PHYSIOLOGICAL STATUS, MORPHOMETRY, AND HERD STRUCTURE OF BORNEAN SAMBAR DEER (RUSA UNICOLOR BROOKEI) UNDER EX SITU CONSERVATION MANAGEMENT IN EAST KALIMANTAN, INDONESIA

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Abstract

Ex situ herds hold Bornean sambar deer (*Rusa unicolor brookei*), a Vulnerable species, yet physiological and demographic data from these herds are scarce. We combined 2021–2025 census records from UPTD PTHPT Api-Api in East Kalimantan, a published physiological cohort of 23 young deer (8 males, 15 females), morphometric data from three studies, and one longitudinal intake and haematology record. We recalculated herd indices, compared the sexes from summary statistics with Welch's t-test and Hedges' g, and checked each dataset for internal consistency. Rectal temperature was 39.66 °C in males and 39.55 °C in females, respiration 64.4 and 56.4 breaths min^{-1}, and pulse 94.5 and 88.6 beats min^{-1}. Males exceeded females in respiration (g = 1.68) and pulse (g = 2.86), but the deer had been driven into a handling crush, so handling arousal and heat load overlap. Reported herd size was 188 in 2021 and 2025, with a peak of 217 in 2023. Documented transfers explain 62% of the 2023–2025 decline. Fawns per adult or young female fell from 1.02 to 0.50, and category sums differed from reported totals in 2022 (+2) and 2025 (−3). Yearling female deer reached 62–68% of adult body length across studies but 86–88% in one study, while head and ear ratios agreed, suggesting inconsistent measurement definitions. The recorded packed cell volume contradicted haemoglobin and erythrocyte counts. The herd persists under ex situ management, but the data neither show adaptation nor test endurance. Individual-level registries, standardised morphometry, and low-handling monitoring with microclimate logs are needed.

Keywords:

Rusa unicolor brookei; ex situ conservation; heat load; herd structure; morphometry

1. Introduction

The sambar (*Rusa unicolor*) is the largest Asian deer, and the IUCN Red List classifies it as Vulnerable (Timmins et al., 2015). The Kalimantan population belongs to the subspecies *R. u. brookei* (Gholib et al., 2025). Wild sampling of this species is costly and rare, so most physiological information comes from a few captive or immobilised animals (Nigam et al., 2020). UPTD PTHPT Api-Api in East Kalimantan has kept sambar since 1990 to conserve regional germplasm (Erni et al., 2025), which makes the herd one of the few places where physiology, growth, and demography can be recorded together.

Herds in the humid lowland tropics face a thermal load that fenced paddocks make harder to escape. Large mammals use behaviour first, through shade seeking and shifts in activity, and then evaporative cooling, which loses effectiveness as environmental vapour pressure approaches that of the skin (Fuller et al., 2016). During a heat wave, reindeer reduced activity and did not recover lost foraging time on the hottest days (Trondrud et al., 2023). Captive red deer calves under high heat stress weighed up to 1.2 kg less at weaning, and the deer lay in shade and used mud baths (Pérez-Barbería et al., 2020). Rectal temperature, respiration rate, and pulse rate serve as routine heat-load indicators in livestock (Sejian et al., 2018; Idris et al., 2021).

These indicators also respond to handling. In physically restrained roe deer, heart rate, body temperature, and the neutrophil-to-lymphocyte ratio served as capture-stress measures, and a leukocyte assay indicated more stress the longer people were present at the capture site before handling (Huber et al., 2017). Mariti et al. (2019) compared blood biochemistry of red deer after chemical and physical restraint as a welfare tool, and handling stress confounds rectal temperature in cattle (Idris et al., 2021). The Five Domains Model treats human interactions as a separate source of negative affect (Mellor et al., 2020). A value taken from a handled deer therefore reflects the handling as well as the climate.

The current study measured rectal temperature, respiration, pulse, and body dimensions in 23 young sambar at Api-Api. They found higher physiological and smaller morphometric values than the reference figures they used and concluded that growth was suboptimal. Adult dimensions (Sibagariang et al., 2025), age-specific reference dimensions (Wirdateti et al., 2009), and blood values from nine young and four adult captive deer (Semiadi et al., 1995) exist, but we found no study that compares these records with each other or with the herd census.

We therefore (1) reanalysed the physiological cohort with effect sizes and read it against handling, (2) audited the 2021–2025 herd census, transfers, and recruitment, (3) compared morphometric data across age classes and studies, and (4) tested the internal consistency of the single haematology record. The records contain no challenge test, so we do not test adaptation or endurance.

2. Materials and Methods

2.1 Site, management, and records

Unit Pelaksana Teknis Daerah Pembibitan Ternak dan Hijaun Pakan Ternak (UPTD PTHPT) Api-Api, Penajam Paser Utara Regency, East Kalimantan Province, keeps sambar in paddocks for young females, breeding females, males, display, and isolation. Gangways connect the paddocks to a dark handling crush. The ration is *Brachiaria humidicola* forage with 15–17% crude protein concentrate, and water is available ad libitum. Deer receive anthelmintics three times a year, vitamins three to six times a year, and foot-and-mouth disease vaccine once a year. We used four record sets. The first is the annual sex and age-class census for 2021–2025 (adult, young, or yearling female deer; fawn), with documented transfers to other institutions: 2 deer to Sepaku and 6 to Samarinda in 2024, and 10 to Penajam Paser Utara in 2025. The second is the physiological cohort of the current study. The third is morphometric data from the current study, Sibagariang et al. (2025; adults, sample size not stated in the records available to us), and Wirdateti et al. (2009; fawns, yearling female deer, and adults by sex). The fourth is one longitudinal record of intake, gain, and haematology from a single deer.

2.2 Physiological measurements

The current study purposively selected 8 males and 15 females classed as yearling female deer in February 2025, using incomplete maturity and safe handling as criteria. Each deer passed through the

gangways into the crush. We measured rectal temperature with a clinical thermometer inserted 5 cm for 1 min, counted respirations (exhalations at the nostrils) for 1 min, and counted pulse with a stethoscope behind the left elbow for 1 min. We measured each variable three times and averaged the results. This study reports means and standard deviations (SD), and we used only these summary statistics.

2.3 Data analysis

For the herd audit, we summed the six sex-by-class counts for each year and subtracted the reported total. Annual change used reported totals. Class proportions used the category sum as the denominator so that they add to 100%. The transfer-adjusted total equals the reported total plus cumulative documented transfers since 2024, assuming no other removals occurred. The recruitment index is fawns divided by adult plus young females, the potential dams. We compared age composition between 2021 and 2025 with a chi-square test and across years with a Cochran–Armitage trend test, and we tested sex ratios with exact binomial tests. The census covers the whole herd, so we treat p-values as descriptors of change size, not as sampling inference.

We compared males and females with Welch's t-test from summary statistics and report Hedges' g with a 95% confidence interval. For morphometry, we expressed data means as a percentage of adult means within Wirdateti et al. (2009), sex by sex, and across this study and Sibagariang et al. (2025), pooling adult sexes. For the haematology record, we derived mean corpuscular haemoglobin (MCH = Hb/RBC), volume (MCV = PCV/RBC), and haemoglobin concentration (MCHC = Hb/PCV), body mass (dry matter intake divided by intake as a fraction of body mass), and the feed-to-gain ratio (intake/gain), and we compared them with Semiadi et al. (1995) and Nigam et al. (2020). Calculations used Python 3 with SciPy 1.17 and Matplotlib.

3. Results

3.1 Herd size, structure, and transfers

Reported herd size was 188 deer in 2021, rose to 215 in 2022 and 217 in 2023, and fell to 199 in 2024 and 188 in 2025 (Table 1). Net change over 2021–2025 was zero, and the decline from the 2023 peak was 13.4%. Category sums differed from reported totals by +2 in 2022 and −3 in 2025. Documented transfers of 8 deer in 2024 and 10 in 2025 account for 44% of the 18-deer decline in 2024 and 91% of the 11-deer decline in 2025, or 18 of 29 deer (62%) over 2023–2025. The unexplained remainder was −11 deer, and the transfer-adjusted total fell 5.1% (217 to 206; Figure 1a). Age composition changed between 2021 and 2025 ($\chi^2 = 17.4$, df = 2, $p < 0.001$, Cramér's V = 0.22). Fawns fell from 33.0% to 17.3% of the herd (trend across years, $z = -4.34$), young deer rose from 35.6% to 55.1%, and adults fell from 31.4% to 27.6%. The records for 1990–1995 do not balance: 23 founders plus 112 additions plus 25 births minus 101 deaths gives 59, whereas the record states 46 deer at year-end, and its sex breakdown (19 males, 7 females) sums to 26.

Table 1. Herd census, recruitment index, and transfer-adjusted totals, 2021–2025

Year	Reported total	Adult M/F	Young M/F	Fawn M/F	Category sum	Sum − total	Total + transfers	Fawn share (%)	Fawns per dam
2021	188	34/25	31/36	28/34	188	0	188	33.0	1.02
2022	215	31/24	38/44	45/35	217	+2	215	36.9	1.18
2023	217	26/21	58/51	28/33	217	0	217	28.1	0.85
2024	199	29/22	52/48	21/27	199	0	207	24.1	0.69
2025	188	29/22	60/42	9/23	185	−3	206	17.3	0.50

M/F = males/females. Young = yearling female deer. Fawn share uses the category sum as denominator. Dams = adult plus young females. Transfers: 8 deer in 2024 and 10 in 2025 (cumulative).

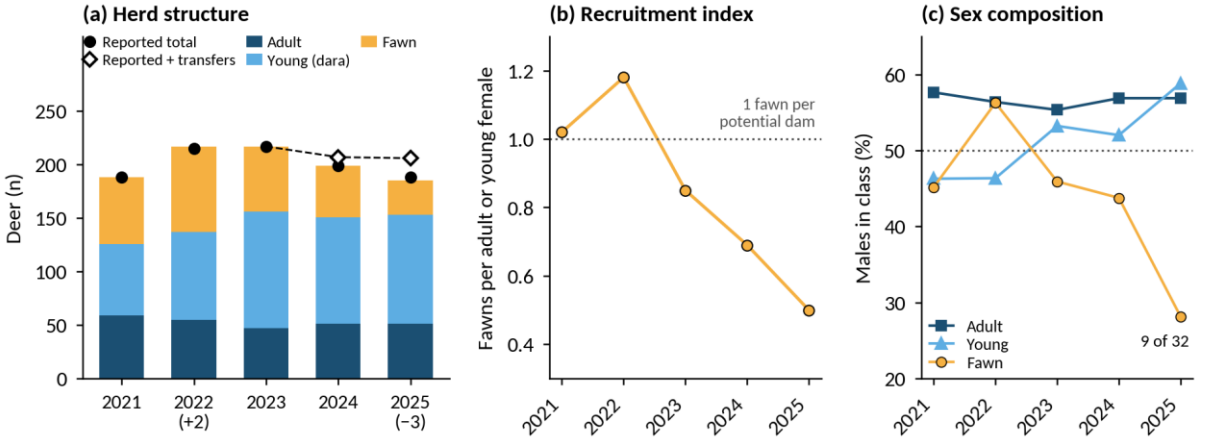

Figure 1. Herd structure and recruitment at UPTD PTHPT Api-Api, 2021–2025. (a) Counts by class; dots are reported totals, diamonds are reported totals plus documented transfers, and figures in parentheses give category sum minus reported total. (b) Fawns per adult or young female. (c) Percentage of males within each class

3.2 Recruitment and sex composition

Fawns per potential dam increased from 1.02 in 2021 to 1.18, 0.85, and 0.69, then to 0.50 in 2025 (Figure 1b). Per adult female alone, the ratio ranged from 1.45 to 3.33, which a species with one fawn per dam per year cannot reach. Adult males outnumbered adult females (149 to 114 over five years, 1.31:1). The male share of fawns fell to 28.1% in 2025 (9 of 32; exact $p = 0.020$), whereas the pooled 2021–2025 share was 46.3% (131 of 283; $p = 0.23$; Figure 1c).

3.3 Physiological indicators

Males had higher respiration and pulse rates than females, and rectal temperature differed little (Table 2, Figure 2). The reported dispersion is narrow for field measurements: coefficients of variation were 0.3–0.4% for temperature, 7–9% for respiration, and 1.5–3.1% for pulse.

Table 2. Physiological indicators of young sambar deer (mean ± SD) and sex contrasts

Variable	Male (n = 8)	Female (n = 15)	Difference	Welch's t (df)	p	Hedges' g (95% CI)
Rectal temperature (°C)	39.66 ± 0.17	39.55 ± 0.11	0.11	1.65 (10.2)	0.128	0.80 (−0.09 to 1.69)
Respiration (breaths min^{-1})	64.40 ± 5.60	56.35 ± 4.02	8.05	3.60 (11.0)	0.004	1.68 (0.70 to 2.67)
Pulse (beats min^{-1})	94.53 ± 2.96	88.55 ± 1.31	5.98	5.44 (8.5)	< 0.001	2.86 (1.67 to 4.05)

Means and SD from the current study. Tests computed from summary statistics; deer were measured in the handling crush.

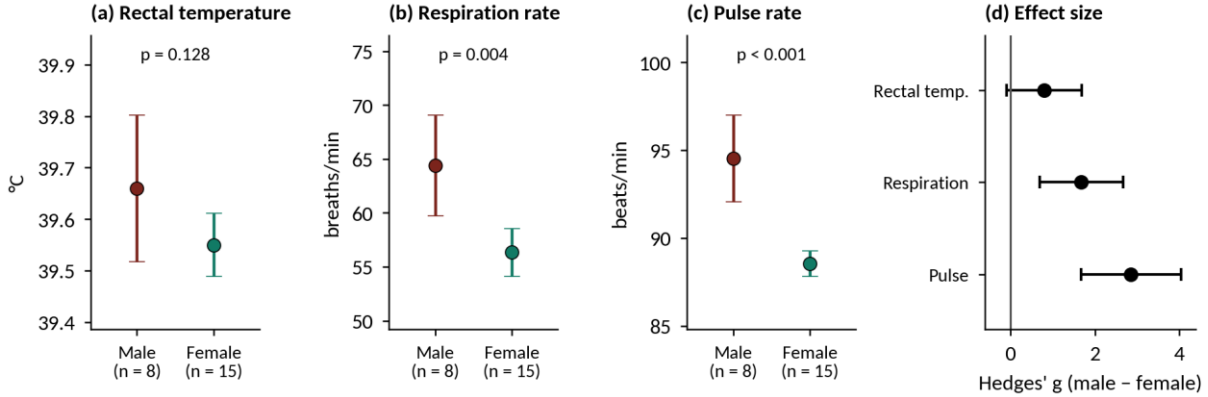

Figure 2. Rectal temperature (a), respiration rate (b), and pulse rate (c) of young sambar deer, with 95% confidence intervals of the mean calculated from reported SD, and Hedges' g with 95% confidence intervals (d). p values are from Welch's t-test.

3.4 Morphometric comparison

The current study recorded body lengths of 74.3 cm in yearling male deer and 81.8 cm in yearling female deer, and Sibagariang et al. (2025) recorded 119.8 cm in adults. Wirdateti et al. (2009) give 79.2 and 75.3 cm for fawns, 93.3 and 85.3 cm for yearling female deer, and 105.5 and 99.7 cm for adults (males, females; Figure 3a). Yearling female deer in this study were shorter than the fawns in Wirdateti et al., and adults in Sibagariang et al. were longer than the adult stags in Wirdateti et al. Yearling female deer reached 85.5–88.4% of adult body length in Wirdateti et al., but 62.0–68.2% across this study and Sibagariang et al. Head length (85.6–87.4% within, 87.0–92.9% across studies) and ear length (93.3–95.1% and 92.4–93.5%) agreed, and head width differed less (81.2–86.4% and 74.5–79.9%; Figure 3b). Adult wither height was 78.6 ± 6.7 cm and pelvic width 25.8 ± 2.5 cm (Sibagariang et al., 2025).

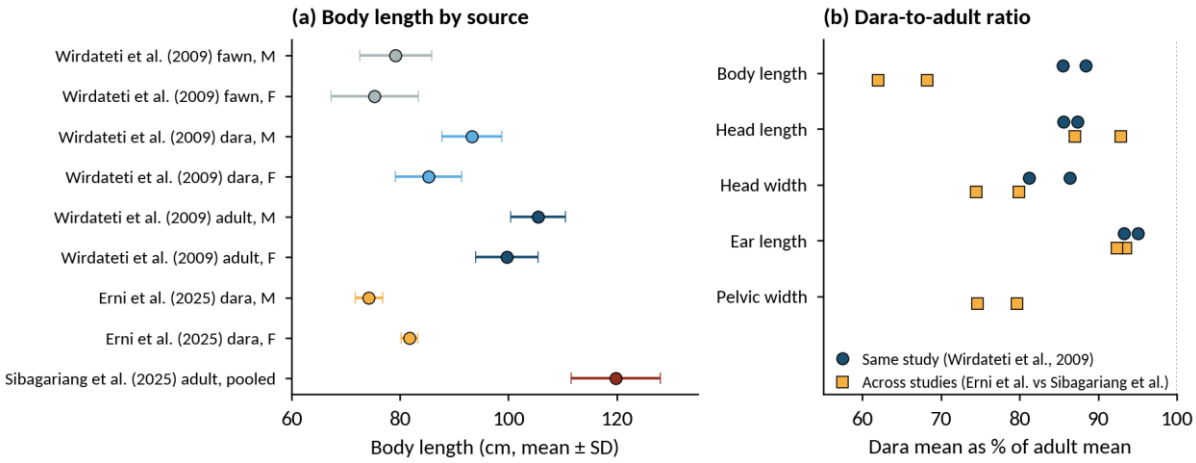

Figure 3. (a) Body length (mean ± SD) by source, class, and sex. (b) Yearling female deer mean as a percentage of adult mean: circles compare yearling female deer and adults within Wirdateti et al. (2009); squares compare Erni et al. (2025) with Sibagariang et al. (2025). Each trait shows two symbols, one per sex of yearling female deer.

3.5 Haematology and growth record

Haemoglobin and erythrocyte counts imply an MCH of 14.2–15.7 pg, which lies within values reported for sambar (Table 3). The recorded PCV implies an MCHC of 181–264 g L^{-1}, below the range of Nigam et al. (2020; 278–435 g L^{-1}) and the means of Semiadi et al. (1995; 311–317 g L^{-1}), and an MCV of 60–78 fL against reference means of 43–53 fL. Leukocyte counts were two to three times the reference means. Intake of 6.27–6.33% of body mass implies a body mass of 15.7–19.2 kg, so the record describes a juvenile, and the feed-to-gain ratio was 8.6–9.6 kg dry matter per kg of gain (intake 987–1,216 g d^{-1}, gain 115–127 g d^{-1}) if the range ends pair.

Table 3. Haematology and growth record of one deer compared with sambar reference studies

Variable	Case record	Semiadi et al. (1995) stags/hinds	Nigam et al. (2020)
Erythrocytes (×10^{12} L^{-1})	7.9–8.4	9.2/9.9	6.4 ± 1.21
Haemoglobin (g L^{-1})	112–132	126/135	109.7 ± 13.2
PCV (L L^{-1})	0.50–0.62 (recorded)	0.4/0.4	0.32 ± 0.08
MCV (fL)	60–78 (derived)	43/45.5	53.5 ± 14.5
MCH (pg)	14.2–15.7 (derived)	13.8/14.4	17.9 ± 5.3
MCHC (g L^{-1})	181–264 (derived)	317/311	337 ± 44
Leukocytes (×10^{9} L^{-1})	9.7–14.8	4.6/4.5	4.7 ± 1.32
Blood pH	7.34–7.45	not reported	not reported

Semiadi et al.: unsedated young housed stags (n = 5) and hinds (n = 4). Nigam et al.: free-ranging deer immobilised with medetomidine–ketamine (n = 32; mean ± SD). Units of the case record were restated; PCV was recorded as 0.50–0.62%.

4. Discussion

4.1 Handling shapes the physiological profile

A rectal temperature of 39.6 °C with respiration of 56–64 breaths min^{-1} and pulse of 89–95 beats min^{-1} describes deer that had just been driven through a gangway into a crush. In the current study, animals leapt up to 2 m along this route. High-intensity exercise raises heat production more than tenfold above rest (Fuller et al., 2016), and restraint stress is measurable in deer through heart rate,

body temperature, and leukocyte indices (Huber et al., 2017). Handling also confounds rectal temperature in cattle, and respiration is difficult to record (Idris et al., 2021). These values therefore cannot separate climate load from handling arousal, and they do not show adaptation or a lack of it.

The current study compared deer with cattle and buffalo, whose respiration rates are 18–33 breaths min−1; we found no reference values for handled sambar in the sources we used, so this comparison shows differences among species and methods, not stress. The Five Domains Model places handling in Domain 4 and infers fear and anxiety from behavioural and physiological responses (Mellor et al., 2020), so respiration and pulse taken in a crush fall under the affective response to handling. The sex contrast in respiration and pulse is large if the reported dispersion is an SD, but the confidence intervals are wide with 8 males, and body size, temperament, or a longer wait in the crush could produce it.

4.2 Thermal load and behavioural regulation

In humid lowland sites such as Api-Api, where this study describes high temperatures and unstable humidity, the literature best supports a behavioural response. Sambar at an Edupark herd in South Kalimantan needed shade for resting and wallows to shed body heat (Murpratiwi & Nurliani, 2023), and sambar in a North Sumatra enclosure spent 55% of observation time resting and 23% eating (Astuti et al., 2026). Reindeer in a heat wave cut activity (Trondrud et al., 2023), and red deer calves grew less under high heat stress (Pérez-Barbería et al., 2020). Evaporative cooling weakens as humidity rises (Fuller et al., 2016), so shade and wallows are a direct management lever. The canopy planting planned at Api-Api follows from this evidence. Visitor numbers were compared with faecal cortisol metabolites in captive sambar (Gholib et al., 2021), and a similar record would let managers test a visitor effect before the planned tourist train and guided tours begin.

4.3 Morphometric comparisons

The current study read the small yearling female deer measurements as incomplete growth linked to feed. The ratios point elsewhere. If nutrition limited growth, every trait would fall short, but head length and ear length in yearling female deer reach 86–95% of adult values in both comparisons, and only body length differs (62–68% across studies versus 86–88% within one). The Methods define body length as the distance from the tuber humeri to the tuber ischii, and the Results describe it as the distance from muzzle to tail base. The adult mean for Sibagariang et al. exceeds that of the adult stags in Wirdateti et al. by 14 cm. Trunk length therefore cannot be compared across these studies until the reference points are standardised. Yearling females were longer than males in this study but shorter in Wirdateti et al., which may reflect differences in age composition or measurement. Withers height is a better target. In five captive stags, it correlated with testicular volume ($r = 0.94$) and with the share of normal spermatozoa ($r = 0.97$; Carneiro et al., 2025), which supports recording it for breeding males.

4.4 Herd structure and record integrity

Three features of the census limit demographic inference. First, the denominator of adult females alone gives more than one fawn per female, so yearling female deer females must breed or the classes do not track reproductive status. Sambar in Victoria first bred at about 1.8 years, and juvenile survival was 0.81 (Watter et al., 2020), which places many yearling females within breeding age. Second, the recruitment index fell from 1.02 to 0.50 while the potential dam pool stayed between 61 and 72, so a smaller dam pool does not explain the drop. Third, transfers explain most of the 2025 decline and only

44% of the 2024 decline. Age structure shapes short-term growth as much as vital rates: in semi-captive Asian elephants, high adult birth rates did not produce high growth because reproductive-age females formed a small share of the population (Jackson et al., 2020). Young deer now make up 55% of the Api-Api herd, so a large cohort approaches breeding age, and recruitment may recover without a change in management or may confirm a real fertility decline. The census cannot distinguish between these.

The 1990–1995 balance and the +2 and −3 discrepancies show that class counts have not been reconciled with an event ledger. Individual records with birth, death, transfer, and reclassification dates are the standard tool for this, and population demography is the most common use of studbook data in zoo research (Brereton, 2024). The adult sex ratio favours males (1.31:1), and stags in velvet showed 8% of recorded sexual behaviour (Gholib et al., 2025), which fits the facility's aim of suppressing rut through velvet harvest. Breeding records would show how many stags sire fawns. The 28% male share of fawns in 2025 coincides with the fall in fawn number and may reflect reclassification more than birth sex.

4.5 Haematology and monitoring

The PCV inconsistency shows why unit checks belong in any monitoring protocol. Leukocyte counts two to three times the reference means fit the excitement-related leukocytosis that Nigam et al. (2020) attribute to splenic contraction in restrained deer, although a unit error cannot be excluded. Karpiński et al. (2023) reported reference values from roe deer captured without anaesthesia, and Api-Api intervals should likewise record how each animal was restrained and how long it waited. A deer of 16–19 kg eating 6.3% of its mass daily is a fawn, so the record supports the feasibility of longitudinal intake and gain monitoring and nothing more.

Four steps follow. Managers should keep an individual registry. They should log air temperature and humidity every 15 min and audit shade and wallow use weekly. They should count respiration from a distance before handling and at fixed times after release, with recovery time as the outcome. A challenge–recovery protocol should proceed only under ethical approval, because recovery after capture depends on the capture method (Bergvall et al., 2021). This analysis has limits: it rests on summary statistics from one cohort of yearling female deer, so age, reproductive state, time of day, and time spent in the crush cannot be modelled; the transfer adjustment assumes no other removals; and the reference values of Wirdateti et al. (2009) come from a published table.

5. Conclusion

Bornean sambar deer at Api-Api persist under ex situ management, and the reported physiological values fit handling arousal and heat load. Transfers explain most of the 2023–2025 drop in herd size, but fawns per potential dam halved and the class counts contain unreconciled errors. Body length cannot be compared across studies, whereas head and ear dimensions agree, so the small yearling female deer measurements do not show stunting. The single haematology record contains a PCV that contradicts its haemoglobin and erythrocyte counts. The data neither show adaptation nor test endurance. The next step is an individual-level registry, one morphometric protocol centred on withers height, and low-handling physiological monitoring paired with microclimate logs and post-handling recovery times.

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