SPSS 1-way analysis of variance with unequal sample size program and *t*-test with pooled variance estimate programs. Duncan's multiple range tests and all other comparisons were considered statistically significant when $P < 0.01$. All differences indicated hereafter were at $P < 0.01$ unless otherwise indicated. All Pearson correlations indicated hereafter were considered significant at $P < 0.005$ unless otherwise indicated.

Where no detectable variation was observed between groups (particularly by season, age, or sex) groups were combined when making comparisons. Small sample sizes prevented a more rigorous linear breakdown by year, sex, capture method, age, and season.

RESULTS

Seventy serum and whole blood samples were collected from 55 bears between 10 May 1982 and 25 July 1984; 34 males and 36 females were captured and blood samples collected. Fifteen bears were captured more than once, no bear was sampled more than 3 times during the study, no samples were taken from the same bear twice in the same season, nor for more than 2 seasons in the same year. The multiple captures were not believed to have altered random population sampling.

Thirty-six bears were culvert-trapped, 28 were captured in foot snares, 4 were treed by hounds, and 2 were immobilized while free-ranging. Snared, treed, and free-ranged bears were combined for analyses because of similar capture stress levels and relatively small sample sizes of the latter groups.

Sixty-one (87%) bears were captured in RNP. Nine (13%) were captured by CDFG personnel after depredations, outside of RNP. Two bears, 1 free-ranging and 1 culvert-trapped, were euthanized by CDFG personnel and blood was collected immediately after death. Blood collected in this manner was believed to be biochemically similar to that of live bears. Cap-

ture records for each individual are summarized by Schroeder (1986).

Some blood parameters did not vary by sex, age, season, or condition and were therefore deleted from the general blood chemistry and hematology data in Table 1. The deleted parameters were calcium, glucose, cholesterol, total and direct bilirubin, GGT, sodium, iron, and BUN/creatinine ratio (Schroeder 1986).

Average MCHC and serum levels of uric acid in 1982 differed from those in 1983 and 1984. Captive bears in 1982 included 6 snared females and 1 euthanized male. No differences were detected between years for blood samples taken from females within similar seasons. Apparent annual variation in MCHC and uric acid were more accurately attributed to capture method and sex-based biases.

Bears captured in culvert traps had higher levels of inorganic phosphorus and lower levels of uric acid, WBC, SGOT, SGPT, and LDH than snared bears (Table 2).

Age was significantly correlated with total protein ($r^2 = 0.4409$), triglycerides ($r^2 = 0.5750$), alkaline phosphatase ($r^2 = -0.4404$), MCV ($r^2 = 0.4963$), MCH ($r^2 = 0.5881$), weight ($r^2 = 0.6412$), head circumference ($r^2 = 0.5179$), girth ($r^2 = 0.5957$), and height at shoulder ($r^2 = 0.6892$). Approximately one-third (32%) of the blood chemical and hematological values differed with age (Table 3).

Head length, height at shoulder, and total length were different for the 3 age classes. Adults were larger in girth and head circumference than cubs and subadults (Table 4).

Male bears had a greater MCH than females. Additional sex-based differences ($P < 0.05$) were detected for inorganic phosphorus, BUN, chloride ion, MCV, MCHC, BUN/creatinine (Table 5), and weight.

Sex and age classes were combined for seasonal comparisons. The 4 season classifications were winter, January–March; spring, April–June; summer, July–September; fall, October–December. Significant seasonal differences were detected for inorganic phosphorus, total protein, creatinine, total globulins, MCH, and MCHC (Table 6). Average age of bears was 5.0 years (SD = 3.1, $N = 70$). Average age at capture was greatest in the spring and lowest in the fall (Table 6); disproportional capture success led to biases in several seasonal parameters.

The mean weight for all bears was 77.4 kg (SD = 36.6, $N = 70$). Males were heavier than females and

Table 1. Blood chemistry and hematology data for 55 black bears (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Parameter (units)	<i>N</i>	\bar{x}	SE
Inorganic phosphorus (mg/dl)	69	5.6	0.2
Potassium ion (mEq/l)	66	4.5	0.1
Chloride ion (mEq/l)	66	103.7	0.4
Total protein (g/dl)	69	6.6	0.1
Albumin (g/dl)	69	3.7	0.04
Total globulins (g/dl)	69	2.9	0.07
Albumin/globulin	69	1.3	0.03
Triglycerides (mg/dl)	66	343.8	14.72
Creatinine (mg/dl)	69	1.5	0.06
Uric acid (mg/dl)	66	1.7	0.08
Alkaline phosphatase (units/l)	68	24.3	1.7
Lactic dehydrogenase (LDH) (I.U./l)	69	990.7	76.7
Serum glutamic-oxalacetic-transaminase (SGOT) (I.U./l)	69	175.1	27.3
Serum glutamic-pyruvic-transaminase (SGPT) (I.U./l)	69	99.9	7.6
Leukocyte count (WBC) (cells/mm ³ × 10 ³)	66	14.81	0.64
Erythrocyte count (RBC) (cells/mm ³ × 10 ⁶)	66	6.75	0.08
Hemoglobin (HGB) (g/l)	66	15.3	0.21
Hematocrit (HCT) (% packed cells)	66	45.5	0.53
Mean corpuscular volume (MCV) (μm ³)	66	67.5	0.33
Mean corpuscular hemoglobin (MCH) (pg)	66	22.7	0.15
Mean corpuscular hemoglobin concentration (MCHC) (%)	66	33.5	0.15

adults were heavier than subadults and cubs (Table 7). Average spring weights were larger than those during any other season; however this was most likely due to seasonal capture biases. Weight was significantly correlated with total serum protein ($r^2 = 0.5625$), glucose ($r^2 = 0.3092$), triglycerides ($r^2 = 0.4226$), alkaline phosphatase ($r^2 = -0.3775$), total globulins ($r^2 = 0.5277$), albumin/globulin ($r^2 = -0.3357$), HGB ($r^2 = 0.3923$), HCT ($r^2 = 0.3513$), MCH ($r^2 = 0.3268$), and annual seasonal periods ($r^2 = -0.3285$). Several of these parameters paralleled age-related differences.

Of 68 inspections for ectoparasites among 55 bears captured, 23 (34%) had none, 37 (54%) had only ticks, 8 (12%) had ticks and lice, and 1 bear had only lice. There were no significant differences in ectoparasite load levels between seasons, but this may be an artifact of the coding scheme. There was a tendency for bears in better condition to have fewer ticks. Bears captured in winter did not have ectoparasites. Pelage condition did not differ significantly between sex or age classes.

The CEI did not differ by capture method, season, age class, or sex. Individual records of ectoparasite

Table 2. Significantly different ($P < 0.01$) blood values by capture method for 55 black bears captured (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Parameter (units)	Culvert traps			Foot snares		
	\bar{x}	SD	<i>N</i>	\bar{x}	SD	<i>N</i>
Inorganic phosphorus (mg/dl)	6.44	1.76	35	4.81	1.88	34
Uric acid (mg/dl)	1.48	0.36	32	1.90	0.78	34
WBC (cells/mm ³ × 10 ³)	12.95	3.96	33	16.67	5.73	33
SGOT (I.U./l)	91.8	64.60	35	260.94	294.00	34
SGPT (I.U./l)	80.3	39.40	35	120.0	76.0	34
LDH (I.U./l)	772.3	226.00	35	1,215.6	825.0	34

Table 3. Blood values by age class for 55 black bears captured (70 total captures) in Redwood National Park and vicinity from 12 May 1982 to 25 July 1984.

Parameter (units)	Cubs			Subadults			Adults		
	\bar{x}	SD	<i>N</i>	\bar{x}	SD	<i>N</i>	\bar{x}	SD	<i>N</i>
Total protein (g/dl)	6.18	0.299	4	6.26	0.464	23	6.86	0.751	42
Triglycerides (mg/dl)	219.2 ^b	31.2	4	295.6 ^b	88.1	23	385.0 ^{a,c}	122.9	39
Alkaline phosphatase (I.U./l)	39.7 ^b	30.9	4	29.5 ^b	12.3	23	19.9 ^{a,c}	10.3	41
Total globulins (g/dl)	2.6	0.2	4	2.5 ^b	0.3	23	3.1 ^a	0.5	42
Albumin/globulin	1.3	0.2	4	1.5 ^b	0.3	23	1.2 ^a	0.2	42
Hemoglobin (HGB) (g/l)	12.2 ^{a,b}	0.5	3	15.2 ^c	1.1	22	15.6 ^c	1.9	41
Mean corpuscular volume (MCV) (μm^3)	63.7 ^b	3.1	3	66.5 ^b	2.1	22	68.3 ^{a,c}	2.6	41
Mean corpuscular hemoglobin (MCH) (pg)	20.0 ^{a,b}	0.8	3	22.3 ^{b,c}	0.8	22	23.1 ^{a,c}	1.0	41
Mean corpuscular hemoglobin concentration (MCHC) (%)	31.4 ^{a,b}	0.8	3	33.4 ^c	0.9	22	33.7 ^c	1.3	41

^a Significantly different from subadults ($P < 0.01$).

^b Significantly different from adults ($P < 0.01$).

^c Significantly different from cubs ($P < 0.01$).

Table 4. Somatic measurements (cm) of 55 black bears captured (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Sex or age (<i>N</i>)	Total length		Height at shoulder		Girth		Head circumference		Head length	
	\bar{x}	(SD)	\bar{x}	(SD)	\bar{x}	(SD)	\bar{x}	(SD)	\bar{x}	(SD)
All males (34)	143.6	(24.6)	68.3	(12.8)	87.4	(20.2)	55.0	(10.3)	32.3	(4.5)
All females (34)	137.0	(12.9)	63.8	(7.1)	80.9	(12.2)	49.8	(6.7)	31.5	(4.1)
Cubs (4)	92.3	(5.5)	43.5	(3.8)	55.2	(4.9)	38.0	(4.6)	23.6	(0.5)
Subadults (23)	128.8	(8.6) ^a	59.9	(6.3) ^a	72.5	(7.5)	46.2	(6.1)	29.5	(2.3) ^a
Adults (41)	151.4	(13.4) ^b	71.6	(7.5) ^b	93.5	(14.0) ^b	57.2	(6.9) ^b	34.1	(3.5) ^b
Entire population (68)	140.3	(19.8)	66.0	(10.5)	84.2	(16.9)	52.4	(9.0)	31.9	(4.2)

^a Significantly larger than cubs (ANOVA, $P < 0.01$).

^b Significantly larger than cubs and subadults (ANOVA, $P < 0.01$).

Table 5. Blood value differences by sex for 55 black bears (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Parameter (units)	Male			Female		
	\bar{x}	SD	<i>N</i>	\bar{x}	SD	<i>N</i>
Mean corpuscular hemoglobin (MCH) (pg)	22.2 ^a	1.1	33	23.2	1.1	33
Inorganic phosphorus (mg/dl)	6.2 ^b	1.9	34	5.1	1.9	35
Blood urea nitrogen (BUN) (mg/dl)	25.8 ^b	15.6	34	19.0	10.3	35
Chloride ion (mEq/l)	104.7 ^b	3.0	33	102.8	3.5	33
Mean corpuscular volume (MCB) (μm^3)	66.7 ^b	2.2	33	68.3	2.9	33
Mean corpuscular hemoglobin concentration (MCHC) (%)	33.2 ^b	1.2	33	33.8	1.2	33
BUN/creatinine	19.7 ^b	13.8	34	14.0	8.2	35

^a Significantly different than females ($P < 0.01$).

^b Significantly different than females ($P < 0.05$).

Table 6. Seasonal comparisons for selected blood parameters, age at capture, and live weight for 55 black bears captured (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Parameter (units)	Winter		Spring		Summer		Fall	
	\bar{x}	SD (N)	\bar{x}	SD (N)	\bar{x}	SD (N)	\bar{x}	SD (N)
Inorganic phosphorus (mg/dl)	2.1 ^{b,c}	0.6 (3)	4.7 ^{b,c}	1.8 (18)	5.8 ^{c,d}	1.6 (36)	7.5 ^{a,b,d}	1.6 (12)
Total protein (g/dl)	6.7 ^b	0.8 (3)	7.1 ^{b,c}	0.9 (18)	6.5 ^{a,d}	0.5 (36)	6.1 ^a	0.5 (12)
Creatinine (mg/dl)	3.1 ^{a,b,c}	0.6 (3)	1.6 ^{c,d}	0.5 (18)	1.4 ^d	0.2 (36)	1.2 ^{a,d}	0.3 (12)
Total globulins (g/dl)	2.9 ^{b,c}	0.4 (3)	3.3 ^{b,c}	0.6 (18)	2.8 ^{a,d}	0.5 (36)	2.5 ^{a,d}	0.4 (12)
Mean corpuscular hemoglobin (pg)	21.3 ^a	1.7 (3)	23.3 ^{c,d}	1.1 (17)	22.8	1.0 (35)	21.8 ^a	0.9 (11)
Mean corpuscular hemoglobin conc. (%)	32.7	1.7 (3)	34.4 ^c	1.0 (17)	33.4	1.0 (35)	32.6 ^a	1.1 (11)
Albumin/globulin	1.2	0.28 (2)	1.3	0.21 (21)	1.3	0.26 (34)	1.5	0.31 (12)
Triglyceride (mg/dl)	304	141 (2)	379	123 (20)	344	128 (32)	292	68 (12)
Age (years)	4.5	6.36 (2)	6.19	2.25 (21)	4.86	2.69 (35)	2.58	2.47 (12)
Weight (kg)	97.5	75.7 (2)	225.7	93.0 (21)	161.1	61.5 (35)	114.9	49.7 (12)

^{a,b,c,d} Significantly different than spring, summer, fall, or winter ($P < 0.01$), respectively.

classification, CEI, weight/total length (PCR-A), and pelage code data are summarized in Schroeder (1986). The CEI was correlated ($P < 0.01$) with PCR-A, PCR-B (body weight/head length), and PCR-C (body weight/height at shoulder). The PCR indices were also intercorrelated. PCR-A was selected to represent the condition of each bear because it was most highly correlated ($P < 0.006$, $r^2 = 0.3121$) with CEI and because total length was least affected by measurement errors. PCR-A was correlated with total protein ($r^2 = 0.5496$), albumin ($r^2 = 0.3481$), triglyceride ($r^2 = 0.4281$), alkaline phosphatase ($r^2 = -0.3556$), total globulins ($r^2 = 0.4866$), MCH ($r^2 = 0.3214$), glucose ($r^2 = 0.3209$), RBC ($r^2 = 0.3259$), HGB ($r^2 = 0.4267$), HCT ($r^2 = 0.3742$), MCHC ($r^2 = 0.3359$), age ($r^2 = 0.5228$), season ($r^2 = -0.3185$), head length ($r^2 = 0.7050$), head circumference ($r^2 = 0.8225$), girth ($r^2 = 0.9107$), and height at shoulder ($r^2 = 0.8031$).

PCR-A values were compared by sex/age class and season (Table 8). Cubs, winter season samples, spring subadult, and fall adult values were deleted from analyses because of small sample size. PCR-A values for the population were larger in the spring. Overall male and female PCR-A values did not differ; however, overall adult values of each sex were greater than corresponding subadult values. Male and female subadult PCR-A values were similar; however, adult males were larger than adult females. No sex-based differences were detected between subadult PCR-A values between summer and fall. Adult male PCR-A values were larger than adult females values in spring. Adult male PCR-A values were larger than

any other sex/age class in the summer. Average PCR-A values for cubs was 0.24 (SD = 0.04, $N = 4$); cubs were captured during September ($N = 2$), October, and January. Small sample sizes prevented comparisons between lactating and barren adult females.

DISCUSSION

General Blood Parameters

In general, whole blood parameters for bears in RNP closely agreed with those of other black bear populations reported by Erickson and Youatt (1961), Seal et al. (1967), Matula et al. (1977), Siperek (1979), and Beeman (1981). However, bears in this study had larger MCVs with correspondingly smaller RBC counts compared to those reported elsewhere. MCH in RNP bears was greater than has been reported elsewhere. Larger MCH compensated for larger MCV, thus making MCHC values comparable to those previously reported. Hematological adaptations that might be expected for populations at different elevations (e.g., elevated MCH) did not appear to account for hematological differences noted because elevations reported by Siperek (1979) and Beeman (1981) were similar to those in RNP.

Most blood chemistry data were consistent with values reported for wild black bears studied by Matula et al. (1977) and Beeman (1981). Bears in RNP, however, had lower serum levels of total protein, cholesterol, uric acid, alkaline phosphatase, and larger mean values of BUN. Generally, serum pro-

teins decreased during starvation and increased during dehydration (Guyton 1976). In many studies, trapped bears remain captured for several hours before immobilization, which leads to temporary starvation and dehydration. Food and water deprivation for trapped RNP bears was decreased because trap transmitters reduced the amount of time a bear was in a trap. This decreased the effects of starvation and dehydration; therefore, values in this study may have been near normal levels. Therefore, my observed total serum protein and albumin levels were probably more a product of dietary influences than of capture and handling techniques.

Few studies relate black bear diets to blood chemistry and hematology, however, Siperek (1979) reported larger total serum protein and albumin levels in bears foraging on "a relatively abundant...source of food" (i.e., a waste disposal site). If total serum protein and albumin levels vary with diet, then RNP bears may have had lower quality diets than bears studied by Siperek (1979).

RNP bears had almost twice the BUN levels of those reported by Matula et al. (1977), Siperek (1979), and Beeman (1981). Tietz (1976) reported that increases in BUN may result from prerenal causes such as water deprivation or increased ingestion of protein. It was unlikely that dietary differences could sustain such elevated BUN levels; the differences were too large and other dietary indicators did not support elevated BUN levels.

A variety of immobilization agents has been used in black bear blood chemistry studies; Beeman (1981) used sernylan (phencyclidine hydrochloride) or M-99 (etorphine hydrochloride); Siperek (1979) used CI-744 and sernylan; and Matula et al. (1977) used M-99. Beeman (1981) found that different sedative drugs produced significantly different BUN levels among immobilized bears. Urea nitrogen is increased as a result of gluconeogenesis from amino acids. Elevated BUN levels in this study were believed to have been a combined response of xylazine hydrochloride and the delay in collecting blood after immobilization.

Sources of Variation in Blood Parameters

Capture Method.—Lee et al. (1977) found significantly higher levels of LDH and SGOT for snared polar bears (*U. maritimus*) compared to polar bears that were culvert-trapped. Snared bears in RNP had higher levels of SGOT, LDH, and SGPT compared to those culvert-trapped. Beeman (1981) and I also

Table 7. Body weights (kg) by sex and age class of 55 black bears captured (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Sex	Cubs		Subadults		Adults		Total	
	\bar{x}	(N)	\bar{x}	(N)	\bar{x}	(N)	\bar{x}	(N)
Male	25.10	(3)	56.21	(13)	122.44	(18)	88.53 ^a	(34)
Female	15.42	(1)	48.67	(10)	76.68	(25)	66.97	(36)
Total	22.68	(4)	52.93	(23)	95.64 ^b	(43)	77.44	(70)

^a Significantly larger than all females (*t*-test, $P < 0.01$).

^b Significantly larger than cubs or subadults (ANOVA, $P < 0.01$).

Table 8. Seasonal PCR-A (body weight/total length) values for sex and age classes of 55 black bears (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984.

Class	Winter			Spring			Summer			Fall			All seasons		
	\bar{x}	SD	N	\bar{x}	SD	N	\bar{x}	SD	N	\bar{x}	SD	N	\bar{x}	SD	N
Males				0.85 ^a	0.18	8	0.56	0.17	18	0.43	0.06	5	0.61	0.22	31
Subadults							0.43	0.07	9	0.42	0.06	4	0.43	0.06	13
Adults				0.85 ^b	0.18	8	0.69 ^c	0.15	9	0.48		1	0.75 ^d	0.19	18
Females	0.43	0.08	2	0.54	0.12	9	0.47	0.11	19	0.48	0.14	3	0.49	0.11	33
Subadults	0.38		1	0.29		1	0.39	0.07	6	0.41	0.05	2	0.38	0.07	10
Adults	0.49		1	0.57	0.08	8	0.51	0.10	13	0.64		1	0.53 ^e	0.09	23
Entire population	0.43	0.08	2	0.69	0.22	17	0.51	0.15	37	0.45	0.09	8	0.55	0.18	64

^a Significantly larger than any other season (ANOVA, $P < 0.01$).

^b Significantly larger than adult females in spring (t -test, $P < 0.01$).

^c Significantly larger than any other sex or age class in summer (ANOVA, $P < 0.01$).

^d Significantly larger than any other sex or age class (ANOVA, $P < 0.01$).

^e Significantly larger than subadult females (t -test, $P < 0.01$).

detected larger WBC values for snared black bears, whereas Lee et al. (1977) noted an increase in WBC in culvert-trapped (vs. snared) polar bears. An increase in glucose levels was expected for snared bears; however, significantly different glucose levels were not evident in bears captured by the differing methods in this study.

Elevated HCT values have been found in snared black bears (Beeman 1981) and polar bears (Lee et al. 1977). Both investigators attributed this increase to splenic contractions that occurred during the stress of capture. Woodland caribou (*R. caribou*) and certain breeds of dogs also had elevated HCT when physically restrained or excited (Karns and Crichton 1978, Schalm et al. 1975). Erythrocyte parameters in RNP bears captured by varying methods did not differ significantly. This may have been partly because researchers responded quickly (often less than 2 hours) after a bear was captured but was more likely attributable to the xylazine-induced splenic relaxation after immobilization.

Serum levels of uric acid and inorganic phosphorus were higher in snared bears than those culvert-trapped. Elevated uric acid levels may have been related to increased metabolism or rapid destruction of cell nucleoproteins (Tilkian et al. 1979; Baron 1982). Larger levels of SGOT and LDH for snared black bears in this study and polar bears (Lee et al. 1977) may have indicated significant striated muscle damage. The destruction of cell nucleoproteins in damaged tissue may also have contributed to the elevation of uric acid levels. Elevation in serum levels of inorganic phosphorus was also associated with capture

stress in snared polar bears (Lee et al. 1977) and in physically restrained woodland caribou (Karns and Crichton 1978). Differential values between capture methods eliminated some blood parameters as indices of physiological condition.

Sex.—Blood parameter differences based on sex have been observed in black bears for MCH, MCHC, serum calcium, and creatinine (Matula et al. 1977, Beeman 1981). Males in this study had smaller ($P < 0.01$) MCH values than females. RNP males also had smaller ($P < 0.05$) MCV and MCHC values and higher ($P < 0.05$) levels of serum inorganic phosphorus, BUN, chloride ion, and BUN/creatinine than females.

Matula et al. (1977) attributed low MCH and MCHC levels in female bears to an iron deficiency anemia due to large iron demands during pregnancy and lactation. RNP females, on the contrary, had larger MCHC, MCV, and MCH values than males with no differences in serum iron. Soil usually contains adequate amounts of iron for the needs of wild animals (Runnels et al. 1965). Bears in RNP did not appear to be deficient in iron because the soils of northcoastal California may readily supply iron simply through grooming and foraging behavior. The RBC count and the concentration of hemoglobin per 100 ml of blood was approximately 10% greater in males for several species of mammals than in females (Glücksman 1981). The source of reversed sexual hematological differences between RNP bears and bears previously studied (Matula et al. 1977, Beeman 1981) was not clear.

BUN levels indicated a higher dietary intake of

protein as described for white-tailed deer (*O. virginianus*; Seal et al. 1972). If this were true for RNP bears, then male bears have a larger intake of dietary protein than females. The BUN levels of RNP bears, however, were nearly double those reported previously for black bears (Matula et al. 1977, Beeman 1981).

As previously discussed, elevated BUN levels in RNP bears may have been attributed to the effects of immobilization with xylazine hydrochloride. If this were true, then it may also have been possible that differences in BUN and BUN/creatinine levels between sexes were due in part to a differential response of each sex to those drugs. Glücksmann (1981) described sex-based differences in sensitivity of some mammals to drugs. Matula et al. (1977) concluded BUN levels were subject to individual variation.

Karns and Crichton (1978) noted a significant decrease in inorganic phosphorus levels during the capture and handling of woodland caribou. Capture stress was believed to contribute to lower inorganic phosphorus levels in RNP bears captured in snares. Therefore, levels of inorganic phosphorus may have indicated a relative degree of capture stress and further supported the conclusion that females were more affected by capture stress than males because females had lower levels of inorganic phosphorus. No differences in inorganic phosphorus were detected in polar bears (Lee et al. 1977). Franzmann and LeResche (1978) found decreased levels of inorganic phosphorus in lactating moose (*Alces alces*).

Age.—Age-related differences in black bears have been reported for MCH, MCV, MCHC, HGB, RBC, HCT, and serum levels of cholesterol, total protein, globulin, total bilirubin, potassium, inorganic phosphorus, creatinine, uric acid, and alkaline phosphatase (Seal et al. 1967, Matula et al. 1977, Beeman 1981). Although many previously reported age-related differences were similar to those found in RNP bears, there were notable exceptions.

All age classes of RNP bears had MCV values smaller than $80 \mu\text{m}^3$ and MCHC values larger than 30%. Cubs had smaller MCHC values than adults or subadults. Seal et al. (1967) and Matula et al. (1977) suggested a hypochromic, microcytic anemia in younger bears. Matula et al. (1977) attributed this anemia to an iron deficiency caused by growth demands. Bears in this study, however, did not exhibit age-based differences in serum iron, nor were younger bears hypochromic. This lack of age-related serum iron differences was further evidence that RNP bears were not iron limited.

Adult bears in this study had larger erythrocytes with correspondingly more hemoglobin per cell, than cubs (Table 3). When compared to adults, subadults had similar amounts of hemoglobin and MCHC; however, they had lower levels of MCH and smaller MCV values. Similar, although not significant, differences were also noted for RBC and HCT. Therefore, bears in this study had larger, more numerous red blood cells with larger hemoglobin concentrations as they matured to adult age (Table 3). Baron (1982) reported that protein deficiency can lead to a hypochromic anemia because the hemoglobin synthesis is impaired. The age-related differences in HGB values may have resulted from differential dietary intake of protein or reflected slight iron deficiencies (Matula et al. 1977). The pattern of hematological differences between age classes suggested nutritional differences. Dietary differences may have permitted adult bears to produce relatively more hemoglobin and larger erythrocytes than younger age classes—similar to patterns observed in wolves (*Canis lupus*) (Seal et al. 1975). Hemoglobin levels were greater with improved condition for moose (Franzmann and LeResche 1978).

Average alkaline phosphatase levels decreased with increased age class of RNP bears. Physiological bone growth elevated alkaline phosphatase in serum (Tietz 1976). Higher levels of alkaline phosphatase in cubs and subadults probably reflected rapid bone growth. Similar trends have been reported previously for black bears (Matula et al. 1977, Beeman 1981) and for polar bears (Lee et al. 1977).

Adult black bears had higher levels of total serum protein; similar to those reported by Matula et al. (1977). Any age-related interpretation of total serum protein must have accounted for the protein demands of each sex and age group. Cubs and subadults would be expected to use protein primarily in forming new body tissues (i.e., growth). Adults require protein to maintain existing tissues. Additional demands are imposed on adult females during pregnancy and lactation. The magnitude of total serum protein level differences attributed to the demands of each sex and age group remains to be determined.

Total serum protein levels reflect the nutritive state of some animals; thus a long period of low protein intake may affect the level of serum proteins (Tietz 1976). Franzmann and LeResche (1978) found significantly higher total serum protein levels in moose as condition improved. Serum albumin, however, is the animal's most sensitive indicator of dietary protein intake. The relationship between age class and

albumin levels in this study could have indicated that adult bears are in better physiological condition than subadults and cubs.

Triglycerides constitute most of adipose tissue mass and are at higher concentrations in blood serum during fat utilization and 4–6 hours after meals high in fat and carbohydrate (Tietz 1976). The significant differences noted between black bear age classes for serum triglycerides indicated that adult bears had a larger dietary intake of foods with more fats and carbohydrate or that they had proportionately larger fat deposits.

Decreased levels of total globulins occurred in cases of total protein deficiency as reported in severe malnutrition (Baron 1982). Lower total globulin levels observed in younger age classes, however, most likely reflected a shorter history of immune system challenges. Thus larger levels of total serum protein and triglycerides in adults may have reflected diets higher in protein, carbohydrate, and fat.

Season.—Seasonal variation for HCT, MCV, MCHC, and serum levels of glucose has been observed in bears (Lee et al. 1977, Matula et al. 1977, Siperek 1979). In this study, MCH, MCHC, and serum levels of phosphorus, total serum protein, creatinine, and globulin varied with season (Table 6). Generally, seasonal variation in blood parameters is a response to changes in the environment, most often food resources. Seasonal variation in blood parameters was also associated with winter dormancy of black bears (Nelson et al. 1973).

The seasonal variation in age at capture, body weight (Table 6), and PCR-A (Table 8) was probably related to the disproportionate number of adult males captured in spring and of subadults captured in fall. Overall average weights for spring were larger than any other season and were attributed to the capture of 16 adults, half of which were large males.

Because of age-related differences previously identified, a capture bias of adults in the spring tended to increase the average levels of parameters that exhibited age- and sex-based differences. The converse was also true in fall, when many subadults were captured and the capture bias worked toward reducing average levels of blood parameters affected by age-related differences. Capture biases appeared to account for seasonal variation observed in MCH, MCHC, and serum levels of total serum protein and total globulins (Table 6). Similarly, these biases may have worked toward reducing expected variation in other parameters (i.e., triglycerides and cholesterol).

Thus these parameters were influenced by differential capture success and the sex- and age-class differences inherent in those animals captured.

Serum creatinine levels decreased and inorganic phosphorus increased during the year. Serum creatinine has been shown to vary seasonally in response to winter dormancy (Nelson et al. 1973). The effects of xylazine hydrochloride and sampling delay after immobilization were believed to have altered the expected seasonal variation patterns on BUN levels in this study. Bears in RNP, especially pregnant females, entered dormancy; however, some bears were known to change dens and consume trapbaits well into the winter. There were also noticeable differences in duration of dormancy and den site selection between sex and age classes (Schroeder, unpubl. data). Explanations for seasonal patterns in inorganic phosphorus levels, considering capture stress and sex-based differences, were not apparent.

Condition Indices

Hanks (1978) described attempts to characterize population condition by blood chemistry, hematology, and body growth. He reported that “the use of blood constituents to describe physiological condition has met with mixed success.” Although this may indeed be true, a majority of studies have not accounted for variations due to capture stress, sex, age, season, and drug immobilization. Blood parameters influenced by these sources of variation are of little practical use in condition evaluation studies unless variation is clearly understood and taken into account.

Riney (1960) described a field technique to classify live animals into 3 condition classes based on the general appearance of the hindquarters. These classes were based on the tendency of an animal to become thin as condition declined. The CEI used in this study was of little use in describing the physiological condition of bears. Evaluation was too subjective to provide reliable condition data. Thus, subtle differences in fat deposition, pelage condition, and ectoparasite load were believed to have produced variation in the CEI assigned to bears of similar physiological condition. There were marked differences in fat reserves between seasons for each age class; however, these were difficult to adequately assess because of capture biases. Another limitation in the use of rating body fat reserves occurred in the younger age classes, where little body fat was deposited regardless of condition.

Further studies should standardize the evaluation with more objective methods. Hanks et al. (1976) noted that 2 animals may appear identical yet have markedly different fat reserves. Although this may be true, body weight and somatic measurements possibly are the most objective units that permit comparison of physical condition for bears.

Use of the PCR-A eliminated the subjectivity of condition code assignments. Hanks (1972) described measurement, age, and weight data to merely represent weights associated with increased length at older ages. However, the relationship of body weight to total length yielded weight per unit length. This relationship actually measured the heaviness (kg/cm) of each bear. Black bear weights were subject to dramatic changes annually. Total length was less variable than weight for each individual and increased annually to adult size. Therefore, heavier bears (larger PCR-A) were not necessarily longer. Thus a subadult may have been comparatively heavier (kg/cm) than an adult bear.

There were limits to the range of PCR-A values in a population. Starvation may have eliminated bears with extremely low PCR-A values. Conversely, the upper limit was determined by the ability of each bear to find food. Bears that could not find enough food died, whereas survivors maximized food intake and increased body weight and thus increased PCR-A. In this manner PCR-A reflected the ability of each bear to obtain food and was not an indicator of environmental conditions per se.

Each bear may have experienced fluctuations in its PCR-A value in response to variations in foraging ability. Changes in phenological patterns, modification of home range size, and bodily injury were possible influences governing foraging ability. In general, black bear life history patterns suggest that each bear would have a greater PCR-A value in fall than spring because of weight loss during winter dormancy. For full-grown bears, weight changes alone influenced PCR-A.

Similarly, there were fluctuations in the average PCR-A value for each sex and age class, that reflected the ability of its members to obtain food. Yet within each sex and age class there were some individuals that exhibited superior competitive ability. Some adult males, for example, competed more successfully than other adult males, often solely because of their larger size. Thus each sex and age class consisted of bears of varying PCR-A values. Variation in PCR-A values reflected the differing abilities of individual

bears to compete for food as well as the sex and age group. This conclusion was supported by the range of seasonal PCR-A values for each sex and age class (Table 8).

If a greater PCR-A value was representative of better competitive ability, then adult males appeared to outcompete the other sex and age groups; adult males had larger PCR-A values than the other groups (Fig. 2). In general, however, there was a relative ranking in the PCR-A values by sex and age class: adult males, adult females, subadult males, and subadult females (highest to lowest, respectively). As would be expected, some adult males were apparently outcompeted by some adult females. Similarly, each group exhibited a range of PCR-A values with overlap between groups where inferior competitors of 1 group were outcompeted by superior competitors of the next lowest group.

Klein (1964) stated that 1 problem in the use of body measurements to quantify growth has been the possible unknown effects of genetic variation on individuals or between populations. Admittedly, it was impossible to assess the influence of genetic variation within the RNP population or between this and other

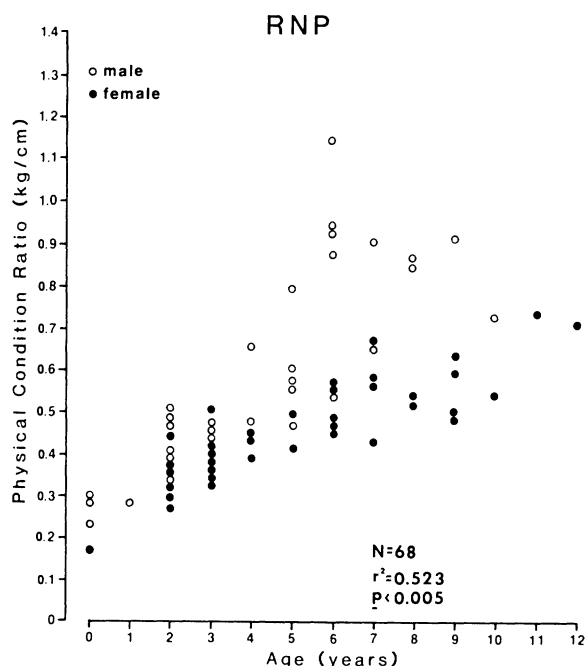


Fig. 2. Physical condition ratio (PCR-A; body weight/total length) by age for 55 black bears captured (70 total captures) in Redwood National Park and vicinity from 10 May 1982 to 25 July 1984. All PCR-A values were recorded using the arcsine-transformation.

studies. Several researchers (e.g., Taber and Dasmann 1958) have used body weights and measurements to compare size differences in animals resulting from variations in relative food abundance or quality rather than genetic origin. Klein (1964) concluded that growth differences in deer were more of nutritional than genetic origin.

Bailey (1968) found that resident cottontail rabbits were in better physical condition than were rabbits that had recently immigrated. He suggested that the poor physical condition of immigrant rabbits could have been the result of inadequate food or other stresses. Similar patterns may have occurred in the RNP bear population, where a resident population of adult animals may have excluded subadults from the residents' home range. These social interactions may have decreased the foods available to the younger bears. Social pressures, therefore, may have directly influenced food intake. A decreased intake of food then would have decreased body weights and reduced PCR-A values for subadults.

Average PCR-A values may have also indicated how a bear population used the food resources within its range. Where food resources were relatively scarce, intraspecific competition would have resulted in lower PCR-A values for the population. Conversely, a population that used a relatively abundant food resource could have experienced less competition and

larger PCR-A values would have been characteristic. In this manner the PCR-A values may have reflected the overall quality or quantity of foods used by the RNP population. Figure 2 may, therefore, reflect the plane of nutrition for bears as a whole in northcoastal California habitats.

Siperek (1979) reported raw weight and somatic data for bears captured in the San Bernardino Mountains (SBM) of southern California. Ninety-two percent of these bears were male. Male SBM bears for all seasons had significantly larger ($P = 0.002$) PCR-A values than those for RNP bears (Fig. 3). Male SBM bears were longer at all ages than comparably aged RNP bears. Total length, head length, and head circumference were measured in the same manner between studies; however, height at shoulder for RNP bears was recorded from the middle of the flexed wrist of the foreleg to the top of the scapula and girth was measured as the axillary circumference of the chest cavity.

Recognizing small sample sizes, physical condition differences between populations were apparent at early ages. PCR-A values for SBM cubs ($\bar{x} = 0.39$, $SD = 0.007$, $N = 3$) were 137% larger than RNP cubs ($\bar{x} = 0.24$, $SD = 0.04$, $N = 4$). Body weights were also larger for SBM bears compared to RNP bears. Siperek (1979) attributed the large size of the SBM bears to little intraspecific competition with

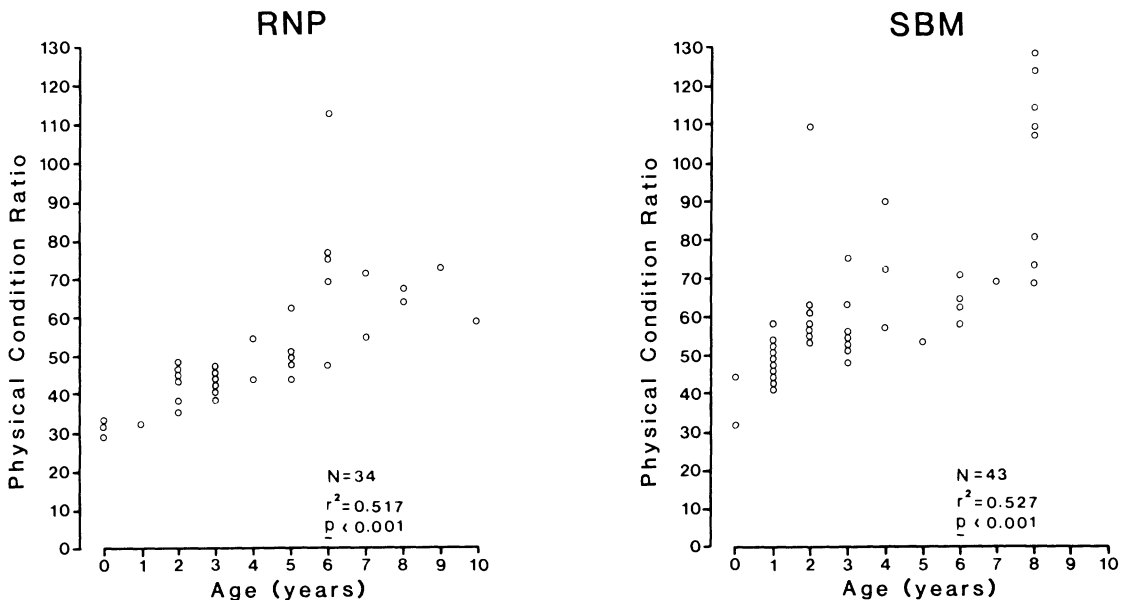


Fig. 3. Physical condition ratio (PCR-A; body weight/total length) by age for male black bears in Redwood National Park and vicinity (RNP) and the San Bernardino Mountains, Calif. (SBM; Siperek 1979). All PCR-A values were recorded using the arcsine-transformation.

abundant food resources and to the fact that the introduced population was still increasing in numbers and distribution.

Klein and Strandgaard (1972) stated that body size of roe deer (*Capreolus capreolus*) was most directly related to population density. They suggested that social pressures, which affected energy expenditure and food intake, influenced body size. This suggested that RNP bears were at a greater population density than SBM bears and that social interaction, based on food resources, influenced body weights and measurements of the 2 populations.

Comparisons of PCR-A values for sex and age classes of RNP and SBM bears indicated that SBM bears attained larger weights and total lengths than RNP bears. The abundant food resources available to SBM bears may have influenced these size differences (Siperek 1979). In this manner, the PCR-A may have reflected the food resources (in quantity and quality) available to each bear population. Taber and Dasmann (1958) used body weight corrected for skeletal size to compare black-tailed deer from different habitat types.

If the PCR-A reflected changes between and within populations based on differing food resources, it would follow that larger PCR-A values would be associated with bears on an improved diet (for a given age class). Animals with access to increased quantity or quality of forage were more likely to be in better physical condition and thus had larger PCR-A values associated with improved condition.

Those blood parameters that were correlated with PCR-A may have reflected improved condition. Those parameters included total serum protein, albumin, total globulins, triglycerides, glucose, RBC, HGB, HCT, and MCH. All but RBC and HCT showed age-related differences, but this was expected because adult bears may have outcompeted younger bears and may thus have been in relatively better condition. The PCR-A value reflected the competitive ability of bears to successfully forage on limited food resources and as such produced a relative ranking of condition not only within a sex and age class, but the population as well.

Larger PCR-A values indicated that body weight was associated with superior foraging ability and, thus, a relatively better diet than bears with lower PCR-A values. Three blood parameters (total serum protein, albumin, and globulin) may best reflect the plane of nutrition for individuals or groups of animals. Decreased serum proteins were associated with

inadequate diets of mule deer (Anderson et al. 1972). Doyle et al. (1975) showed increases in total serum protein with increased body weight in raccoons (*Procyon lotor*). Albumin did not respond to rapid changes in nutritional status (Baron 1982) and therefore may have been a good indicator of long-term dietary patterns. The 3 protein parameters may have also correlated with production of hemoglobin and erythrocytes, as increased MCH and RBC were associated with increased intake of dietary protein.

Several blood parameters varied with changes in physical condition. Rosen and Bischoff (1952) reported a decline in RBC and HGB as mule deer lost weight and their condition deteriorated. Franzmann (1972) suggested HCT values were indicators of condition in bighorn sheep (*Ovis canadensis*). Kitts et al. (1956), however, did not detect any difference in HCT for black-tailed deer fed varying diets.

In these comparisons the PCR-A must be regarded as a variable that reflected the interactions of many environmental and, possibly, genotypic factors. Those factors included race, sex, age, sexual condition, social status, season, weather, disease, and food availability or quality (Bailey 1968). Blood parameters were also subject to variation by sex, age, diet, capture method, and season. Interpretation of blood chemistry and hematological data associated with physical condition must attempt to account for observed variation and those patterns considered "normal" for individual animals in a specific ecosystem.

Comparisons between populations indicated differences in intraspecific interactions and food resources. There were, however, specific hematological and biochemical differences reported between populations that were a result of varying capture methods, immobilizing drugs, and laboratory procedures used to collect and analyze blood samples. Furthermore, there were certain blood chemical and hematological parameters that differed markedly from previously reported studies. These latter differences were difficult to explain. The variation in some blood chemical and hematological parameters between populations may be reduced with standardization of collection and analytical techniques; however, additional studies are necessary to elucidate possible geographically based variation.

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