Running Title: Serum biochemistry of Sunda pangolins

Title: SERUM BIOCHEMISTRY AND SELECT MINERAL PARAMETERS OF PRE-RELEASE SUNDA PANGOLINS (*MANIS JAVANICA*) FOLLOWING REHABILITATION IN VIETNAM

Authors: Jennifer H. Yu, DVM, MS, Ngoc Duyen Huong Nguyen, BSc, Hai Kim Lam, BSc, Jessica Jimerson, LVT, Lee-Ann C. Hayek, PhD, Bonnie L. Raphael, DVM, Dipl. ACZM, Van Thai Nguyen, and Marc T. Valitutto, VMD

Corresponding Author: Jennifer H. Yu, Tel: +1 408-410-5401, E-mail: jennhyu@gmail.com

Affiliations:
From the Global Health Program, Smithsonian's National Zoological Park and Conservation Biology Institute, 3001 Connecticut Ave NW, Washington, DC, 20008, USA (Yu, Raphael, Valitutto); Save Vietnam's Wildlife, Cuc Phuong National Park, Nho Quan, Ninh Binh Province 432857, Vietnam (Nguyen, Lam, Jimerson, Nguyen); National Museum of Natural History, Smithsonian Institution, Mathematics and Statistics, MRC-121, Washington DC 20560, USA (Hayek); Wildlife Conservation Society, 2300 Southern Boulevard, New York, NY, 10460, USA (Raphael). Present addresses: Jimerson: Endangered Primate Rescue Center, Cuc Phuong National Park, Nho Quan, Ninh Binh Province 432857, Vietnam; Valitutto: EcoHealth Alliance, 520 Eighth Avenue Suite 1200, New York NY, 10018, USA.

ABSTRACT

Native to Southeast Asia, the Sunda pangolin (*Manis javanica*) is critically endangered largely due to poorly regulated wildlife trade, consumptive practices, and use in traditional Chinese medicine. Efforts to rescue and rehabilitate animals confiscated from the illegal trade are complicated by a general lack of knowledge surrounding the normal health and disease processes unique to the species. To provide clinical reference intervals for normal health states of Sunda pangolins, biochemical parameters were determined from rescued individuals in Vietnam that had undergone a 14-day observation period and met a set of criteria for release back into the wild. Blood samples were collected from 42 apparently healthy Sunda pangolins while anesthetized or awake. Packed cell volume (PCV) and total solids (TS) were determined manually, while serum biochemistry values were determined in-house using a benchtop analyzer. Additional biochemical and mineral parameters not included in the primary panel were determined from a subset of ten pangolins through an external diagnostic laboratory. Overall reference intervals were calculated for PCV and TS (n = 29), and standard serum biochemistry parameters (n = 42). Females and males demonstrated significant variation with respect to body mass, potassium (K+), and phosphorus (PHOS), while age was a significant source of variation in alkaline phosphatase (ALP). Seasonal variation in glucose (GLU), creatinine (CRE), total proteins (TP), sodium (Na), calcium (Ca), and K+ was also observed. Comparisons between anesthetized and awake pangolins demonstrated significant variation in GLU, CRE, and K+. The parameters determined in this study can serve as a clinical reference for ex-situ Sunda pangolin conservation efforts. In the context of wildlife rehabilitation, serial bloodwork allows for continued monitoring of patient health and should inform decision-making regarding release readiness and timing.

INTRODUCTION

Sunda pangolins (*Manis javanica*) are one of eight extant species of scaly anteaters (Pholidota: Manidae) that are currently under threat of extinction due to increasingly unsustainable harvest for consumption, international trade in skins, and cultural uses like traditional Chinese medicine.[6,19,50] While pangolins are protected under Appendix I of the Convention on International Trade in Endangered Speecies (CITES), the persistence of international trafficking and escalating demand have accelerated the decline of all eight species, with those endemic to Asia particularly at risk.[7,19–20,50] Between 1977 and 2012, over 500,000 Asian pangolins are estimated to have been traded internationally based on CITES data (although this underestimates the suspected true volume of unreported trade), with Sunda pangolins comprising approximately 87% of this trade.[7]

In-country conservation initiatives like Save Vietnam's Wildlife (SVW) are invaluable resources for the rescue and rehabilitation of pangolins that are confiscated from the illegal trade.[21,49] However, rehabilitation efforts are often hampered by challenges stemming from their specialized ecology. Sunda pangolins are nocturnal, semi-fossorial, semi-arboreal, and obligate myrmecophages, conditions which can be difficult to replicate in captivity. The challenges of meeting their ecological needs contributes to the species' high susceptibility to stress under human care, and impedes our ability to collect data on their basic health needs.[12,36,44–45,49] The success of in-situ and ex-situ pangolin conservation measures necessitates an understanding of the species' normal physiology and prompt recognition of disease states.[36,45] Additionally, pangolins are often in debilitated condition by the time of confiscation, due to high stress from prolonged periods of travel and captivity, trauma from mishandling or force-feeding inappropriate diets, unfamiliar environments and climates, and exposure to new pathogens.[45,49]

Once the animals are transferred to rehabilitation facilities, readily accessible patient-side diagnostics are essential for timely medical care.

To this end, serum biochemical analysis is a basic yet critical foundation of a clinician's diagnostic process, enabling inference of patient health status, detection of underlying pathologies and disease processes, and interpretation of the functional state of internal organs.[42] In the context of wildlife rehabilitation, pre-release biochemical evaluation for assessment of health should factor into considerations of individual readiness for release to ensure the best possible chance of survival in the wild.[18,29,42–43,47] The establishment of normal biochemical parameters for Sunda pangolins may contribute to increasing successful clinical, rehabilitation, and conservation outcomes. In this study, serum biochemistry reference intervals were developed from a population of apparently healthy Sunda pangolins that had been confiscated from illegal trade, undergone a period of rehabilitation, and were clinically deemed ready for release.

MATERIALS AND METHODS

Study Sites:

Animal sampling occurred at SVW rehabilitation centers situated in Cuc Phuong and Pu Mat National Parks, in Ninh Binh and Nghe An provinces respectively, located near the northernmost extent of the species' known range in Vietnam.[6,12] Samples were collected from December 2018 through July 2019, encompassing both a cool, dry winter and a warm, humid summer season. Climate at both sites is temperate to subtropical, with mean temperatures ranging from 9 ℃–32 ℃.[3,15,48]

Animals and Husbandry:

The study population consisted of individuals that had been rescued or confiscated from trade by Vietnamese authorities, transferred to SVW facilities, and had undergone a period of quarantine and rehabilitation appropriate for their presenting condition at intake. Duration of the rehabilitation period ranged from 20–194 days (mean 65.14 days, SD 46.79 days), with the exception of two long-term non-releasable residents of the center. The original sources and time in human captivity prior to intake were unknown.

Study pangolins were housed individually in 2 m x 2.5 m x 2 m enclosures with concrete substrate and wire mesh ceiling. In each enclosure, two wooden bed-boxes placed inside concrete dens were provided: one placed at ground-level, and the second 0.7–1.5 m from the ground, accessible by a branch. Bedding consisted of fabric sheets, towels, or blankets, which were changed daily. Furnishings included tree branches to allow for climbing behavior,[8] and in some cases soil and leaf litter were provisioned. Enclosures were cleaned, scrubbed, and hosed daily. When changing enclosures between patients, surfaces were disinfected with bleach and Virkon™ (Lanxess Corporation, Pittsburgh, PA 15275, USA). Pangolins were fed either once (March – July) or twice (December – February) daily, depending on season. Diets consisted of frozen-thawed ant eggs, and occasionally silkworm larvae or pupae (December – January), offered at approximately 5–15% of body weight, depending on individual condition. Dietary items were either purchased from qualified commercial retailers and transported frozen to the rehabilitation centers or collected from the wild. Clean water was provided and changed daily.

Apparently healthy study animals near or at release condition were selected based on physical exam, basic diagnostics (i.e. hematology, parasite screening)and absence of clinical signs of systemic disease (Table 1). Study pangolins may have received injectable or oral medications during rehabilitation, including H2 agonists, antiparasitics, antibiotics, antifungals,

anti-inflammatory agents and analgesics, and other supportive medications (e.g. vitamin B complex, bromhexine, diazepam, metoclopramide). However, with the exception of subcutaneous isotonic fluids, a washout period of at least 7–14 days was implemented prior to sample collection, balancing widely accepted recommendations for cessation of medications prior to release with the well-being of the easily stressed pangolins.[48] Barring minor superficial wounds and skin lesions, any apparent pathologies excluded pangolins from the study (Table 1). All study activities received ethical approvals by the Smithsonian Institution's Animal Care and Use Committee (protocol 18-35).

Anesthetic and Handling Protocols:

Twenty-six pangolins were anesthetized for sample collection. Prior to each sampling event, every individual was food-fasted for a period of at least ten hours, while allowing for the animals' typical nocturnal feeding behavior. Water was available ad libitum per routine husbandry. During daylight hours, each pangolin was removed from its enclosure, placed immediately into a 91.4 cm x 63.5 cm x 68.6 cm plastic pet carrier, and transported to the clinic (within five minutes). Using the carrier as an anesthetic induction chamber attached to a non-rebreathing circuit, the animal was induced using 5% isoflurane at an O_2 flow rate of 5–10 L/min. Once induced (typically within 5–10 minutes), each individual was removed from the chamber and connected to the anesthetic circuit via a small animal anesthetic mask with rubber diaphragm. Anesthetic gas was reduced and maintained at 1–3% isoflurane delivered with 1.5–2 L/min O_2.[10] Throughout each anesthetic event, patients were warmed with heating pads. Upon reaching a light anesthetic plane, a physical exam was performed, and blood was collected for basic health and pathogen screening. Following sample collection, pangolins were recovered by discontinuing isoflurane while providing supplemental oxygen. Once appropriate mentation, control of the head, and ability to stand, locomote, and curl the tail were regained, pangolins were returned to their enclosures. At least 48 hours elapsed between each anesthetic event and release to the wild to allow monitoring for post-anesthetic complications.

In order to compare blood values between anesthetized and awake animals, sixteen animals were sampled awake without anesthetics. The animals were briefly restrained by experienced staff to reduce stress as much as possible, and the tail manually uncurled and extended for venipuncture. The animals were immediately returned to their enclosures following sample collection.

Sample Collection and Biochemical Analysis:

Whole blood (3–5 ml) was collected from the ventral coccygeal vein of each individual using 23g or 22g needles and placed into EDTA collection tubes and integrated serum separator tubes (Monoject™ Corvac™, Covidien, Minneapolis, MN 55432, USA).[10] Whole blood from the EDTA tubes was loaded into microhematocrit tubes and centrifuged (ZipCombo Centrifuge, LW Scientific, Lawrenceville, GA 30045, USA), and packed cell volume (PCV) was manually determined. Total solids (TS) were ascertained via refractometer. Serum separator tubes were allowed to separate passively for approximately 10-20 minutes at room temperature, then centrifuged (Waverly Scientific, Waverly, IA 50677, USA). Approximately 90–120 µl of serum from each sample was loaded into a VetScan® Comprehensive Diagnostic Profile reagent rotor cartridge (Abaxis, Union City, CA 94587, USA) and analyzed in-house using a benchtop Abaxis VetScan® VS2 clinical chemistry analyzer (Abaxis, Union City, CA 94587, USA). Measured analytes were alanine aminotransferase (ALT), albumin (ALB), alkaline phosphatase (ALP),

amylase (AMY), total calcium (Ca), creatinine (CRE), glucose (GLU), phosphorus (PHOS), potassium (K+), sodium (Na), total bilirubin (TBIL), total protein (TP), and blood urea nitrogen (BUN), while globulin (GLOB) was calculated. Hemolysis, lipemia, and icterus were also reported by the analyzer (scored as 0,+1,+2,+3). All samples were analyzed within one hour of collection.

The remaining serum was stored in 1.5–2 ml aliquots and stored frozen for approximately one month at -20 ℃. Samples from a subset of ten pangolins were transported to a diagnostic lab in Hanoi for analysis of additional parameters not included in the initial panel: aspartate aminotransferase (AST), triglycerides (TGL), cholesterol (CHOL), chloride (Cl), creatine kinase (CK), zinc (Zn), and iron (Fe).

Reference Interval Calculation:

Using Reference Value Advisor (Version 2.1, National Veterinary School of Toulouse, Toulouse, 31300, France, 2009) implemented in Microsoft Excel, Dixon-Reed and Tukey's tests were run to detect outliers of single parameters for exclusion. A tendency to exclude definitive extreme outliers was adopted, while suspect values tended to be included per Clinical Laboratory and Standards Institute (CLSI) recommendations. Anderson-Darling tests and visual inspection were performed to assess normality and symmetry, respectively. Five biochemistry parameters were found to follow a non-Gaussian distribution (Table 5) and were adjusted using Box-Cox transformations to approximate normality and symmetry. From the overall study population, reference intervals with 90% confidence intervals for lower and upper limits were generated for PCV, TS, ALT, ALB, ALP, AMY, Ca, CRE, GLOB, GLU, PHOS, K+, Na, TBIL, TP, and BUN in accordance with recommendations from the American Society for Veterinary Clinical Pathology (ASVCP) following the 2008 CLSI guidelines.[16] Reference intervals were developed using the robust method for Box-Cox transformed data, or nonparametric methods for small populations when assumptions of Gaussian distribution and symmetry were not met.[16–17]

Comparative Statistics:

Data for each category of measurement or variable were initially analyzed separately and in total. Descriptive statistics and histograms were calculated on totals, as well as by sex, weight, age (subadult/adult), season, and mental state (anesthetized vs. awake). Tests of assumptions were completed prior to fitting general linear models. Normality testing was performed using both the Shapiro-Wilk test and the Kolmogorov-Smirnov test with Lillifors' significance correction, and data were examined visually by plotting fitted curves to histograms. Heterogeneity of variance was examined with Levene's test. The most serious violation of assumptions for tests of means are heterogeneity and skew. After assumptions testing and transformations, there was no necessity to use any category of hypothesis test except parametric for our data, regardless of sample size. Two measures – TBIL and ALP – showed assumption violation, which were resolved with Box-Cox transformation. Based upon results of the tests of assumptions, means were tested with independent means testing within the general linear model factorial structure, both with and without covariates.

For consistency and ease of presentation, in the body of the text we use as labels the original measure, for both raw and transformed variables. In the body of the tables we present observed probability of test result (P), while we considered a test value of $p \leq 0.05$ as significant.

RESULTS

A total of 42 Sunda pangolins – 25 males and 17 females – met criteria for inclusion (Table 1).[8,12] Eight individuals (four males, four females) with a body mass ≤ 3.0 kg classified as "subadults," while the rest were considered "adults."[12] Eighteen animals were sampled during the cooler, dry winter season from December 2018 through February 2019, while 24 individuals were sampled during the hot, humid summer season from May through July 2019. Body weights of all study animals ranged from 2.3–7.6 kg, with an overall mean of 4.52 kg (SD 1.383 kg). Sexual dimorphism in weight ($F_{1,40} = 8.53$, $P = 0.006$) was evident, with females averaging 3.83 kg (SD 0.850 kg), and males averaging 5.00 kg (SD 1.487 kg). Out of 42 total blood samples, six showed hemolysis (three mild [+1], two moderate [+2], one gross [+3]). Hemolysis may have occurred due to the use of a small-gauge needle, or resistance from animals during venipuncture. Thirteen samples demonstrated lipemia (nine mild [+1], three moderate [+2], and one gross [+3]). No samples exhibited measurable icterus. The Abaxis VS2 system suppresses analyte results if interference by hemolysis, lipemia, or icterus is detected;[42] however, no values were affected by these processes to a measurable degree, as reported by the analyzer.

Clinical reference intervals and descriptive statistics are depicted in Tables 2–5. In addition to body mass (weight), both PHOS ($F_{1,40} = 7.83$, $P = 0.008$) and K+ ($F_{1,40} = 5.67$, $P = 0.022$) showed significant sexual dimorphism (Table 2). Additionally, means for the subadults ($n = 8$) demonstrated significant difference from adults ($n = 34$) in ALP ($F_{1,40} = 10.57$, $P = 0.002$), with the former averaging 374.8 ± 187.5 U/L and the latter averaging 211.5 ± 149.1 U/L ($F_{1,40} = 10.57$, $P = 0.002$). However, when Box-Cox transformed, the means were 1.44 ± 0.01 and 1.43 ± 0.01, respectively. When stratified by age and sex, TBIL ($F_{1,6} = 7.48$, $P = 0.034$) and PHOS ($F_{1,6} = 8.61$, $P = 0.005$) differed between subadult males ($n = 4$) and females ($n = 4$), while K+ varied ($F_{1,32} = 2.22$, $P = 0.039$) between adult males ($n = 21$) and females ($n = 13$). Significant differences by season were found for GLU ($F_{1,40} = 16.73$, $P = 0.000$), CRE ($F_{1,40} = 10.70$, $P = 0.002$), Ca ($F_{1,40} = 20.49$, $P = 0.000$), Na ($F_{1,40} = 7.10$, $P = 0.011$), K+ ($F_{1,40} = 59.07$, $P = 0.000$), and TP ($F_{1,40} = 6.05$, $P = 0.018$) (Table 3). Comparisons between anesthetized and awake pangolins showed significant variation in GLU ($F_{1,40} = 9.73$, $P = 0.003$), CRE ($F_{1,40} = 6.44$, $P = 0.015$), and K+ ($F_{1,40} = 14.44$, $P = 0.005$) (Table 4). For PCV and TS ($n = 29$), as well as the second assay panel ($n = 10$), no significant variation by sex, age, season, or mental state (anesthetized vs. awake) was found.

DISCUSSION

The serum biochemical reference ranges developed in this study may prove to be a valuable resource for the assessment of health status in Sunda pangolins, and for continued monitoring if evaluated serially. In the context of wildlife rehabilitation, they provide a useful baseline against which to monitor the recovery process, and may be helpful in guiding decision-making concerning readiness for release back into the wild. Although Sunda pangolin biochemistry parameters have been published previously, these correspond to different populations and stages of rehabilitation.[1,40] Collectively, these studies offer a more comprehensive resource, and provide insight into how health states may change during rehabilitation. The present study also compared biochemistry parameters between different sub-populations in an attempt to identify sources of variation. However, subdividing the population results in small sample sizes and thus less precise or stable estimates of population parameters, so observed data trends should be interpreted with caution.

Significant variation in ALP was observed between subadult and adult pangolins, a well-documented pattern in other species, including Sunda and other pangolins.[1,11,41] Although useful

as an indicator of liver disease or cholestasis, ALP is non-specific due to the expression of multiple isoforms from various cell types, such as bone. ALP elevations in young animals are often attributed to osteoblastic activity associated with normal bone growth.[41] In this study, the difference in ALP between subadults and adults may reflect a developmental mid-stage between true juveniles and subadults, but should be interpreted with caution given the small subadult sample size (n = 8). Neonates and juvenile pangolins ≤ 2.0 kg were excluded for their well-being, while subadults (2.1–3.0 kg) were included; these weight-based delineations were based on prior reports for this species and informed by observations from previous rescued pangolins (SVW, unpubl. data).[12] However, in a species in which reproduction is suspected to occur year-round, the time to (and weight at) sexual maturity is not well understood;[12] these weight-based classes only represent a best approximation of age.

In addition to age-related variation, several parameters also differed with respect to sex. Sexual dimorphism was evident in body mass, a well-described observation in this species.[24,39] Females and males also differed significantly in K+ and PHOS, a pattern that has also been reported in other mammals, but is of unknown or limited biological relevance.[28,38,46] In the present study, effort was made to exclude gravid females, but the ability to detect pregnancy was limited to physical exam without the benefit of diagnostic imaging. Thus, it is possible that females in early stages of pregnancy were inadvertently included; how this may have affected the biochemistry results is uncertain. Hemolysis may also have artifactually elevated K+ and PHOS to a degree that was not detectable by the analyzer; however, it should be noted that detailed investigation of electrolyte contents of pangolin cells has not been reported in the literature.

Physiological shifts due to environmental factors may explain some of the seasonal variation observed in this study. Seasonal variation in CRE may reflect differences in ambient temperature when sampled, glomerular filtration rate, or environmental stress;[23] alterations in TP may similarly reflect hydration status.[14,23] Seasonal differences in GLU observed in this study could be attributed to dietary changes; the diets fed at SVW are to some extent, wild-sourced, so variation in insect populations fed may be reflected in the pangolins' nutritional state.

Similarly to African white-bellied tree pangolins (*Phataginus tricuspis*), Sunda pangolins in this study were found to have higher K+ and lower GLU when sampled awake compared to anesthetized with inhalant agents. The clinical relevance is unknown, although it was speculated by Bailey et al. (2018) that vasodilation and changes in intravascular volume may impact electrolyte concentration.[2] Differences in K+ might also derive from hemolysis with venipuncture technique with a manually restrained animal, while GLU variation could be due to differential stress during chamber induction or manual restraint, as mediated by corticosteroid release. Anecdotally, both methods resulted in signs of stress from the animal, including curling, struggling or resistance, and/or defensive hissing. With experienced handlers, total time exposed to or around humans was shorter in duration with manual restraint compared to chamber induction. More data – particularly measurement of cortisol or other specific objective stress indicators – would be needed to confirm this speculation.

Notably, a subjectively thick lipid layer was observed grossly in some samples following centrifugation; this could reflect the high cholesterol and lipid content of their insect-based diet.[4,34] Serum cholesterol and triglycerides quantified for ten pangolins in this study (Table5) were substantially lower than those of Formosan pangolins, the only other species for which values have been published, to the authors' knowledge.[11,22] This could reflect species variation, dietary differences, fasting period, or artifact from sample handling or storage conditions. Thirteen samples in this study recorded slight to gross lipemia per the analyzer results. While this

did not affect the analytes evaluated by the Abaxis VS2 analyzer, this may have affected TGL results from the second assay, especially if centrifuged further. Thus, TGL and CHOL values presented here should be interpreted cautiously. It is also important to note that diets fed at SVW facilities can be inconsistent due to availability of their commercial and wild-sourced diet, and there may be nutritional differences not accounted for in this study. It is also worth noting that one longer-term resident of the facility included in the study was over-conditioned; however, her TGL and CHOL values clustered near the means and were not considered outliers.

In previous studies, serum biochemistries of Sunda pangolins were ascertained at intake at Singapore Zoological Gardens (SZG) using the same biochemical analyzer,[1] while a more limited study was conducted using pre-release Sunda pangolins in Thailand using other methods.[40] Comparatively, the present study offers an updated and expanded set of biochemistry profiles. Reference intervals developed here for electrolytes and minerals (Na, K+, Ca, PHOS) are comparable to those previous studies, as expected given their tight physiologic regulation. Kidney parameters BUN and CRE were also similar across studies. However, ALT and ALP in the present study skewed lower and occupied narrower ranges than previously reported results; narrower ranges were also seen for ALB, GLOB, TBIL, and AMY. GLU occupied a narrower range compared to Ahmad et al.'s (2018) study, but a wider range compared to results from Thomas et al. (2015).[1,40] Collectively, the three studies offer a broader understanding of normal health states for Sunda pangolins.

Differences in Sunda pangolin biochemistry profiles may stem from methodological differences in several key aspects: 1) investigation of different populations (possibly originating from distinct geographic regions) exposed to varying climatic conditions; 2) differences in animal management prior to analysis; and 3) time-point of study population selection and sampling (i.e. at intake vs. at the end-point of rehabilitation). The geographic origins of Sunda pangolins confiscated from the illegal trade often remain unidentified; thus, local adaptation to conditions at receiving facilities, time in captivity or transport, capture methods, degree of human handling or exposure, dietary composition, and prior history of disease or exposure to infectious agents are all questionable at the time of intake, but can have measurable effects on serum biochemistries.[9,26–27,30] Once in rehabilitation, differing management strategies may further influence physiologic condition of the respective study populations; these include medications, diet, and the degree of human exposure. In the present study, the authors elected to assess biochemical parameters at the end-point of rehabilitation, after a period of monitoring under quarantine. This enables clinicians to recognize disease states that may not become apparent until after arrival at the facility, and also allows confiscated pangolins to better acclimatize to local climate conditions, a stable diet, and to human presence. Moreover, this provides for the passing of convalescent periods of disease, during which the animal may still carry infectious agents. The reference intervals established here represent a closer approximation of healthy pangolins compared to previous reports, given the selection of animals that have successfully undergone rehabilitation and have been deemed suitable for release.

The results of this study are also comparable to Formosan pangolins (*Manis pentadactyla pentadactyla*) in Taiwan.[11,22] Electrolyte parameters are similar between species, with slight differences in kidney and liver values. Notably, Sunda pangolin phosphorus values were considerably higher than those of Formosan pangolins, while TGL and CHOL skewed lower. Temminck's pangolins (*Smutsia temminckii*) from Zimbabwe demonstrated greater ranges (especially maximum values) for most liver values, GLU, and interestingly K+.[13] However, there is a paucity of species-specific health data for other members of the pangolin family.[2,11,22,29,45]

It should be noted that portable or bench-top analyzers like the Abaxis VS2 system use a variety of assay methods for determination of biochemical parameters. By necessity, these often deviate from reference methods, and thus imprecise measurement is possible. Aside from inter-species variation, differences between our observed results and other studies may be attributable to inter-analyzer or inter-assay variability.[42]

The reference intervals developed in the present study pertain to a population under specific conditions and settings. In addition to intrinsic daily or interindividual variation, other sources of variation may include reproductive or gestational status and acclimatization to specific climate or environmental conditions, which can influence physiologic status.[14,25,35] Additionally, the health and physiologic states of individuals undergoing rehabilitation may not approximate free-ranging animals due to artificial conditions imposed under human care.[5,33,37] Consideration should be given to the influence of management decisions on biochemical parameters, which may be affected by dietary composition, fasting duration, stress from handling or human disturbance while in captivity, capture and restraint methods, anesthetic protocol, and medications.[2,9,31–32,37] Finally, underlying pathologies do not always manifest as clinical disease and are not always detectable by diagnostics or physical exam; thus, our definition of "healthy" as informed by the clinician's judgment may be limited.

CONCLUSIONS

The reference intervals developed here provide an updated and expanded set of serum biochemistry parameters to guide clinical decision-making for Sunda pangolins, and can prove useful for ex-situ conservation initiatives. Our results build upon previous research to offer a more complete perspective on Sunda pangolin health states, but should still be interpreted in light of management conditions.

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TABLES

Table 1. Selection criteria for Sunda pangolins included in study population.

Table 2. Descriptive statistics for body weight, PCV, TS, and serum biochemistry parameters of male and female Sunda pangolins.

Table 3. Descriptive statistics for body weight and serum biochemistry of pangolins sampled in the cold, dry season (Dec – Feb) vs. the hot, humid season (May – July).

Table 4. Descriptive statistics for body weight, PCV, TS, and serum biochemistry of anesthetized and awake pangolins.

Table 5. Overall descriptive statistics, 95% confidence intervals for means, and reference intervals with 90% confidence intervals for upper and lower limits for select Sunda pangolin hematology and serum biochemistry parameters. LL = lower limit; UL = upper limit.