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Source: Journal of Wildlife Diseases, 44(2) : 295-303

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-44.2.295

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Journal of Wildlife Diseases, 44(2), 2008, pp. 295–303
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HEMATOLOGY AND SERUM BIOCHEMISTRY OF THE BRUSH-TAILED ROCK-WALLABY (*PETROGALE PENICILLATA*)

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ABSTRACT: In Australia the brush-tailed rock-wallaby (*Petrogale penicillata*) is the subject of a national recovery plan, and several sites have been selected for reintroductions. Condition of wild populations and individual animals can be monitored using hematologic and serum biochemistry analytes, and hematologic variables have been correlated with postrelease survival in other species. Prior to such monitoring, reference values for blood variables are required, but these data have not been available for the brush-tailed rock-wallaby. During four trapping periods from November 2004 to August 2005, 116 blood samples were collected from 44 brush-tailed rock-wallabies in a wild colony in southeast Queensland. Some variables varied with sex, age, method of restraint, lactation demands, and trapping period. After partitioning, when required, reference ranges for hematology and serum biochemistry variables were established. This study provides the most comprehensive serum biochemistry reference range for any macropodid marsupial yet published.

Key words: Australia, hematology, biochemistry, brush-tailed rock-wallaby, clinical pathology, *Petrogale penicillata*.

INTRODUCTION

Hematologic and serum biochemistry analytes may be used to assess the condition of wild populations, giving indications of disease, nutritional status, habitat quality, and other stressors (Hanks, 1981). Data may be interpreted at both the population and individual animal levels and can be important for health monitoring of endangered species. Blood variables also can be useful predictors of survival in reintroduction and translocation programs (Mathews et al., 2006). For maximum benefit, prior establishment of reference values and knowledge of variation in these values under a range of different conditions are required. Differences in various values may occur with age, sex, and method of restraint; indeed, some of these values have been shown to vary with age and sex in Australian marsupials (Kuttner and Wiesner, 1987; Spencer and Speare, 1992; Wells et al., 2000). To date, surprisingly few baseline data have been collected for free-living Australian fauna, and many of the studies that have been done considered only a few variables because blood collection was an ancillary part of the study (Stirrat, 2003).

The brush-tailed rock-wallaby (*Petrogale penicillata*) is a medium-sized nocturnal macropodid marsupial dependent on rocky habitats. The species used to be abundant and widespread throughout the mountainous country of southeast Australia. However, it is now critically endangered in Victoria, endangered in New South Wales, and threatened in Queensland, with population numbers declining throughout its range (Clancy and Close, 1997; Dovey et al., 1997; Menkhorst and Jarman, 2005). The brush-tailed rock-wallaby is the subject of a high-profile national recovery plan, with captive breeding programs underway and sites being prepared for reintroductions in Victoria (Menkhorst and Jarman, 2005). Animals live in small colonies, usually of fewer than 30 individuals (Jarman and Bayne, 1997), and exhibit sexual dimorphism, with average weights of 7.9 and 6.3 kg for adult males and females, respectively (Strahan, 1995). Sexual maturity has been recorded in captive males at 23 months and females at 21 months (Taggart et al., 2005), but data from a wild colony in southeast Queensland suggest that females may not rear a pouch young until they are three yr old (A. W. Goldizen, unpub. data).

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The hematology of a colony of the closely related allied rock-wallaby (*Petrogale assimilis*) has been studied, but serum biochemistry analytes were not reported (Spencer and Speare, 1992). No reference values exist for free-living brush-tailed rock-wallabies. The aims of this study were to establish reference values for both hematologic and biochemical analytes for the brush-tailed rock-wallaby from a nonthreatened wild population, and to determine variations in these values among sexes, age classes, and methods of restraint (manual or gaseous anesthesia) during different time periods over 12 mo.

MATERIALS AND METHODS

The Hurdle Creek brush-tailed rock-wallaby colony, located on private property above the southern cliffs of Hurdle Creek valley, Mount Colliery, Queensland (28°17′S, 152°19′E, altitude range 850–1,050 m) has been the focus of behavioral, mark-recapture, and genetic studies (Laws and Goldizen, 2003; Hazlitt et al., 2004). The population has been studied in detail since late 2000 and, at any one time, is thought to comprise 35–40 animals including juveniles (Laws and Goldizen, 2003).

The study site is in a summer rainfall area with relatively warm, wet summers, and cool, dry winters. During the study period rainfall was below average; rainfall at Tannymorel, approximately 7 km from the study site, was 242 mm from November 2004 to March 2005 (historic average 412 mm) and 126 mm from April to August 2005 (historic average 201 mm). Mean maximum and minimum daily temperatures at Warwick, approximately 40 km northwest of the study site, are 29.9 and 16.6 C in summer and 18.9 and 3.5 C in winter (Bureau of Meteorology, Australian Government).

Animals in this colony were caught during four trapping periods of 2–4 wk duration: 1: November 2004; 2: January–February 2005; 3: April–May 2005; and 4: July–August 2005. Metal treadle traps were placed along the top of cliffs, baited with apple and sweet potato, and lined with foam and shade cloth. Rock-wallabies were caught after sunset as they emerged above the cliffs to feed in the grassland and mixed eucalypt forest (Laws and Goldizen, 2003). On the first occasion an animal was trapped, a blood sample was taken from the jugular vein under general anesthesia, using 2–3% isoflurane (Attane, Pharmtech, West Pymble, New South Wales, Australia) in oxygen, as part of a more detailed health study. Subsequent samples were collected from the lateral coccygeal vein of the tail with the animal manually restrained in a Hessian sack. Animals were given a brief clinical examination and identified using a microchip (LifeChip/Digivet.com Pty Ltd, Baulkham Hills, New South Wales, Australia) injected subcutaneously. Individuals were sampled on only one occasion during each trapping period. Females were classed as adults if they had a pouch young or one or more teats had been used (Poole and Catling, 1974). Reproductive status of adult females was noted and classified according to lactation demands. Those with a pouch young in the second half of pouch life, with pes length greater than 48 mm (Wynd et al., 2006), or a young at foot (indicated by a lactating teat not associated with a pouch young) were classed as having a high energetic demand from lactation, whereas those with a small pouch young, with pes less than 48 mm, or an empty pouch were considered to have lower energetic requirements. Males were classed as adults if they were >5 kg and had descended testes (Hazlitt et al., 2004).

Two to four milliliters of blood was collected from each animal. One milliliter was added to an EDTA tube and stored at 4 C for hematology. Two blood smears were made from the EDTA tube within 2 hr of sample collection. The remainder was transferred to a clot activating tube, the serum separated by centrifugation (1,500 × G at 4 C for 10 min), and stored at −20 C prior to biochemistry analysis. Whole blood was analyzed using an Abaxis Vetscan HMT analyzer (Union City, California, USA) for the following hematologic variables: hemoglobin (Hb), red blood cell count (RCC), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), mean corpuscular hemoglobin (MCH), platelet count, mean platelet volume (MPV), platelet hematocrit (PCT), and white blood cell count (WCC). Differential counts of white cells ($n=100$) were made on smears stained with Wright's methanol–based stain. The smears were examined under light microscopy (Olympus BH2) at 400× magnification. Sera were analyzed using an Olympus AU400 biochemistry analyzer for aspartate aminotransferase (AST), alkaline phosphatase (ALP), creatinine phosphokinase (CPK), gamma glutamyl transferase (GGT), total protein, albumin, globulin, albumin globulin ratio, urea, creatinine, cholesterol, triglycerides, total bilirubin, glucose, calcium, phosphorus, and magnesium.

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All statistical analyses were undertaken using Stata Version 9 (StataCorp, College Station, Texas, USA). Blood variables were analyzed using generalized estimating equations to account for dependence of repeated measurements from one animal. Blood variables were log transformed when required to achieve a normal distribution, and monocyte and eosinophil counts were log transformed after adding one to each value. Univariable analyses were used to assess associations between each of sex, age class, trapping period, method of restraint, and lactation demand and each outcome variable using Wald *P* values. Where more than one factor was significant at $P<0.05$ on univariable screening, these were fitted simultaneously and each retained in the final model if significant. Model specifications included normally distributed residuals, identity link functions, exchangeable correlation structures, and robust standard errors.

For presentation of reference ranges, samples were partitioned if differences between groups (sex, age class, or method of restraint) were significant, and the adjusted coefficient was greater than 10% of the average of the mean values for the two groups or the adjusted ratio was greater than 10%. Multiple partitioning was required for several variables. Partitioning of values of adult females according to lactation demands was not undertaken as sample sizes were too small (Solberg, 1987) Reference intervals are presented as the central 0.95 fraction (Solberg, 1987).

RESULTS

During the course of the study, 44 animals (27 females and 17 males) were trapped, and 115 blood samples collected. No animals showed clinical signs of disease at the time of capture.

Significant gender differences were found for four variables. Male animals had significantly higher PCV, RCC, CPK, and total bilirubin (Table 1). Significant differences between age classes were detected for several variables (Table 2). Adult animals typically had a higher platelet count and PCT but a lower WCC that reflected lower total lymphocyte and monocyte counts but higher numbers of eosinophils. Calcium, phosphorus, GGT, AST, ALP, and glucose concentrations were lower, but creatinine and triglyceride concentrations higher. Total protein was higher, with lower concentrations of albumin but higher globulin. General anesthesia significantly reduced several blood variables: Hb, RCC, PCV, absolute lymphocyte count, calcium, magnesium, GGT, total protein, albumin, globulin, creatinine, and cholesterol. However, platelets and PCT were significantly elevated (Table 3). Among adult females those with lower lactation demands had a significantly higher Hb concentration, and eosinophil count, but lower lymphocyte count and triglyceride concentration (Table 4).

Significant differences were detected between trapping periods for most blood variables, but point estimates were imprecise in most cases; therefore the magnitude and pattern of effects could not be described precisely. Exceptions were RCC, PCV, phosphorus, creatinine, and triglycerides (Table 5). Reference intervals for hematologic and serum biochemistry variables are presented in Tables 6 and 7 and are partitioned where appropriate.

DISCUSSION

This study provides the first hematologic and biochemistry reference intervals for the brush-tailed rock-wallaby in southeast Queensland and the most comprehensive set of serum biochemistry reference intervals yet published for any macropodid marsupial. Hematologic reference ranges for many macropodid species have been compiled by Clark (2004), and the variation between species for many of these variables highlights the need for the compilation of species-specific data. There are no published reference intervals for serum biochemistry values for other members of the *Petrogale* genus. The hematologic values from our study were similar to those for the allied rock-wallaby (Spencer and Speare, 1992) with the exception of a markedly lower MCV (mean 69.83 compared to 82.28). Both *Petrogale* species had high WCC counts compared to macropodids of the genus *Macropus* (Presidente, 1978),

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TABLE 1. Variation between sexes in hematologic and serum biochemistry variables for brush-tailed rock-wallabies (*Petrogale penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005. For normally distributed variables, coefficients represent differences in male from female values and are adjusted for other variables if they had a significant effect on each variable (season, age class, method of restraint). For data transformed prior to analysis adjusted ratio of male values relative to females is given.

	Crude mean (SD)			
Outcome variable	Female $n=64$	Male $n=51$	Adjusted effect size	P value
Normally distributed data:			Estimated difference (CI):	
PCV[a] (l/l)	0.41 (0.059)	0.43 (0.067)	0.02 (0.00, 0.04)	0.036
RCC[a] (10^{12}/l)	5.6 (0.89)	6.2 (0.89)	0.4 (0.1, 0.6)	0.023
Total bilirubin (μmol/l)	2.88 (1.200)	3.42 (1.198)	0.50 (0.00, 1.00)	0.048
Data transformed prior to analysis:			Estimated ratio (CI):	
CPK[a] (IU/l)	812 (524.6)	1,335 (1694.5)	1.37 (1.06, 1.75)	0.015

[a] PCV = packed cell volume; RCC = red blood cell count; CPK = creatinine phosphokinase.

which Spencer and Speare (1992) attributed to the tendency of rock-wallabies to live in crowded colonies. Data on biochemistry analytes in macropodids have been gathered only from the agile wallaby (Stirrat, 2003) and the tammar wallaby (Deane et al., 1997), and these do not include values for AST, ALP, CPK, GGT, or bilirubin. The ranges for most variables from our study were wide and, where data are available, comparable to those from other macropodids.

TABLE 2. Variation between age classes in hematologic and serum biochemistry variables for brush-tailed rock-wallabies (*P. penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005. For normally distributed variables, coefficients represent differences in subadult from adult values and are adjusted for other variables if they had a significant effect on each variable (season, sex, method of restraint). For data transformed prior to analysis adjusted ratio of subadult values relative to adults is given.

	Crude mean (SD)			
Outcome variable	Adult, $n=67$ unless stated	Subadult, $n=48$	Adjusted effect size	P value
Normally distributed data:			Estimated difference (CI):	
Phosphorus (mmol/l)	1.90 (0.496) $n=58$	2.27 (0.605)	0.36 (0.16, 0.57)	0.001
GGT[a] (IU/l)	10.9 (2.95)	14.3 (3.87)	3.1 (1.5, 4.6)	<0.001
Protein (g/l)	64 (7.8)	59 (7.4)	−5 (−8, −3)	<0.001
Albumin (g/l)	36.5 (3.60) $n=68$	38.6 (3.07)	1.4 (0.6, 2.2)	<0.001
Globulin (g/l)	27.3 (5.12)	20.7 (5.01)	6.6 (−9.3, −3.8)	<0.001
Creatinine (μmol/l)	91 (12.4)	72 (16.0)	−21 (−26, −16)	<0.001
Glucose (mmol/l)	6.2 (1.37)	7.0 (1.06)	1.1 (0.5, 1.8)	0.001
Data transformed prior to analysis:			Estimated ratio (CI):	
Platelets (10^9/l)	193 (147.4)	97 (80.3)	0.52 (0.39, 0.69)	<0.001
PCT[a] (fL)	0.17 (0.133) $n=66$	0.09 (0.086)	0.55 (0.41, 0.75)	<0.001
WCC[a] (10^9/l)	7.4 (2.04)	9.9 (2.98)	1.29 (1.15, 1.46)	<0.001
Lymphocytes (10^9/l)	3.81 (1.544) $n=65$	6.09 (2.293)	1.60 (1.34, 1.91)	<0.001
Monocytes (10^9/l)	0.28 (0.177) $n=65$	0.39 (0.365)	1.07 (1.01, 1.15)	0.030
Eosinophils (10^9/l)	0.62 (0.516) $n=65$	0.40 (0.298)	0.88 (0.80, 0.98)	0.017
AST[a] (IU/l)	33.9 (10.09) $n=68$	42.5 (24.86)	1.18 (1.01, 1.37)	0.032
ALP[a] (IU/l)	405 (140.0) $n=68$	1412 (605.6)	3.13 (2.36, 4.15)	<0.001
Calcium (mmol/l)	2.39 (0.164) $n=66$	2.53 (0.107)	1.04 (1.03, 1.06)	<0.001
Triglycerides (mmol/l)	0.31 (0.153) $n=68$	0.22 (0.089)	0.78 (0.64, 0.94)	0.011

[a] GGT = gamma glutamyl transferase; PCT = platelet hematocrit; WCC = white blood cell count; AST = aspartate aminotransferase; ALP = alkaline phosphatase.

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TABLE 3. Variation between methods of restraint in hematologic and serum biochemistry variables for brush-tailed rock-wallabies (*P. penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005. For normally distributed variables, coefficients represent differences in anesthetized from manually restrained values and are adjusted for other variables if they had a significant effect on each variable (season, age class, sex). For data transformed prior to analysis adjusted ratio of anesthetized values relative to manually restrained values is given.

	Crude mean (SD)			
Outcome variable	Manual restraint, $n=76$ unless stated	Anesthetized, $n=39$	Adjusted effect size	*P* value
Normally distributed data:			Estimated difference (CI):	
Hb[a] (g/dl)	14.9 (1.64)	12.6 (1.90)	−1.7 (−2.7, −0.7)	0.001
RCC[a] (10^{12}/l)	6.4 (0.71)	5.3 (0.77)	−0.6 (−1.0, −0.3)	0.001
PCV[a] (l/l)	0.45 (0.046)	0.36 (0.052)	−0.05 (−0.08, −0.02)	<0.001
Magnesium (mmol/l)	0.88 (0.121) $n=75$	0.75 (0.100)	−0.08 (−0.14, −0.02)	0.009
GGT[a] (IU/l)	13.1 (4.00)	10.8 (2.63)	−1.3 (−2.2, −0.3)	0.008
Protein (g/l)	66 (6.2)	54 (5.0)	−10 (−13, −6)	<0.001
Albumin (g/l)	39.4 (2.10) $n=77$	33.4 (2.12)	−5.2 (−6.8, −3.6)	<0.001
Globulin (g/l)	26.5 (5.69)	20.9 (4.95)	−4.0 (−5.9, −2.0)	<0.001
Creatinine (μmol/l)	87 (15.7)	74 (15.4)	−7 (−12, −2)	0.006
Cholesterol (mmol/l)	2.71 (0.393) $n=77$	2.37 (0.386)	−0.27 (−0.45, −0.09)	0.003
Data transformed prior to analysis:			Estimated ratio (CI):	
Platelets (10^9/l)	132 (134.9) $n=75$	195 (118.7)	1.52 (1.10, 2.10)	0.012
PCT[a] (fl)	0.11 (0.122) $n=75$	0.18 (0.106)	1.70 (1.24, 2.32)	0.001
Lymphocytes (10^9/l)	5.2 (2.18) $n=75$	4.0 (2.06)	0.77 (0.60, 1.00)	0.051
Calcium (mmol/l)	2.53 (0.094) $n=75$	2.29 (0.129)	0.92 (0.89, 0.95)	<0.001

[a] Hb = hemoglobin; RCC = red blood cell count; PCV = packed cell volume; GGT = gamma glutamyl transferase; PCT = platelet hematocrit.

Similar sex differences were noted for some variables in both the brush-tailed and allied rock-wallabies; for example, higher PCV and RCC values were found among males in both species (Spencer and Speare, 1992). In contrast, no sex differences were noted for hematologic variables in agile wallabies or eastern gray kangaroos (Presidente, 1978; Stirrat, 2003). Some of the differences observed between adult and

TABLE 4. Variation in hematologic and serum biochemistry variables for brush-tailed rock-wallabies (*P. penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005, between females with high lactation demands and those not lactating or with low lactation demands. For normally distributed variables, coefficients represent differences in values between nonlactating or low-level lactating females and those with high lactation demands and are adjusted for other variables if they had a significant effect on each variable (season and method of restraint). For data transformed prior to analysis adjusted ratio of low demand values relative to high demand values is given.

	Crude mean (SD)			
Outcome variable	High lactation demand, $n=12$	Low lactation demand/ not lactating, $n=24$ unless stated	Adjusted effect size	*P* value
Normally distributed data:			Estimated difference (CI):	
Hb[a] (g/dl)	12.6 (2.18)	14.0 (2.01) $n=26$	1.5 (0.8, 2.2)	<0.001
Data transformed prior to analysis:			Estimated ratio (CI):	
Lymphocytes (10^9/l)	4.5 (1.62)	3.5 (1.55)	0.58 (0.38, 0.87)	0.009
Eosinophils (10^9/l)	0.40 (0.350)	0.78 (0.508)	1.25 (1.10, 1.42)	0.001
Triglycerides (mmol/l)	0.43 (0.183)	0.29 (0.146) $n=27$	0.60 (0.43, 0.84)	0.003

[a] Hb = hemoglobin.

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TABLE 5. Variation in hematologic and serum biochemistry variables between trapping periods for brush-tailed rock-wallabies (*P. penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005. For normally distributed variables, coefficients represent differences in values between the stated trapping period and trapping period 1 and are adjusted for other variables if they had a significant effect on each variable (season, sex, and method of restraint). For data transformed prior to analysis the adjusted ratio relative to the trapping period 1 value is given.

Outcome variable	Estimated difference[a]				
	RCC[b] (10^{12}/l)	PCV[b] (l/l)	Phosphorus (mmol/l)	Creatinine (μmol/l)	Estimated ratio triglycerides[a]
Trapping period 2	0.53 (0.05, 1.01)	0.04 (0.01, 0.08)	−0.52 (−0.93, −0.10)	6.1 (1.5, 10.6)	0.74 (0.56, 0.99)
Trapping period 3	0.85 (0.37, 1.34)	0.07 (0.03, 0.10)	−0.84 (−1.28, −0.40)	21.0 (14.6, 27.5)	0.54 (0.39, 0.74)
Trapping period 4	0.94 (0.47, 1.42)	0.08 (0.05, 0.11)	−0.50 (−0.93, −0.06)	13.8 (7.2, 20.3)	0.57 (0.40, 0.81)

[a] Relative to trapping period 1.

[b] RCC = red blood cell count; PCV = packed cell volume.

subadult brush-tailed rock-wallabies were also identified between adult and juvenile tammar wallabies, including lower calcium, phosphorus, and glucose and higher protein and creatinine concentrations in the adult animals. The higher creatinine concentrations may reflect an increase in muscle mass with increasing age (Duncan et al., 1994). The higher eosinophil count seen in adult animals may be a reflection of increased exposure to parasites; this is consistent with the finding that adult brush-tailed rock-wallabies in this colony have significantly higher fecal egg counts compared to juveniles (Barnes et al., unpub. data).

Significantly lower values for many of the blood variables recorded in anesthetized, compared to manually restrained, brush-tailed rock-wallabies have been reported in other species (Wesson et al., 1979; Kuttner and Wiesner, 1987; Cross et al., 1988; Crooks et al., 2003). Under anesthesia there may be a backflow of erythrocytes to the spleen and extravasal fluid shift that effectively dilutes the blood (Kuttner and Wiesner, 1987); in addition manual restraint may result in greater handling stress causing splenic contraction that releases sequestered red cells into the circulation. However, the elevated platelet count and PCT are unexpected, and we cannot provide a physiologic explanation for these findings.

Nearly all variables showed significant variation between trapping periods, but patterns were not easily discernable. As the study was restricted to less than a year, it was not possible to determine whether these differences reflected seasonal variation. Differences may reflect the nutritional quality of available food, which was likely to have been lower during the cool, dry winter period. However, nutritional composition of herbage was not determined in this study.

Given the expense of captive breeding and reintroduction programs, it is important to monitor their outcomes closely. Hematologic variables such as RCC, PCV, and Hb have been positively associated with postrelease survival and overall longevity in the water vole (*Arvicola terres-*

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TABLE 6. Reference hematologic values for the brush-tailed rock-wallaby (*P. penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005.

Variable	Subgroup	Mean (SD)	Reference interval[a]	*n*
Hb[b] (g/dl)	Manual restraint	14.9 (1.64)	11.9–18.5	76
	Anesthetized	12.6 (1.90)	9.3–18.0	39
RCC[b] (10^{12}/l)	Manual restraint	6.4 (0.71)	4.7–7.5	76
	Anesthetized	5.3 (0.77)	3.9–7.3	39
PCV[b] (l/l)	Manual restraint	0.45 (0.046)	0.34–0.52	76
	Anesthetized	0.36 (0.052)	0.28–0.52	39
MCHC[b] (g/dl)		33.5 (2.36)	27.9–37.2	115
MCH[b] (pg)		23.4 (1.96)	19.0–27.1	115
MCV[b] (fl)		70 (3.1)	62–75	115
Platelets (10^9/l)	Adult, manual restraint	173 (159.1)	9–848	41
	Adult, anesthetized	225 (123.0)	61–618	26
	Subadult, manual restraint	83 (74.1)	20–334	34
	Subadult, anesthetized	135.92 (85.9)	20–371	13
MPV[b] (fl)		7.7 (0.67)	6.7–9.1	114
PCT[b] (fl)	Adult, manual restraint	0.15 (0.148)	0.01–0.70	40
	Adult, anesthetized	0.19 (0.105)	0.05–0.45	26
	Subadult, manual restraint	0.06 (0.053)	0.02–0.24	35
	Subadult, anesthetized	0.16 (0.111)	0.02–0.34	13
WCC[b] (10^9/l)	Adult	7.4 (2.04)	3.7–11.8	68
	Subadult	9.9 (2.98)	4.7–9.0	48
Neutrophils (10^9/l)		2.82 (1.236)	0.96–5.71	113
Lymphocytes (10^9/l)	Adult, manual restraint	4.19 (1.439)	2.05–7.92	40
	Adult, anesthetized	3.21 (1.542)	0.67–7.30	25
	Subadult, manual restraint	6.28 (2.366)	3.12–11.77	35
	Subadult, anesthetized	5.58 (2.087)	2.16–9.86	13
Monocytes (10^9/l)		0.33 (0.277)	0.00–1.22	113
Eosinophils (10^9/l)		0.52 (0.449)	0.00–1.75	113
Basophils (10^9/l)		0.04 (0.080)	0.00–0.34	113

[a] Central 0.95 fraction.

[b] Hb = hemoglobin; RCC = red blood cell count; PCV = packed cell volume; MCHC = mean corpuscular hemoglobin concentration; MCH = mean corpuscular hemoglobin; MCV = mean corpuscular volume; MPV = mean platelet volume; PCT = platelet hematocrit; WCC = white blood cell count.

tris) in one of the few studies where detailed follow-up monitoring has been undertaken after reintroduction (Mathews et al., 2006). The data from this study show that there are some differences in hematologic variables among species of the genus *Petrogale* and other macropodids. This highlights the importance of establishing reference ranges for individual species if blood variables are to be used to monitor population condition and/or health of individuals. Differences in variables between sexes, age classes, and methods of restraint may be significant, and interpretation is further complicated by the fact that such differences are not consistent between macropodid species. Used in combination with other indicators of condition, data gathered during this study will be valuable for long-term postrelease health monitoring of brush-tailed rock-wallabies in translocations that are currently being planned.

ACKNOWLEDGMENTS

We would like to thank the Moore family for access to their property during the course of the study and R. Laws and G. Maggs from

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TABLE 7. Reference serum biochemistry values for the brush-tailed rock-wallaby (*P. penicillata*) at Hurdle Creek, Queensland, November 2004–August 2005.

Variable	Subgroup	Mean (SD)	Reference interval[a]	*n*
Calcium (mmol/l)		2.45 (0.157)	2.08–2.68	114
Magnesium (mmol/l)		0.83 (0.130)	0.62–1.21	115
Phosphorus (mmol/l)	Adult	1.90 (0.496)	0.75–3.26	58
	Subadult	2.27 (0.605)	1.04–3.67	47
AST[b] (IU/l)	Adult	33.9 (10.09)	20.7–61.2	67
	Subadult	42.5 (24.86)	19.9–64.8	48
ALP[b] (IU/l)	Adult	405 (140.0)	196–827	68
	Subadult	1,411 (605.6)	465–2775	48
CPK[b] (IU/l)	Female	812 (524.6)	293–2723	64
	Male	1,335 (1,694.5)	303–9503	51
GGT[b] (IU/l)	Adult, manual restraint	11.4 (3.36)	6.1–20.0	41
	Adult, anesthetized	10.12 (1.99)	7.0–14.0	26
	Subadult, manual restraint	15.09 (3.79)	9.0–27.0	35
	Subadult, anesthetized	12.08 (3.30)	6.0–18.0	13
Protein (g/l)	Manual restraint	66 (6.2)	52–75	76
	Anesthetized	54 (5.0)	42–64	39
Albumin (g/l)	Manual restraint	39.4 (2.10)	34.9–43.0	77
	Anesthetized	33.4 (2.12)	30.0–38.0	39
Globulin (g/l)	Adult, manual restraint	29.9 (4.48)	15.3–37.0	41
	Adult, anesthetized	23.4 (3.16)	17.0–28.0	26
	Subadult, manual restraint	22.43 (4.11)	14.0–30.0	35
	Subadult, anesthetized	16.08 (4.31)	9.0–25.0	13
Albumin:Globulin		1.62 (0.462)	1.07–2.76	115
Urea (mmol/l)		10.0 (1.94)	4.9–13.3	115
Creatinine (μmol/l)	Adult	91 (12.4)	65–125	67
	Subadult	72 (16.0)	38–104	48
Cholesterol (mmol/l)	Manual restraint	2.71 (0.393)	2.10–3.71	77
	Anesthetized	2.37 (0.386)	1.70–3.60	39
Triglycerides (mmol/l)	Adult	0.31 (0.153)	0.10–0.68	68
	Subadult	0.22 (0.089)	0.10–0.40	48
Total bilirubin (μmol/l)	Female	2.88 (1.200)	0.63–6.59	64
	Male	3.42 (1.198)	0.63–6.31	51
Glucose (mmol/l)	Adult	6.2 (1.37)	3.4–9.5	67
	Subadult	7.0 (1.06)	4.7–9.0	48

[a] Central 0.95 fraction.

[b] AST = aspartate aminotransferase; ALP = alkaline phosphatase; CPK = creatinine phosphokinase; GGT = gamma glutamyl transferase.

Queensland Parks and Wildlife Service for their enormous support with fieldwork. We are grateful to all who have worked and volunteered at the field site, in particular D. Sigg, who established the initial program and provided invaluable training. We also thank J. Morton for his input and advice in data analysis. This work was approved by the University of Queensland Animal Ethics Committee (Approval number ZOO/ENT/229/04/ARC) and Queensland Parks and Wildlife Service (Scientific Purposes Permit WISP 02502704). This project was funded by a University of Queensland Early Career Research Grant to G. Coleman, an Australian Research Council grant to A. Goldizen, P. Jarman, and G. Lundie-Jenkins, a Wildlife Disease Association (Australasian Section) Research Grant to T. Barnes, and a contribution from the Australian Wildlife Health Network. T. Barnes was in receipt of an International Post-Graduate Research Scholarship funded by the Australian Government.

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Received for publication 17 June 2007.

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