HEMATOLOGY, PLASMA BIOCHEMISTRY, AND URINALYSIS OF FREE-RANGING GREY-HEADED FLYING FOXES (PTEROPUS POLIOCEPHALUS) IN AUSTRALIA


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Abstract: The grey-headed flying fox (Pteropus poliocephalus) is a species endemic to coastal eastern Australia. This study presents a comprehensive set of biochemistry, hematology, and urinalysis biomarkers from which reference values were derived. Blood samples collected from free-ranging P. poliocephalus were submitted for hematology (n = 140) and plasma biochemistry (n = 161) and urine for urinalysis (n = 95). The values for P. poliocephalus were broadly consistent with those values published for other Australian Pteropus species. Statistically significant within-species age and sex effects were observed: adult P. poliocephalus had higher mean corpuscular volume, mean corpuscular hemoglobin, urea, creatinine, bilirubin, alanine transferase (ALT), protein, globulin, urinary specific gravity, and urinary ketones, whereas subadults had higher mean red blood cell, white blood cell (WBC), lymphocyte, and monocyte counts, and juveniles had higher mean neutrophil count and alkaline phosphatase; male P. poliocephalus had higher mean reticulocyte count, alanine transferase, glucose, and urinary ketones, whereas females had higher mean WBC, lymphocyte, and monocyte counts. The findings inform both clinical and research scenarios for P. poliocephalus in captivity or rehabilitation and for health assessments of free-living populations.

Key words: grey-headed flying fox, hematology, plasma biochemistry, Pteropus poliocephalus, reference values, urinalysis.

INTRODUCTION

The grey-headed flying fox (Pteropus poliocephalus) is a species of bat endemic to coastal eastern Australia. The species is currently listed as vulnerable on the International Union for Conservation of Nature Red List and is protected by the Australian government Environment Protection and Biodiversity Conservation Act because of declining populations. They are reported to occur from Rockhampton in central Queensland, south through the conjoined states of New South Wales and Victoria, to Adelaide in South Australia. However, a colony was recently observed in Ingham in north Queensland (L. Huth and D. Melville, pers. comm.), hundreds of kilometers north of the reported range, indicating that the species’ range is dynamic at the margins. The species is nectarivorous and frugivorous, and is recognized as an important pollinator and seed disperser for many species of Australian native flora. It is nomadic, with individuals reported to travel up to 50 km a night while foraging; by day, they roost in arboreal colonies frequently comprising several thousand individuals. In the northern part of their range they frequently co-roost with Pteropus alecto (black flying fox) and Pteropus scapulatus (little red flying fox), and with Pteropus...
conspicillatus (spectacled flying fox) at the northern extreme.3,5,6 Although hematology and biochemistry values for various Pteropus species have been published previously,11,12,14,16,20,23,33 many are incomplete, and none include concurrent urinalysis data that can provide an additional insight to the health status of the study population. Such biomarker profiles are fundamental indicators of both individual animal health and population health. They provide valuable information with respect to disease, trauma, and energy status that, in turn, can reflect local environmental conditions and habitat quality. The establishment of reference values derived from free-living populations is especially important for species with a threatened status, because they provide useful information for those involved in the care and rehabilitation of captive animals, as well as a benchmark for researchers involved in health surveillance studies of wild populations. In the case of P. poliocephalus, reference values could be particularly valuable during increasingly frequent extreme summer temperature events that cause high morbidity and mortality, resulting in large numbers of flying foxes requiring veterinary care and rehabilitation.31 More broadly, interest in the physiology of pteropid bats has increased since their identification as reservoirs for zoonotic viruses such as Hendra and Nipah viruses,10 and the availability of comprehensive biomarker profiles for these species could contribute to a better understanding of any physiologic and immunologic “cause or effect” associations with such infections.

The study provides a comprehensive set of hematology, biochemistry, and urinalysis values for P. poliocephalus, as well as cohort-specific values of sex and age and derived reference values for key variables.

MATERIALS AND METHODS

Animals

Blood and urine samples were collected from P. poliocephalus captured at a roost in the Royal Botanic Garden, Sydney, New South Wales, Australia, over 5 days in May 2012. Additional unpaired urine samples were collected in late April 2012. Animals were captured primarily to facilitate assessment before a planned dispersal of the roost.28 Capture was conducted under the New South Wales Office of Environment and Heritage Animal Ethics Committee permit (110620-05) and scientific license (s100268); anesthesia and sample collection were conducted under permit (120206-02) and scientific license (s100537). Equal numbers of samples were sought from each age cohort of juvenile, subadult, and adult as defined below.

Methodology

Bats were captured in mist nets (12 m wide × 5 m deep) hoisted between 15-m aluminum masts, as they returned predawn to roost between 4 and 6 AM. They were removed from the net immediately on capture, placed in individual cotton bags (pillow cases), and allowed to hang calmly before processing in order of capture between 7 AM and 12 noon.6 Under veterinary supervision, each bat was anesthetized using isoflurane in oxygen by facemask.15 Bodyweight (g), forearm length (mm), body condition score (based on pectoral muscle mass, with 1 = poor, 2 = less than fair, 3 = fair, 4 = greater than fair, and 5 = good), sex (male, female), age (juvenile, subadult, or adult, based on morphometrics and sexual maturity), reproductive status (palpably pregnant, lactating),7 and any apparent physical injuries or medical conditions were recorded. A blood sample of typically 2.8 ml, but always less than 1% of total individual body weight, was collected from the marginal wing (cephalic) vein into a 1.3-ml lithium heparin blood tube (Sarstedt AG & Co, Mawson Lakes, South Australia 5095, Australia) and a 0.5-ml ethylenediaminetetraacetic acid tube (Becton Dickson, Macquarie University Research Park, North Ryde, New South Wales 2113, Australia), and 1 ml into a serum tube (Becton Dickson). Blood smears were made at the time of collection and air dried; blood glucose concentration was also measured at the time of collection using an Accu-Chek Performa™ glucometer (Roche Diagnostics, North Ryde, New South Wales 2113, Australia). Sample processing typically lagged sample collection by 1–2 hr, with samples held on ice bricks for a maximum of 3 hr pending processing. Care was taken to ensure that samples stored on ice bricks were not in direct contact with the bricks to avoid cell lysis. A urine sample was sought from each animal as free-catch after micturition or transabdominal bladder expression during anesthesia. Urine was collected into a sterile container, stored on ice bricks, and tested within 4 hr of collection. Postanesthesia, each bat was marked with a nontoxic acrylic nail paint on the right hindlimb claws to avoid resampling if the bat was recaptured; each was then monitored until conscious, returned to its pillowcase, and allowed to recover for at least another 30 min before being
released at the roost site. No mortalities were associated with capture, sampling, or release.

Laboratory analyses

Hematology and clinical biochemistry: Blood samples were centrifuged for 10 min at 1,000 g within 3 hr of collection. Plasma and serum yield was collected and stored on ice bricks or refrigerated at 5°C pending shipment to the laboratory. Serum samples were shipped on ice bricks to the Elizabeth Macarthur Agriculture Institute (Narran, New South Wales, Australia) the afternoon of capture and screened to determine Hendra virus RNA status before further testing. Hendra virus was not detected in any sample, so all plasma and whole blood samples were shipped on ice bricks the following morning (Veterinary Pathology Diagnostic Service, University of Sydney, Sydney School of Veterinary Science) for hematologic and biochemical analyses, which were completed within 24 hr of sample collection. Complete blood counts were conducted using a Sysmex XT-2000iV Automated Hematology System (IDEXX Laboratories, Rydalmere, New South Wales 2116, Australia), and biochemical analyses were conducted using a Konelab 20 XTi Clinical Chemistry Analyzer System (Thermo Fisher Scientific Australia, Scoresby, Victoria 3179, Australia). All values were reported in Système International units.

Urinalysis: Urine specific gravity (USG) was measured using a handheld clinical refractometer. Urinary nitrates, ketones, protein, glucose (all reported as mg/dl), urine pH, blood (erythrocytes/μl), and leukocytes (leukocytes/μl) were measured using Urispec Plus reagent test strips (Henry Schein Australia, Waterloo, New South Wales 2017, Australia). Samples were ascribed the highest semiquantitative value for the corresponding color reaction of the test strip or intensity upon visual assessment. Where the collected urine volume was inadequate for a complete urinalysis, only USG was measured. Urine concentration was classified as hyposthenuric (USG < 1.008), isosthenuric (USG 1.008–1.012), minimally/weakly concentrated (USG > 1.012–1.034), or hypersthenuric (USG > 1.035) on the basis of published criteria for domestic species. Sediment analysis was not undertaken.

Statistical analyses

Generalized linear mixed models (GLMMs) were used to analyze the data by restricted maximum likelihood (REML) in GenStat (2016). The binomial distribution with the logit link function was adopted for the binary data and the normal distribution with the identity link function for the continuous variables. Residual plots were used to check the assumptions of homogeneous variances and low skewness, and the log transformation was applied as needed. Type III testing (backward elimination of terms from the full fixed model) was used in model selection. The primary fixed effects were sex (male, female), age (adult, subadult, or juvenile), and their interaction (sex*age). Additionally, body condition score was screened for any effect on the measured variables. The random effects in the GLMMs were the sampling dates and animals within these, and were restricted to avoid negative estimated variance components.

Given evident age and sex effects in some variables, reference values were calculated as the 95% confidence interval for each age/sex combination using the individual standard deviations from each group. All available data were used to quantify the distribution of each variable; for urinalysis variables, the inclusion of unpaired data ensured that information on data distribution was maximized. No apparent outliers were present; hence, the expectation is that about 95% of the population’s values will fall within the tabulated reference values.

Statistical significance was determined at the 5% (P < 0.05) level.

RESULTS

Blood samples were collected from 161 bats (60 adults, 44 subadults, 57 juveniles), with 140 blood samples submitted for hematology and 161 plasma samples submitted for plasma biochemistry. Clotting of whole blood samples precluded paired samples for hematology and biochemical panels for some bats (n = 21), and some plasma samples were of insufficient volume to conduct the full panel of biochemical tests (n = 9). Urine samples were collected from 95 bats, of which 76 had adequate volume for complete urinalysis, including 30 with paired blood samples, and 19 had volume sufficient for partial urinalysis, including 17 with paired blood samples.

The reference values for key hematologic, biochemical, and urinary variables for age and sex class categories are presented (Table 1). Urinary glucose, urobilinogen, and bilirubin had uniformly zero values; urinary blood, protein, leukocytes, and nitrites were assessed predominantly as zero, with a small percentage of samples yielding nonzero values for one or more variables.
Table 1. Mean and reference values (based on 95% confidence intervals for the study population) for hematology, biochemistry, and urinalysis stratified for age and sex in free-ranging grey-headed flying fox (*Pteropus poliocephalus*).\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>Adult female</th>
<th>Adult male</th>
<th>Subadult female</th>
<th>Subadult male</th>
<th>Juvenile female</th>
<th>Juvenile male</th>
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<tr>
<td><strong>Hematology</strong></td>
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<tr>
<td>Hb (g/L)</td>
<td>159.2 (141–177)</td>
<td>149.5 (137–167)</td>
<td>156 (149–165)</td>
<td>149.9 (142–152)</td>
<td>151.2 (147–157)</td>
<td>149.9 (142–152)</td>
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<tr>
<td>RBC (3 x 10(^{12})/L)</td>
<td>9.67 (8.4–10.9)</td>
<td>8.98 (8.1–10.1)</td>
<td>9.82 (8.6–11.1)</td>
<td>9.45 (8.6–10.8)</td>
<td>9.12 (8.4–10.5)</td>
<td>9.43 (8.6–10.8)</td>
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<tr>
<td>Hct</td>
<td>0.38 (0.34–0.42)</td>
<td>0.36 (0.3–0.4)</td>
<td>0.37 (0.34–0.4)</td>
<td>0.36 (0.3–0.4)</td>
<td>0.36 (0.3–0.4)</td>
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<td>MCV (fL)</td>
<td>39.23 (34–44)</td>
<td>39.67 (35–45)</td>
<td>37.82 (34–42)</td>
<td>38.01 (34–42)</td>
<td>38.01 (34–42)</td>
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<td>MCH (pg)</td>
<td>16.51 (14.7–18.3)</td>
<td>16.67 (14.8–18.6)</td>
<td>15.91 (14.5–17.4)</td>
<td>15.88 (14.3–17.4)</td>
<td>15.88 (14.3–17.4)</td>
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<tr>
<td>MCHC (g/L)</td>
<td>420.6 (408–433)</td>
<td>420.8 (403–438)</td>
<td>420.5 (409–432)</td>
<td>417.8 (405–430)</td>
<td>418.1 (401–435)</td>
<td>417.1 (402–432)</td>
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<tr>
<td>Platelets (3 x 10(^9)/L)</td>
<td>482.4 (271–693)</td>
<td>529.8 (320–740)</td>
<td>511.4 (270–753)</td>
<td>524 (288–760)</td>
<td>536.3 (225–848)</td>
<td>551.3 (287–816)</td>
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<tr>
<td><strong>Biochemistry</strong></td>
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<td>Urea (mmol/L)</td>
<td>1.73 (0.7–3.7)</td>
<td>1.63 (0.32–2.4)</td>
<td>1.35 (0.62–2.4)</td>
<td>1.05 (0.62–2.4)</td>
<td>1.03 (0.62–2.4)</td>
<td>1.07 (0.62–2.4)</td>
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<tr>
<td>Creatinine (l mol/L)</td>
<td>4.79 (3.1–6.3)</td>
<td>4.79 (3.1–6.3)</td>
<td>4.79 (3.1–6.3)</td>
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<td>T. bilirubin (l mol/L)</td>
<td>2.33 (1.33–3.3)</td>
<td>2.33 (1.33–3.3)</td>
<td>2.33 (1.33–3.3)</td>
<td>2.33 (1.33–3.3)</td>
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<tr>
<td>AST (U/L)</td>
<td>72.19 (33–111)</td>
<td>74.13 (23–126)</td>
<td>71.31 (27–115)</td>
<td>70.43 (13–128)</td>
<td>74.11 (32–117)</td>
<td>87.63 (35–140)</td>
</tr>
<tr>
<td>ALT (U/L)</td>
<td>12.68 (0.0–28)</td>
<td>16.7 (0.0–42)</td>
<td>10 (0.0–24)</td>
<td>14.89 (0.0–28)</td>
<td>9.85 (0.0–20)</td>
<td>12.74 (0.0–28)</td>
</tr>
<tr>
<td>ALP (U/L)</td>
<td>648 (190–1106)</td>
<td>561 (90–1072)</td>
<td>1,166 (205–2,127)</td>
<td>1,509 (166–2,350)</td>
<td>1,539 (166–2,350)</td>
<td>1,539 (166–2,350)</td>
</tr>
<tr>
<td>Protein (g/L)</td>
<td>52.49 (29–69)</td>
<td>54.31 (65–84)</td>
<td>54.31 (65–84)</td>
<td>41.06 (21–42)</td>
<td>41.06 (21–42)</td>
<td>41.06 (21–42)</td>
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<tr>
<td>Globulin (g/L)</td>
<td>37.27 (29–48)</td>
<td>36.25 (34–47)</td>
<td>36.25 (34–47)</td>
<td>29.91 (19–40)</td>
<td>29.91 (19–40)</td>
<td>29.91 (19–40)</td>
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<tr>
<td>Uric acid (mg/dL)</td>
<td>0.18 (0.07–0.33)</td>
<td>0.21 (0.13–0.33)</td>
<td>0.21 (0.13–0.33)</td>
<td>0.21 (0.13–0.33)</td>
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<td><strong>Urinalysis</strong></td>
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<tr>
<td>USG</td>
<td>1.019 (1.01–1.02)</td>
<td>1.019 (1.01–1.02)</td>
<td>1.019 (1.01–1.02)</td>
<td>1.019 (1.01–1.02)</td>
<td>1.019 (1.01–1.02)</td>
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<tr>
<td>pH</td>
<td>6.87 (6.5–7.4)</td>
<td>6.87 (6.5–7.4)</td>
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<td>6.87 (6.5–7.4)</td>
<td>6.87 (6.5–7.4)</td>
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<td>Ketones</td>
<td>106.5 (0.0–3.71)</td>
<td>106.5 (0.0–3.71)</td>
<td>106.5 (0.0–3.71)</td>
<td>106.5 (0.0–3.71)</td>
<td>106.5 (0.0–3.71)</td>
<td>106.5 (0.0–3.71)</td>
</tr>
</tbody>
</table>

\(^a\) Hb indicates hemoglobin; RBC, red blood cell; Hct, hematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; WBC, white blood cell; Ret, reticulocyte; T. bilirubin, total bilirubin; AST, aspartate aminotransferase; ALT, alanine transferase; USG, urine specific gravity; ALP, alkaline phosphatase; CK, creatinine kinase.

\(^b\) Urine was classified as hyposthenuric (USG < 1.008), isosthenuric (USG = 1.008–1.012), minimally/weakly concentrated (USG > 1.012–1.034), or hypersthenuric (USG > 1.035).
Comparative urine concentration by age class is shown (Fig. 1). The main effects of age and of sex on hematologic, biochemical, and urinary variables are presented below.

Compared with the other age categories, adult bats had significantly higher mean corpuscular volume, mean corpuscular hemoglobin, urea, total bilirubin, protein, globulin (all $P < 0.001$), creatinine ($P = 0.041$), alanine transferase (ALT; $P = 0.043$), USG ($P = 0.045$), and urinary ketones ($P = 0.005$); subadult bats had significantly higher mean red blood cell (RBC; $P = 0.013$), white blood cell (WBC), lymphocyte, and monocyte counts (all $P < 0.001$); and juvenile bats had significantly higher mean neutrophil count and alkaline phosphatase (ALP; both $P < 0.001$). Female bats yielded significantly higher WBC ($P = 0.009$), lymphocyte ($P < 0.001$), and monocyte counts ($P = 0.005$) than male bats, whereas male bats had significantly higher reticulocyte counts ($P = 0.001$), ALT ($P = 0.003$), glucose ($P = 0.043$), and urinary ketones ($P < 0.001$) than female bats. With sex and age interactions, adult and subadult female bats had significantly higher hemoglobin (Hb), RBC, and hematocrit (Hct) than their male counterparts, but the converse was reported for (Hb), RBC, and hematocrit (Hct) than their male counterparts, but the converse was reported for juvenile and subadult male bats had significantly higher total bilirubin, protein, globulin (all $P < 0.001$). Female bats associated with these more clinically-relevant urine concentration categories ($p = 0.195$).

Of the morphometric variables, mean weight, mean forearm, and mean weight–forearm ratio differed significantly with age ($P < 0.001$). Adult 746 g, subadult 631 g, juvenile 519 g; $P < 0.001$, adult 162.1 mm, subadult 154.1 mm, juvenile 147.2 mm; $P < 0.001$, adult 4.6, subadult 4.1, juvenile 3.46, respectively). Similarly, mean weight and mean weight–forearm ratio differed significantly with sex ($P < 0.001$). Males 653 g, females 605 g; $P < 0.001$, males 4.19, females 3.92, respectively). Bats with a “good” body condition score had significantly higher Hb (158 vs 149), RBC (9.72 vs 9.35), ALP (1,228 vs 976), and Hct (0.376 vs 0.357) than those with a “poor” body condition score.

**DISCUSSION**

Although hematologic and biochemical values for free-ranging *Pteropus poliocephalus* have previously been reported, this study reports a comprehensive set of values from a discrete population at a point in time and includes urinalysis values. All bats were assessed to be clinically healthy by physical examination by experienced veterinarians; thus, the data derived from the sample provides a sound basis for calculation of valid reference values. It has been reported that inhalant anesthetic can affect hematologic and biochemistry values; however, the low concentration of isoflurane and the short duration of anesthesia (2–5 min) in this study minimizes this potential effect. This contention is further supported by the broad agreement between the findings of this study and those reported by various authors for various *Pteropus* species globally. Additionally, clinicians and others utilizing these data will likely be taking samples from similarly anesthetized animals. More broadly, the use of inhalation anesthetic ensures that essential animal welfare and human biosafety considerations can be met.

The paper presents derived reference values reflecting 95% confidence intervals, as well as probability levels and means for variables that differ significantly across age and sex cohorts. The former is useful in assessing individual or population health, and for interspecies comparisons; the latter is informative with respect to population variability. Sex-specific seasonal changes for *P. poliocephalus* have been previously demonstrated, highlighting the difference in timing of maximal reproductive effort between sexes. This study focused on animals sampled in May, when females are in early gestation and males postmating; previous studies of free-ranging *P. alecto* with a synchronous life cycle to *P. poliocephalus* suggest this time period is the least physiologically demanding interval during the year. Thus, it is not surprising that all values largely overlap between the sexes. The identified significant differences between males and females are unlikely to represent clinical differences and more likely reflect lifecycle physiologic changes. For example, the higher total white cell count (in particular, the higher lymphocyte count) in females is plausibly associated with early pregnancy, and the higher ALT and glucose in males may reflect physiologic recovery after the mating season. The high urinary ketone concentration in male *P. poliocephalus* is consistent with that reported previously in male *P. alecto* and is unlikely to reflect underlying pathology. In a clinical scenario, interpretation of ketonuria in male Australian *Pteropus* bats should be made in the context of other clinical findings, and putatively considered a normal finding in the absence of evident clinical disease. With respect to age, the reference values also largely overlap between age classes with a few exceptions. It is
well established that elevated ALP, as seen in the subadults and juveniles in this study, occurs in animals still undergoing skeletal growth. Interestsingly, “high” ALP values compared with other mammalian species have been reported in multiple Pteropus species, and warrant further investigation. In other animal species, elevated ALP has been associated with elevated cortisol concentrations, but the latter is inconsistent with the generally lower serum cortisol concentrations reported in P. poliocephalus and, indeed, in all Australian Pteropus species at this time of year. Measuring the specific concentrations of cortisol-induced isoforms of ALP was beyond the scope of this study. The higher leukocyte counts in juveniles and subadults is consistent with the published findings in captive Pteropus hypomelanus (variable or island flying fox) and comparable to studies in other mammals and reflects a maturation of the immune system. The higher plasma protein, urea, creatinine and bilirubin, and urinary ketones and specific gravity in adults plausibly reflect changing food resources and increased physiologic demand of foraging as animals mature. 

The derived reference values are broadly consistent with those of other Pteropus species. Hematologic and biochemistry values for two other free-living Australian Pteropus species (P. alecto and P. conspicillatus) have been reported, enabling interspecies comparisons. In this study, P. poliocephalus mean erythrocyte values were generally lower than those of P. alecto and P. conspicillatus for the same time of year, as were body condition scores, suggesting that the lower mean erythrocyte

![Figure 1.](https://bioone.org/journals/Journal-of-Zoo-and-Wildlife-Medicine)
values may be reflecting suboptimal nutrition in the population at the time of sampling. The higher mean protein, urea and creatinine values in *P. poliocephalus* could also reflect suboptimal nutrition and muscle catabolism. However, the differences are marginal and unlikely to indicate an important clinical effect given that creatinine kinase, bilirubin, and all liver enzymes are consistent with normal values of other Australian species. Alternatively, the higher mean protein, urea, and creatinine values could reflect the reported higher proteinaceous diet of *P. poliocephalus* compared with *P. alecto* and *P. conspicillatus*.2,27

The study has several limitations. Spatially, the sample was drawn from a single population; however, because *P. poliocephalus* is a highly mobile species,26 it is contended that that the sample can be considered broadly representative of the total species population, notwithstanding the potential for some influence of local environment and food source. Temporally, the sample is more limited, and the identified minor variation in several variables may reflect temporary physiologic effects associated with life cycle stage. Conversely, the cross-sectional design may have precluded identification of other associations or interactions temporally associated with life cycle stage: for example, the seasonal variation in urinary pH between males and females reported in a longitudinal study of *P. alecto*.19 Although 50% of urine samples were unpaired, the proximate timing of collection of these additional samples and the ability of GLMM analysis to accommodate missing data make their inclusion both epidemiologically and statistically robust. Finally, with the exception of ketones, where strong correlation was present,19 urinary dipstick results have not been validated by analytical methods in *Pteropus* species; thus, their accuracy cannot be assured. However, because dipsticks are routinely used in a clinical setting, this population-derived data provide a relevant clinical reference. In terms of better understanding the physiologic basis for some variable values, analytical validation would undoubtedly be advantageous but was beyond the scope of this study.

**CONCLUSIONS**

The study provides a complete set of biochemical, hematologic, and urinary biomarker values for *P. poliocephalus*, including age- and sex-specific values that expand and strengthen currently available information for the species. Additionally, it presents derived reference values for key biomarker variables. Biomarker values for *P. poliocephalus* were broadly consistent with those published for other Australian *Pteropus* species. Observed sex differences are unlikely to represent clinical differences and more likely reflect lifecycle physiologic changes at the time of sampling. Observed age differences likely reflect physical and physiologic immaturity, although some could plausibly reflect food and foraging differences. The high ALP values, high ketone values of males, and low USG values in *P. poliocephalus* are consistent with reports of other species and warrant further targeted investigation to establish the physiologic basis. The findings are of value to both clinical and research scenarios for *P. poliocephalus* populations in captivity, for individual animals in rehabilitation, and for population health assessments of free-living populations.

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