# BULLetin

Journal of the IUCN SSC Asian Wild Cattle Specialist Group

IUCN SSC Species Survival Commission AWCSG Asian Wild Cattle Specialist Group

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Cover Photo: Camera trap image of bull banteng grazing, Tabin Wildlife Reserve, Sabah

Credit: Zainal Zahari/ Borneo Rhino Alliance (BORA)

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Asian Wild Cattle Specialist Group

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# EDITOR'S NOTE

*By Amy Humphreys, AWCSG Programme Coordinator*

Welcome to the 9th issue of BULLetin, the newsletter of the IUCN SSC Asian Wild Cattle Specialist Group (AWCSG). At the time of editing, the Specialist Group is also undergoing a period of transition in its leadership, with James Burton moving into the role of Emeritus Chair and Qamar Qureshi (South Asia) and Philippe Chardonne (African buffalo) joining as new Co-Chairs; full introductions will follow in the next issue. This issue brings together new science, field experience, and community-driven action as the region's wild bovids face unprecedented pressures.

We open with the uplisting of the banteng (*Bos javanicus*) to Critically Endangered on the IUCN Red List. The scale of decline described here is stark, yet this article also reminds us that sustained investment in protection can reverse trends, as demonstrated in parts of Java and Thailand. As the banteng enters the Green Status of Species assessment process, it is timely to reflect not only on loss, but also on recovery pathways.

An important outcome of banteng-focused discussions during 2025 was the formation of a new range-wide Banteng Working Group under the IUCN SSC Asian Wild Cattle Specialist Group, formalised during a multi-country coordination meeting in November. Bringing together practitioners, researchers, NGOs, and government representatives from across the species' range, the Working Group was established in response to the banteng's recent uplisting and the need for stronger coordination across countries. Updates shared at the meeting highlighted striking regional contrasts from recovering populations in parts of Thailand to extremely small, precarious populations in Viet Nam, Lao PDR, and several transboundary landscapes alongside a strong consensus on priorities, including improved population monitoring and modelling, recovery planning, threat reduction (particularly addressing snaring), and strengthened transboundary collaboration. The Working Group will also support the ongoing Green Status of Species assessment by consolidating population data and documenting conservation actions across management units.

This issue also features groundbreaking genomic research on the saola (*Pseudoryx ngetinhensis*), one of the world's most elusive large mammals. The findings underline both the extreme vulnerability of the species and the potential role of carefully managed conservation interventions should individuals still persist in the wild, adding an important genetic dimension to ongoing efforts to prevent the saola's disappearance.

Field-based conservation is a central theme, from the application of the Double Observer Point Count for tamaraw (*Bubalus mindorensis*) monitoring in the Philippines to evidence that habitat enrichment can improve reproductive success in Bornean banteng, highlighting the role of rigorous methods and sustained commitment in strengthening conservation decision-making.

We are also pleased to showcase the inaugural Sabah Banteng Day, an inspiring example of how conservation science, sport, and community pride can come together to foster local stewardship for endangered species.

Finally, a detailed field study from Sabah, Malaysia, examines whether targeted habitat interventions can enhance nutrition and reproductive performance in wild Bornean banteng (*Bos javanicus lowi*). By combining pasture management, weed removal, and mineral supplementation within a forest reserve, the study provides empirical evidence linking habitat quality to fecundity in a small, isolated banteng population.

Stay up to date with our activities and Asian wild cattle news via our website (asianwildcattle.org) and social media (Facebook: IUCN Asian Wild Cattle Specialist Group; Instagram: @iucn_wildcattle). We thank our authors, reviewers, field teams, and partners for their contributions, and hope this issue informs and inspires continued collaboration to secure the future of Asia's wild cattle.

# NEWS AND UPDATES

## Banteng up-listed to Critically Endangered as a result of incessant poaching and habitat loss

*By Milou Groenenberg and Martha M. Hurley*

On the 28th of October 2024, the banteng (*Bos javanicus*) was uplisted from 'Endangered' to 'Critically Endangered' on the IUCN Red List of Threatened Species™ (Gray and Groenenberg, 2024). This tragic status change is the consequence of an estimated global population decline of more than 80% over the past two decades which is largely attributable to unabated pressures from illegal hunting and habitat loss.

Thanks to the efforts of numerous experts across the banteng range countries, updated information on banteng population status and trends was accumulated. The current total global population is estimated at approximately 3,300 (2,475–4,900) individuals and is declining. Despite this, there is still some reason for optimism. Banteng populations in major national parks on Java appear to be stable, and in Thailand's Western Forest Complex (WEFCOM) banteng populations are even increasing in both abundance and distribution (Phoonjampa et al., 2021). Conservation success in this Thai protected area is largely attributed to long-term investments in effective protection to suppress poaching and habitat degradation.

This updated Critically Endangered listing was featured in various international and national media outlets and was accompanied by a call for action from James Burton, Chair, IUCN SSC Asian Wild Cattle Specialist Group: "*We call on all stakeholders to collaborate and take the urgently needed actions to reverse the negative trend. Increasing effectiveness of protection from hunting, as well as maintaining and expanding suitable habitat and connectivity, are essential for long-term population viability / future of Banteng.*"

As a next step, a Green Status of Species (GSS) assessment of banteng is being undertaken. This approach evaluates past, present, and future conservation efforts across the banteng's historical range to estimate its current recovery status and the impact of future actions in both the near and long term (IUCN, 2021). As mentioned above, some conservation efforts in parts of the banteng's range have proven effective to date. Hopefully these can be extended - or adapted – to other regions which currently host potentially viable banteng populations (e.g., eastern and northern Cambodia, Java, Sabah). Their incorporation into a forward-looking species recovery model such as the GSS will buttress current on-the-ground conservation and research efforts and provide support for future ones.

Hopefully, the combined red and green list assessments will help raise the profile of this charismatic wild cattle species and thereby raise awareness and funding support for the urgent and critical conservation actions that need to be implemented in order to prevent the species' extinction.

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# Population structure in the saola has consequences for its genetic health

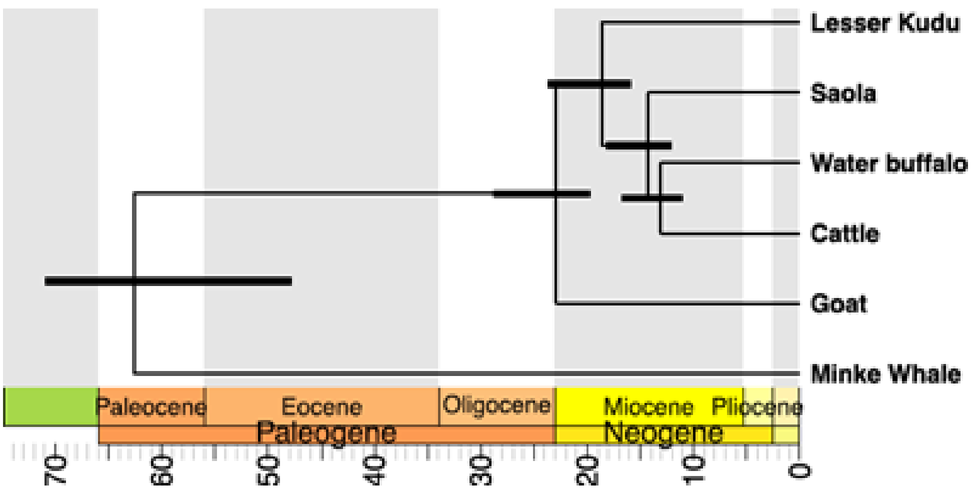
*By Rasmus Heller, Mikkel-Holger Strander Sinding and Genís Garcia-Erill*

The saola (*Pseudoryx ngetinhensis*) is arguably one of the world's most mysterious large mammals. It was not discovered, or at least formally described, until 1993 in an isolated mountainous region between Vietnam and Laos (Van Dung et al. 1993). Population sizes were already low at that point, and they have decreased further since then. The last confirmed sighting was in 2013 by a camera trap, and there are now legitimate concerns about its continued survival in the wild. Due to these facts, little is known about the saola, including its diet, behaviour, ecology, history and genetic variation.

Vietnamese scientists had been able to collect a number of saola specimens from hunter's huts in the region where it was first discovered, and these samples had been shared with Danish researchers to facilitate DNA extraction and a genetic characterization of the elusive species. However, at the time (in the 90s), DNA extraction from these degraded samples proved elusive, and only a small fragment of the mitochondrial DNA could be sequenced (Van Dung et al. 1993). In 2015, we and other researchers from the Department of Biology and Globe Institute at the University of Copenhagen explored the possibility of giving DNA extraction another try with recently developed ancient DNA techniques. Furthermore, more samples had been collected by our Vietnamese collaborators, providing a larger number of specimens to try DNA extraction on. This proved highly successful, and a total of 33 samples provided enough DNA to warrant whole-genome sequencing. One sample even yielded good enough DNA to attempt long-range insert size mate-pair libraries, which can be used for de novo genome assembly.

Due to the degraded nature of the DNA, extra care had to be taken in the bioinformatics processing of the raw data, and eventually only 26 individuals were included in the analyses, some of which were still of such a compromised quality that they could not be used for the most sensitive analyses. Despite these limitations, we managed to carry out a series of analyses that shed considerable light on this most enigmatic of mammals. First, we resolved the phylogenetic placement of the saola as a sole sister lineage to the cattle and buffalos, but 14 million years divergent from them (Figure 1). This proves that the saola is quite evolutionary distinct, and therefore represents important biodiversity lost in case it goes extinct.

Second, we found a surprising amount of population structure among the samples, which grouped very distinctly into a northern and a southern genetic



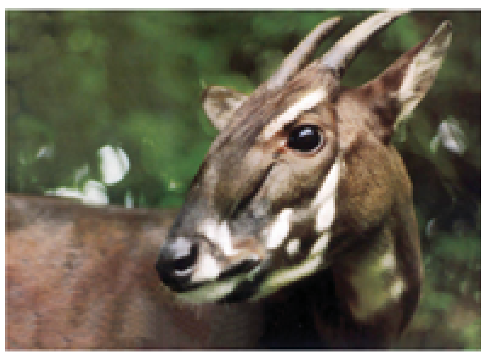



**Figure 1:** Placing the saola in the bovid phylogeny. The saola is the closest relative to the group encompassing cattle and buffalos, and diverged from them about 14 million years ago. Photo by Toon Fey, WWF.

cluster (Figure 2). These two populations have a differentiation index of *F*ST~0.49, about as high as Reticulated and Masai giraffes (Bertola et al. 2024), which were recently classified as distinct species (IUCN 2025).

However, the two saola populations are highly differentiated because they had historically low and declining population sizes since their inferred split about 5000-20,000 years ago, which is recent in evolutionary times (Fig. 3), and not due to having been isolated for 100,000s of years like the giraffes.

As expected due to the low historical population size, saolas have very low genetic diversity and high genetic load, on par with other threatened species with extremely reduced population sizes (Figure 4).

However, using simulations we showed that saolas have actually purged a lot of genetic load from their genomes as a by-product of the sustained population decline, meaning that their load is now much lower than it would have been if their population decline had been more sudden.

Furthermore, we also found that the loss of diversity in each population due to the effects of inbreeding and genetic drift was sufficiently independent that they to a large extent did not lose diversity in the same regions, and that at least some diversity is retained in most genomic regions when considered across the two populations. Obviously this is not useful for the saolas in their present, isolated state (assuming some are still even out there), but what we found - again using simulations - was that this complementarity could actually be good news for the species.

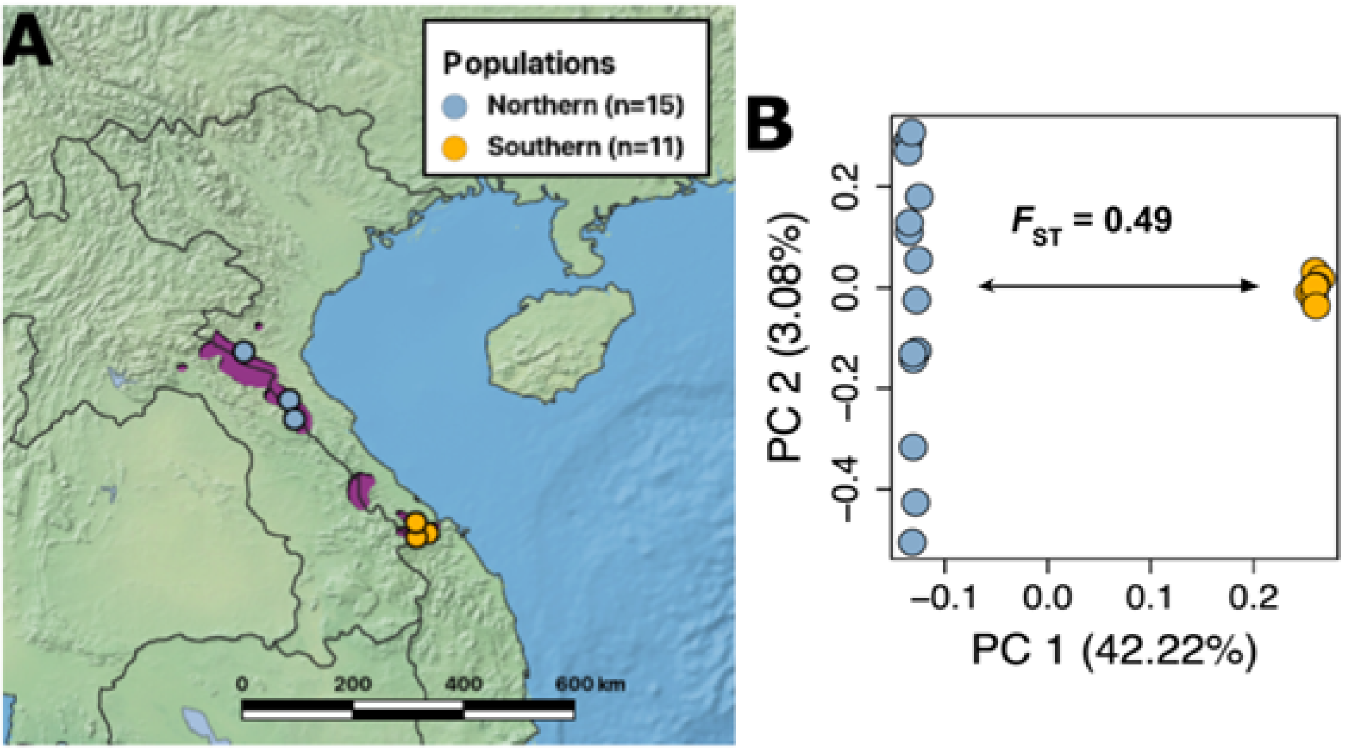



**Figure 2**: Two distinct saola populations with high genetic differentiation were identified. A: Map of the analyzed samples; B: Principal Component Analysis showing large differentiation, with FST between the Northern and Southern population.

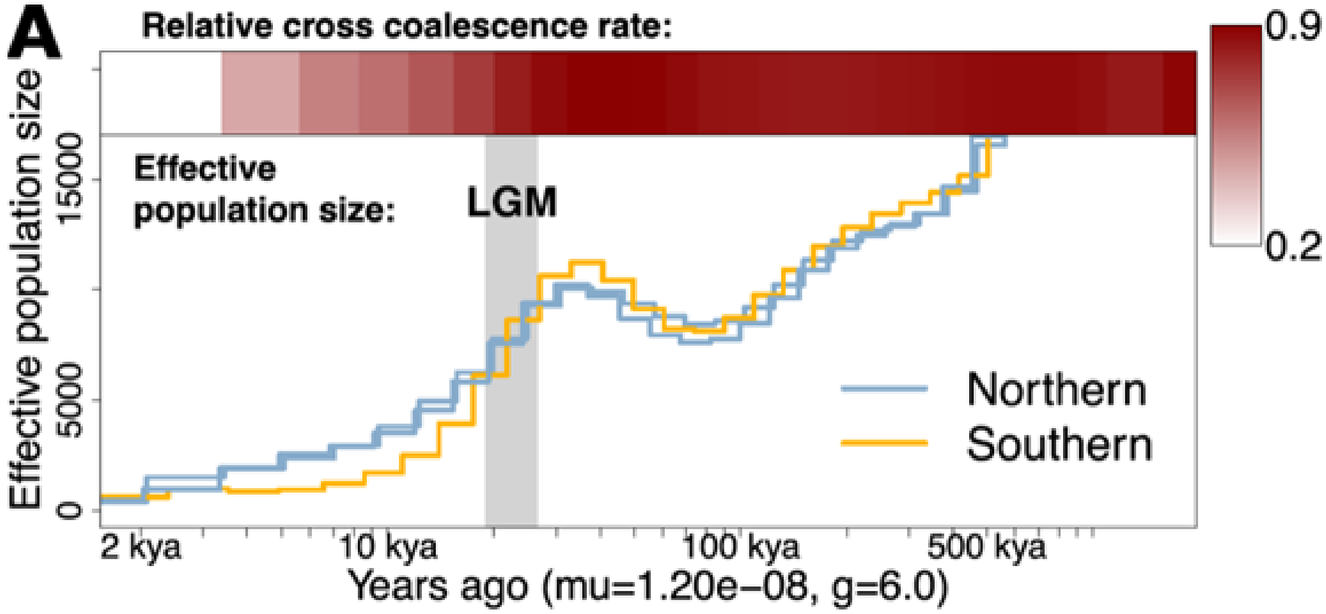



**Figure 3:** Population size history based on a PSMC analysis. Effective population sizes of the two inferred populations are shown with blue and yellow curves. Above the main plot is the relative cross coalescence rate between pseudo-haploid regions across the two populations, indicating the level of cross-population genetic connectivity (or divergence) over time.

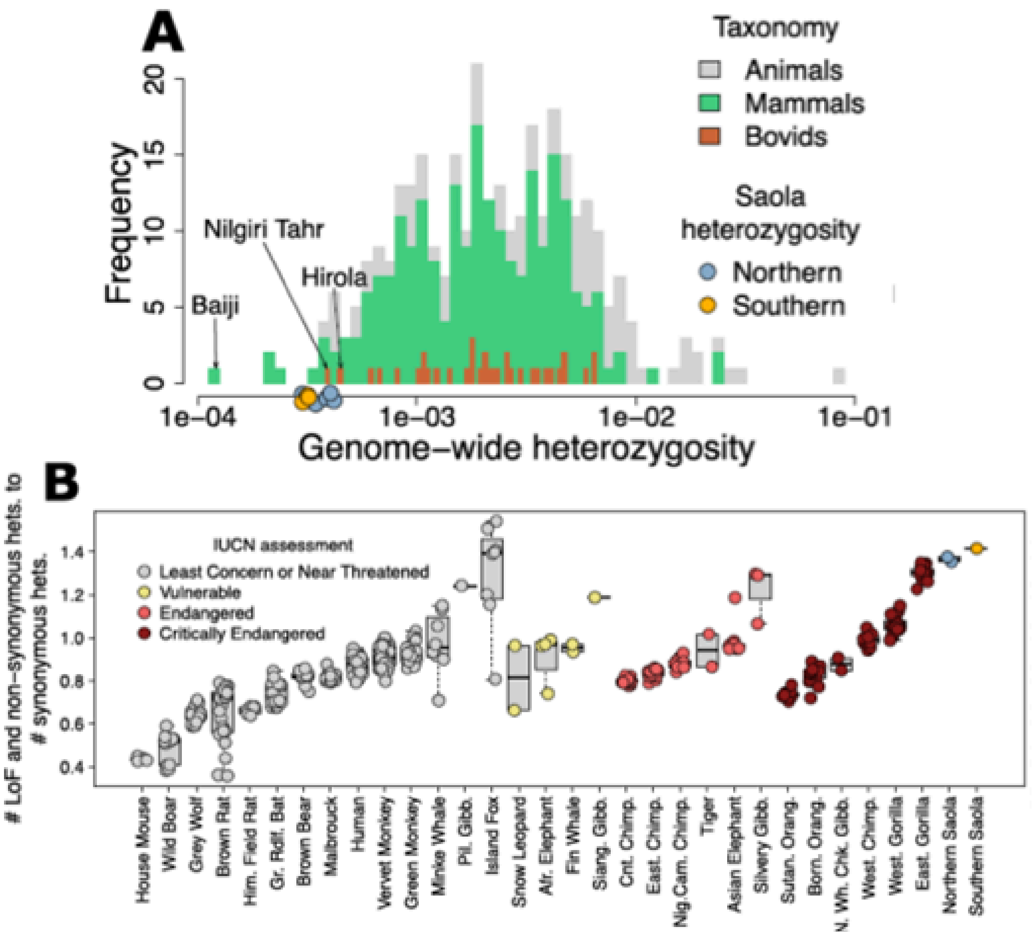



***Figure 4:*** Genetic diversity in the saola. A: Genome-wide heterozygosity in saola individuals compared with a range of other animals with whole-genome data; B: Genetic load measured by the number of Loss of Function (LoF) and non-synonymous heterozygote sites divided by the number of synonymous heterozygous sites for a range of individuals. Saolas are on the extreme right, showing very high genetic load. The IUCN Red List category of each species is denoted by grey to red colors.

IF - and that's a big if - a number of individuals from each population could be brought together in a captive breeding program, then their genetic health and survival chances would be much higher than it is in each of the two isolated populations naturally occurring in the wild. According to our simulations, 24 founders (12 from each population) may be required to reach a reasonable probability of population survival (Figure 5). This is a very optimistic scenario, as it is unlikely that 24 founders can be found and brought into a productive breeding program. We emphasize that this simulation comes with uncertainty and simplifying assumptions, and it deals only with the effects of genetic load and sex ratio stochasticity (i.e. taking into account that populations die out if any one of the sexes becomes extinct). However, we believe that such simulations are still useful to provide at least some expectations about the effect of accumulated genetic load on species survival on the short to medium term.

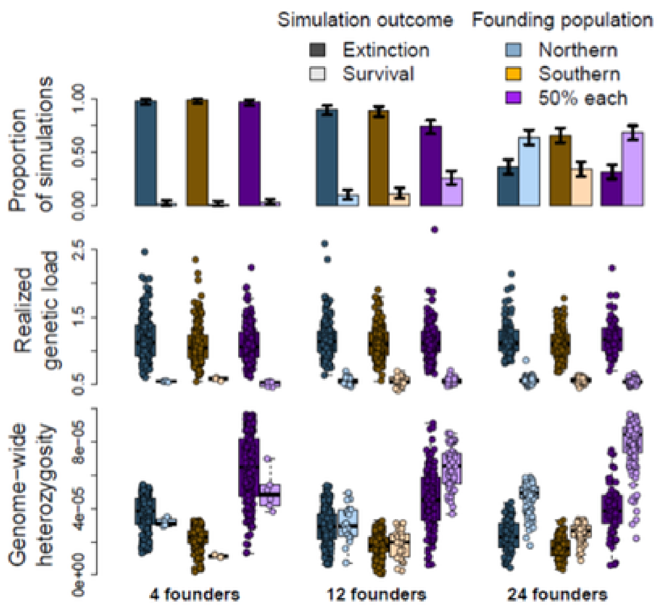



**Figure 5:** Forward simulations of the population survival (top row), genetic load (middle row) and genetic diversity (bottom row) of saolas under different management scenarios: 4, 12 or 24 founders derived from either the Northern, Southern or a mixed founding population. Population survival becomes more probable than extinction only with 24 founders mixed from the Northern and Southern population (top right barplots).

In conclusion, this study provides the first whole-genome based insights into what might be the most endangered and understudied large terrestrial mammal in the world. We urge that more resources are devoted to try and locate live saola individuals, and that a captive breeding program with contributions from both populations may offer the best chances of species survival.

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# Sabah banteng day 2025: Conservation through community and sport

*By Amy Humphreys, edited from Sabah Banteng Day & Sports for Conservation with Community 2025 report by Flayceana M. Binijin & Fadlin Linsai*

**Figure 1:** The women's tug of war match was driven by passion and relentless energy © Sheelasheena Damian/WWF - Malaysia

In August 2025, the Sabah Wildlife Department and WWF-Malaysia launched the inaugural Sabah Banteng Day in Lahad Datu, Malaysia a pioneering event that blended conservation science with community engagement and sport. Held over two days, the event aimed to raise awareness of the endangered Bornean banteng (*Bos javanicus lowi*) while fostering local stewardship through inclusive activities.

The event featured two key components. The first was the official launch of Sabah Banteng Day, marked by the unveiling of two major conservation tools: the Mid-term Review of the Bornean Banteng Action Plan 2019–2028 and a new Research and Monitoring Manual. These resources provide updated insights and field methodologies for identifying, aging, and profiling banteng populations, critical steps in guiding conservation efforts.

The second component, "Sports for Conservation', introduced the Banteng Cup, a spirited tournament involving football, volleyball, and tug-of-war. With 149 registered athletes and broad community participation, the games promoted teamwork and environmental responsibility.

Community response was overwhelmingly positive. A total of 211 participants engaged in the event, with 94% of exhibition visitors expressing high satisfaction. While male participation was higher overall, the exhibition drew a balanced gender mix and a strong turnout from children and youth, highlighting its educational reach.

This innovative approach demonstrates how conservation can thrive when science is paired with cultural relevance and community pride. Sabah Banteng Day sets a compelling precedent for integrating biodiversity protection with grassroots engagement.

# Double observer point count operation of tamaraw at Mounts Iglit-Baco Natural Park, Mindoro, Philippines

*By D'ABOVILLE Foundation and Demo Farm Inc.*

**Rationale and development**

The double observer estimator method, combined with the point count approach (direct field observations) also refered to as the simultaneous multi vantage point count method (Bonenfant et al, 2023), was introduced at Mounts Iglit-Baco Natural Park (MIBNP) to address the main limitations of the simultaneous multi-vantage point count method that has been used for the annual tamaraw (*Bubalus mindorensis*) population survey since 2000. These limitations include: (a) the absence of a confidence interval (CI), (b) the fact that detection probability is not included in the estimates, and (c) the problem of subjectivity when removing multiple counts. The final aim of the double observer approach is to provide a more robust estimate of the true number of tamaraw inside the 2200ha count zone.

The double observer estimator method was first tested at MIBNP during the annual tamaraw population count 2019 on five (5) vantage points (VP). It was then repeated in 2021 on fifteen (15) vantage points. The protocol was then refined and simplified to overcome the issues faced in the initial trials and to facilitate implementation by local teams. This refined protocol was used in subsequent years (2022, 2023, 2024, 2025). There were slight changes in the set-up of the operations between years (number of teams, survey conducted simultaneously with the annual count or not) but these are not expected to have major impacts on the results. Refresher trainings were organized prior to each operation to ensure that participants were familiar with the survey protocols.

A statistical model was developed in 2022 to analyse the data. The model was tested after each double observer point count survey to validate the consistency of the statistical method.

**2025 DOPC Operation**

In 2025, the Double Observer Point Count operation (DOPC) was carried out from April 1 to April 7. This period was just after the annual point count, and therefore with similar vegetation conditions in the count zone. We set a total of nine (9) teams composed of three (3) people each (observer 1, observer 2 + 1 referee) and additional camp helpers. As for the previous years, one objective of the protocol and field itinerary (location of each team on their assigned VP at the same time across the count zone) was made to reduce the chance of two

**Figure 1:** One team of two independent observers on their assigned vantage point during the Double Observer Point Count operation in April 2025 (© DAF)

adjacent VPs, with high risk of count the same animal multiple times, to be monitored at the same time. A refresher training was conducted on the first day before deployment of the teams, in order to recall the rules of the protocol and the consolidation process. We covered a total of eighteen (18) vantage points (only Tarzan and Saligue east were not included due to absence of observation, or counting of very few animals during the annual count), each team moving to its next assigned VP after the second day. For each VP, we carried out a total of 4 sessions (2 evenings and 2 mornings) encompassing 2 sub-counting sessions of 15min with a one hour interval between each sub-session. As in previous years, the information recorded included number of reproductive (adult and sub-adult male/female) and non-reproductive (calf, yearling, juvenile, sub-adult) animals.

Immediately after each screening, observers consolidated their raw data to determine which animals were individually seen by observer 1 only, observer 2 only, and by both. The consolidated results were reviewed and finalized following the completion of the operation. These finalized data were then used in the statistical model.

### General observations during the operation and what we learned

- Observation: The absence of certain participants during the agreed upon date for the training (for various reasons) may generates operational vulnerabilities, particularly in understanding protocols across team - it is crucial to have clear and effective coordination with PAMO and TCPO on this.
- Observation: There were instances where adherence to the assigned monitoring schedule was not strictly followed, which may potentially affect the accuracy of the data - commitment to fully respect the protocol and planned scheduled sessions must be ensured in all cases.
- Observation: It seems important to re-explain the fundamental concept/principles underlying the DOPC at every operation so the participants appreciate that this method aims at addressing the limits of the simultaneous multi-vantage point count method as used for tamaraw – the DOPC is not the future and alternative counting method in itself.
- Observation: Getting the right amount of supplies, and appropriate equipment for the entirety of the DOPC is always a challenge. Although there was sufficient this time, there were some issues with rice quantity and availability of equipment - supply and equipment are technical problems easy to address that should not affect the overall quality of results.

**Results of the 2025 DOPC operation**

The consolidated data were analyzed by our scientific partner from France, Dr. Christophe Bonenfant. To ensure consistency in the model and its outputs, data from previous operations were reprocessed alongside the 2025 dataset.

The confidence interval provides the lower and higher estimate for each population estimate as returned by the statistical method.

| Year | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| Annual point count | 403 | 325 | 433 | 380 |
| DOPC with confidence interval | 180<br>[143 – 199] | 185<br>[139 – 243] | 238<br>[193 – 290] | 261<br>[207 – 323] |

**Figure 2:** This table summarizes the estimated number of tamaraw as returned by the statistical model and compares it with the results of the annual count.

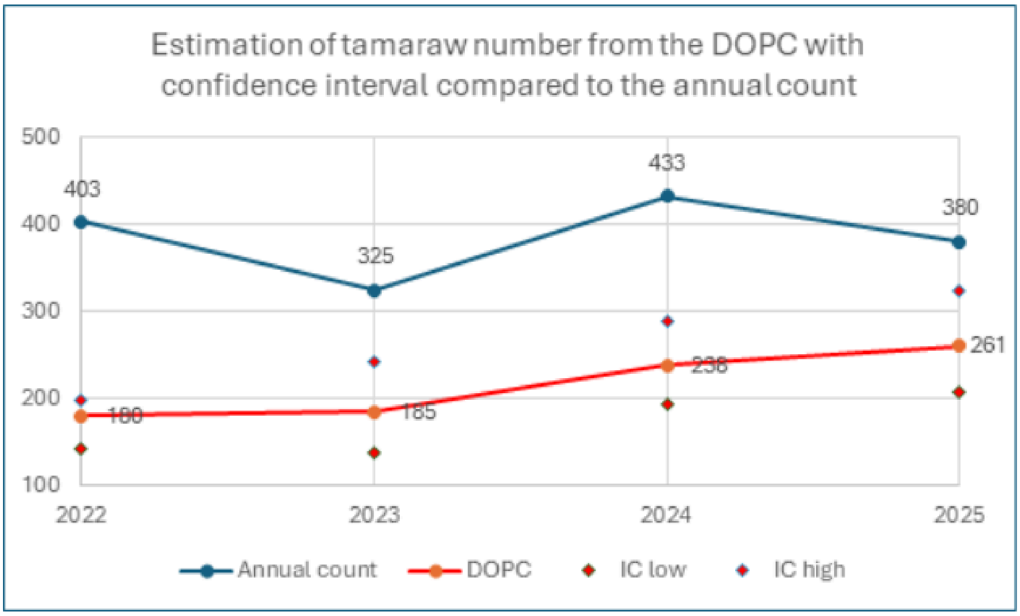


**Figure 3:** The graph highlights the difference in trends and estimates as returned by each counting method

## Conclusion and interpretation

The results from the double observer estimator indicate that, for all DOPC operations, the probability of tamaraw detection was less than 1. In practical terms, this means that some animals are missed by observers from their vantage points, emphasising the relevancy of the double observer approach

As with previous years, the DOPC 2025 estimates a tamaraw population much lower than the annual count suggests (approximately 44% less in average). In addition, the variability between years is much lower with the DOPC compared with the annual count making the DOPC estimate biologically more realistic; for instance, the increase from 325 animals in 2023 to 433 animals in 2024 from the annual tamaraw count is not possible for a large herbivore like the tamaraw with litter size of one calf and almost a year of pregnancy.

This reinforces the idea that the DOPC dramatically limits errors associated to the census operation, and particularly the subjectivity when trying to identify multiple counts across vantage points (observer bias, consolidation phase…). Overall, the annual point count shows high variability but a relatively stable trend, averaging around 385 individuals over four years, suggesting the population may have reached a plateau. In contrast, the DOPC indicates a slight increase in the estimated number of tamaraw over the four operations. However, it is important to examine the details carefully before drawing any definitive conclusions.

First, we should consider the intrinsic limits of any census method relying on direct observation of animals in the wild. Although the DOPC method explicitly accounts for imperfect detection probability, the data collection itself is subject to the same constraints that are present with the annual count. These constraints include the fact that animals may be missed due to inclement weather conditions or human disturbance. For instance, weather conditions and limited visibility were flagged as a particular issue during the 2022 and 2023 surveys, while disturbance from external people moving across the count zone may have disturb the normal behaviour of the animals. In addition, it appears that the teams' ability to adhere to the protocol particularly in terms of data consolidation—has improved over time. As a result, the observed increase over the four operations may be partly attributed to these methodological improvements, rather than solely reflecting a true rise in tamaraw numbers. For the above reasons, we can assume that the method likely underestimated the population in 2022 and 2023 compared to 2024 and 2025. Second, it is also important to consider the confidence interval—one of the key strengths of the DOPC method and, conversely, a principal limitation of the simultaneous multi-vantage point count approach. Notably, the width of the confidence interval (i.e., the range between the lower and upper bounds) is a good indicator to understand and interpret the results observed.

More specifically, population estimates, as returned by the DOPC, show that the higher value of the confidence interval estimate in 2022 (N=199) if very close to the value of the lower confidence interval estimate in 2025 (N=207). Considering that both results are statistically plausible, this may indicate a stable rather than increasing population. This interpretation actually aligns with the findings of the annual point count. Notably, both values are also close to the average number estimated by the DOPC across the four years ($M_{mean}$ = 216).

In conclusion, and after four years of implementing the DOPC alongside the annual count, the DOPC proves a more reliable method, effectively addressing key limitations of the traditional count. Although the results of the annual count are a good indication of the relative trend of the population over time, the method only provides a relative abundance estimates which appears to overestimate the true number of tamaraw without any information on the range of error. Reversely, the DOPC provided a more realistic estimate of actual tamaraw numbers.

While we remain hopeful for a genuine increase in the tamaraw population, the overall data suggest a possible stagnation in the population, with approximately 200 to 220 individuals present within the count zone. Nevertheless, four data points are insufficient to draw definitive conclusions about long-term population trends and dynamics. It is therefore essential to continue building the DOPC time series until a full transition is achieved through the implementation of the Ecological Change Indicator (ECI) package, which was endorsed by the Corridor Alliance Advisory Committee (CAAC), Resolution No. 1 series 2024.

In addition and despite the fact that comparisons between the DOPC and the annual count provide useful insights, the decision to discontinue the annual count (for reasons such as budget, human resource and time limitations)—potentially even before the grassland burning phase-out—is ultimately a matter for policymakers.

The double observer point count operation is conducted in collaboration with the Philippines Department of Environment and Natural Resources (DENR), more specifically the Tamaraw Conservation Program Office (TCPO) and Protected Area Management Office for Mts Iglit-Baco Natural Park (PAMO MIBNP).

Since its initial test in 2019, the following partners have been supporting the operation: Re:wild, Mandai Nature, ZGAP, Berlin Tierpark, AFdPZ and UKAID DARWIN I.

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# An experiment in enhancing nutrition for wild Bornean banteng in Sabah, Malaysia

*By Zainal, Z.Z[1], Alvin Erut[1], Abdul Hamid Ahmad[2] AND Payne, JOHN[2]*
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*1 Borneo Rhino Alliance, Lahad Datu, Malaysia, 2 Borneo Rhino Alliance, Lahad Datu, Malaysia*

**Abstract**

The Bornean sub-species of the banteng (*Bos javanicus lowi*) is scattered into isolated herds, stagnating or declining, with total numbers believed to be in the low hundreds, and with none in captivity. The post-Pleistocene, pre-Anthropocene preferred habitats of Bornean banteng would have been riversides, swidden farms and periodically burned lands, but those habitats have almost entirely disappeared in favour of permanent crops and human settlements. In Sabah, Malaysia, most of the approximately ten remaining Bornean banteng herds live in forest reserves with very few grassy sites. As these previously logged forests regenerate naturally with tree cover over time, availability of grasses to banteng will decrease even further. The hypothesis that Bornean banteng numbers can recover only if grass quality and productivity is enhanced where remnant herds still exist was tested by interventions on an abandoned logging road in Tabin Wildlife Reserve. From 2019 to 2024, birth rate of banteng in the last-remaining herd there increased in tandem with development and maintenance of 5 hectares of grassland and constant provision of mineral sources. Development and maintenance of managed pastures with mineral sources inside forest reserves may represent a significant means to help recover the Bornean banteng population, by increasing the reproductive potential and sizes of the scattered remnant herds.

**Keywords**

Bornean banteng, grass, weed removal, minerals, birth rate

**Introduction**

Following the rise in sea level between the last glacial maximum (c. 21,000 years BP) to around 11,000 BP, there was a 50% loss of the exposed Sunda land area (Sathiamurthy & Voris, 2006; Kim et al, 2023), including loss of grasslands through expansion of rainforest (Bird et al, 2005; Wurster et al, 2019). Wild bovids would likely have lost vast areas that incorporated grazing land. Charles Wharton (1968) demonstrated convincingly that after around 11,000 years BP, human use of fire to burn forest and in more recent millennia to grow rice and other food crops - thereby evolving a swidden farming system with long fallows containing grasses - was the key to sustaining habitats that allowed survival of wild bovids in Southeast Asia during the Holocene epoch. Naturally grassy riverbanks, many uninhabited by humans until recent centuries, would have added tothe available bovid feeding habitats. The Bornean sub-species of banteng (*Bos javanicus lowi*) was locally common in the late nineteenth century. For example, Anon. (1892) reports the finding and shooting of wild banteng within a day's travel of Kudat town on three out of four days in September 1892, in habitat consisting of a mosaic of grasslands and secondary woody growth.

Since then, Bornean banteng was wiped out of most of its former range through a combination of use since the late nineteenth century of firearms for killing them (for meat or trophies) and a massive change in rural human economies from swidden to settled farming over the twentieth century. Following the great El Nino droughts and fires that affected Borneo in 1982-83 and 1997-98, the governments of all Borneo regions strengthened, and largely implemented, legal restrictions on use of fire to prepare land for cultivation. Thus, the original preferred habitats of Bornean banteng have almost entirely disappeared over the past century.

The survival of the Bornean banteng probably now depends on interventions in Sabah, the region of Malaysia that occupies the northern 10% of Borneo. This is because, apart from one small cluster in the

Sarawak and Brunei border area and in a few widely-scattered sites in the Kalimantan provinces Sabah has the greatest number of small, scattered remnant herds (Phillipps & Phillipps, 2018; Pustaka Yayorin, 2019). The patchwork of regenerating vegetation previously generated by swidden farming has to some degree been mimicked by commercial logging of dipterocarp forests from the 1920s to early-2000s (Ibbotson, 2014). But those logged forests have now either been converted to permanent plantations or left to regenerate naturally back to forest cover within recently-legislated protected forests.

It is popularly believed that the greatest threat to the survival of the Bornean banteng is illegal hunting. In the Bornean Banteng Action Plan for Sabah (Sabah Wildlife Department, 2019) the emise of this sub-species is attributed to 'hunting and indirect snaring, habitat loss (including pastures) and fragmentation. However, noting that the 2016 estimate for Bornean banteng numbers in Sabah (about 350 in total; Sabah Wildlife Department, 2019) is not much different from a 1982 estimate (300-550 in total; Payne & Davies, 1982), Payne et al (2021) suggested that the wide scatter of small, isolated clusters, evident stagnation in numbers at all locations and observed variation in individual body condition were likely due largely to lack of sufficient year-round quality food. As the protected areas now containing wild banteng are almost entirely covered in woody vegetation, and woody plants are unlikely to be a limiting factor in the banteng diet, they suggested that (apart from captive breeding, which has not materialised) the most important intervention to prevent the extinction of the Bornean banteng would be the establishment of managed grasslands where banteng herds still occur. This idea was pursued by Borneo Rhino Alliance (BORA) on an abandoned old logging road in Tabin Wildlife Reserve. The work was done to seek proof of concept that targeted habitat modification can influence positively the fecundity of Bornean banteng in regenerating logged forest.

**Study area**

The study area lies within the western boundary of Tabin Wildlife Reserve (1,255 km2), north-east of Lahad Datu town in eastern Sabah (Figure 1). Prior to the 1960s, the entire region was covered in

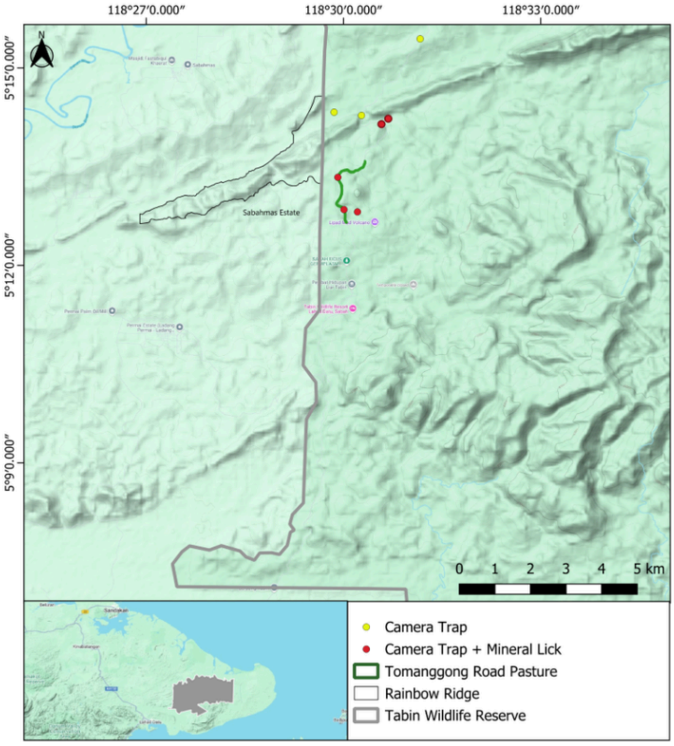


**Figure 1:** Location of the study area

closed-canopy natural dipterocarp forest, with prime banteng habitat confined to the banks of the largest rivers in the region. Annual rainfall over 11 years (2013-2023) at the nearest location to the study area (20 km to the south) averaged 3,300mm (1,969mm - 4,613mm). Periods of very little rain occur rarely. Soils are clay-rich, on underlying sedimentary rocks.

The specific study area is an abandoned road (known as Tomanggong road) built along gentle hill slopes and used from around 1972 to 1984 for log extraction from the surrounding dipterocarp forest using massive trucks. In 1984, the remaining former commercial forest was re-designated as Tabin Wildlife Reserve and commercial wood extraction was ended by 1990. The road was re-opened and used intermittently by four-wheel drive vehicles between around 1990 to 2014 as an alternative access route to an oil palm plantation, since when the road was abandoned. By 2018, most of the Tomanggong road had been reduced to a 1-2 meters wide pathway maintained by ungulates through thick secondary plant growth composed largely of native and invasive exotics forbs and shrubs, with natural successional tree regrowth along the apron and woody plants gradually replacing forbs and grasses. In 2019, we chose a 2.5 km portion of the road (N 05.19135°, E 118.52298° to N05.22688°, E118.52766°, elevation 50-140m asl) for management interventions aimed at improving Bornean banteng nutrition. We chose this particular site because of the observed periodic presence there of a herd of Bornean banteng, accessibility, and non-necessity to fell trees. In addition, the study area lies within a kilometre of an oil palm estate under the Wilmar International group, into which the Tomanggong road banteng frequently venture, presumably to eat grass. The 2.5 km stretch of road and its apron selected for development of pasture varies in width, with an average of about 20 m. Thus, the area of pasture developed in this study is about 5 hectares. Monitoring by BORA and WWF-Malaysia throughout Tabin Wildlife Reserve since 2021 indicates that the study herd reported here is now the only remaining herd of banteng in the Reserve. Thus, no control site is available to compare results of the interventions on Tomanggong road, and no statistical analysis of the results is possible.

**Methods**

**Habitat improvement**

We assumed that the factors limiting banteng numbers and reproduction are year-round availability of high-quality (young and short) grass and / or essential minerals that may be limiting for large herbivores in equatorial rainforest vegetation. We learned from recent feeding signs which plant species were often eaten by banteng, and which rarely or never eaten. Starting in year 2020, we manually cut grasses to favour new growth and, most crucially, removed plant species rarely or never eaten by banteng, and added 10 kg multi-mineral blocks (containing Na, Ca, P, S, Fe, Mn, Mg, Zn, I, Co, K, Se and Cu) at two sites, subsequently five sites, along the road, with replacement as necessary). Initial preparation of the 5 hectares took almost one year of effort. Favoured food plants already growing on site were noted to be the grasses *Paspalum conjugatum* and *Axonopus compressus*. We did not find banteng feeding on common forbs and shrubs that repeatedly invade the site, including *Chromolaena odorata, Clidemia hirta, Mikania micrantha, Mimosa pudica, Caesalpinia sumatrana, Melastoma malabathricum, Alocasia macrorrhizos* and Zingiberaceae species. We removed those plants (referred to as ‘weeds’) manually, in teams of 4 to 6 men, monthly, with removal at any given site done every two or three months. At several sites where grass did not grow well, fertilizer was applied in the early stages of the study, but this was discontinued as it was realized that overall grass production was hardly impacted by application in just a few sites. In order to increase the diversity of grasses in the study area, we planted Napier grass (*Pennesetum purpureum*), as well as native fig trees, *Ficus francisci* and *F. racemosa*, whose leaves were observed to be relished by deer and banteng.

**Monitoring with camera traps**

Banteng inhabiting the Tomanggong road are extremely wary of humans, and in 2019 were visiting the selected study area only rarely and at unpredictable intervals. Monitoring could be achieved only by deployment of camera traps. We used eight to twelve camera traps (CTs) to monitor the Tomanggong road from October 2019 to December 2024. We chose locations for setting CTs based on where it was thought that good images would be obtained. We set most of the CTs along the side of the old road, and some on adjacent forested trails. Several CT models were used, depending on budget availability and failures of individual CTs. We programmed CTs to take videos (one video clip of 10-30 seconds) and still images (three images at one second interval per trigger), changing to videos only in later years. We checked the CTs at monthly intervals, retrieving the secure digital (SD) cards and changing batteries. Images and video clips from the CTs were manually analyzed, and tabulated on a monthly basis for body condition scores, health, behaviour, age, individual identification, reproduction, and distribution.

**Body condition scoring (BCS) and age**

Body condition scoring (BCS) was done by inspection of CT images. The five-point scoring system used in cattle industries world-wide and tested by Prosser et al (2016) for banteng in Sabah was used in this study. BCS evaluation can differ between observers (Audigé et al 1998). This concern was eliminated by a single person (ZZZ) assessing BCS throughout the study.

## Herd demography

Initially, we estimated ages of banteng seen on CTs based on daily records of weight and height of two Bali cattle (closely related to Bornean banteng; one male, one female) that were hand-raised from a week after their birth by BORA staff from January 2020 to mid-2021 in the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah. Subsequently, the known ages of Bornean banteng calves born during this study were used as a guide. We installed measuring stakes (Figure 2) in front of several camera traps to measure the shoulder height of individual banteng as an indicator of age and growth. Additional major features in determining age were coat colour, horn length and shape. In the case of bulls, in addition to horn length, shape and colour, the size of the boss and presence of wrinkles around the eyes and frontal were used as an indicator of age. Calves could be identified readily in CT images and videos due to their small size, pale colour and horn 'buds' or very short horns. Not all individual calves can be distinguished from each other in all images, but the overall annual number of births could be confirmed by viewing of multiple videos. Following repeated attempts to derive a practical Banteng age/sex classification from CT images, the following was chosen: dominant bulls (>7 years), adult bulls (>4 years to 7 years), heifer bulls (up to 4 years), cows (>4 years), heifers (up to 4 years), and calves (less than 12 months).

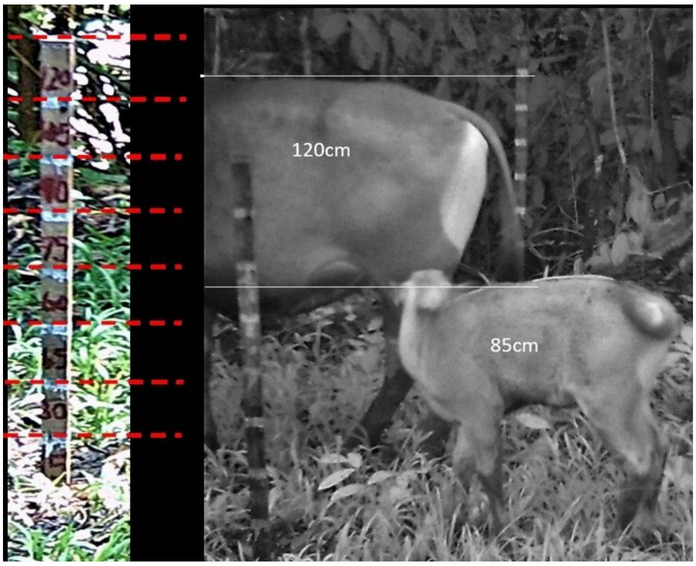


**Figure 2:** Measuring stakes placed in front of camera traps allowed for estimation of age and growth rates

## Reproductive performance

We assessed breeding performance by recording births in each year. We assumed that, as with cattle and Malayan gaur (Norsyamimi et al. 2023) in healthy condition individual Bornean banteng cows can calve once a year.

## Results

## Habitat improvement

All the observed favoured food plants were grasses, notably (in decreasing order of preference) carpet grass (Axonopus compressus), buffalo grass (Paspalum conjugatum), giant paspalum (Paspalum urvillei), itchgrass (Rottboellia glandulosa) and Leptochloa panicea. It was noted that the banteng very rarely fed on tall grasses (more than about 60 cm tall) or on grasses that were flowering or fruiting. P. urvillei and R. glandulosa had to be trimmed periodically before the culm became too tall for banteng to feed on them, but the other three species were grazed sufficiently by banteng and deer to retain a lower height.

Some sedges, shrubs and woody plants were eaten in smaller quantities. Of the ten plant species listed in previous publications as favourites of Bornean banteng foods (Gardner et al, 2019) we did not observe two of them (Chromolaena odorata and Mikania species) to be consumed by banteng on Tomanggong road. Weed removal proved to be the major consumer of time in this study. Airborne and bird dispersed seeds of forbs, shrubs and woody plants frequently showered the Tomanggong road, and germinated rapidly, one of the worst being Clidemia hirta (Figure 3).

We made a quantitative assessment of the manpower requirements to maintain the pasture. Even the best-adapted people cannot carry out sustained normal outdoor activities when the wet bulb temperature reaches 32°C (Raymond et al, 2020). Humidity in tropical rainforest varies through time, but in Tabin it will likely approach human tolerance level by late morning on hottest days. We made a quantitative assessment of the manpower requirements to maintain the pasture.

Even the best-adapted people cannot carry out sustained normal outdoor activities when the wet bulb temperature reaches 32°C (Raymond et al, 2020). Humidity in tropical rainforest varies through time, but in Tabin it will likely approach human tolerance level by late morning on hottest days. Weeding during heavy rainfall was not practical. A typical work plan would be 07.30 am to 1.30 pm, including one hour of rest, and 5 hours of work. Reaching the far end of the pasture took at least 45 minutes of fast walking by experienced workers. It was found that, on average, one worker can remove the great majority of weeds from a pasture length of 12 metres in one hour of work. With a gap of 2 to 3 months between removal of weeds from any particular stretch of pasture, there was approximately 12.5 kg of weeds per 12 metres.

Mineral licks The multi-mineral blocks proved to be a very significant attraction to the banteng, and were licked by probably all banteng herd members whenever they visited the Tomanggong road. Actual usage by banteng is impossible to gauge, as the same blocks were licked by many other wild mammal species including all ungulates and macaques. Rainfall hastened loss.

Monitoring with camera traps About half of all CTs were irreparably damaged over the study period due to electronic failures, rusted components or physically by elephants or macaques. Loss of function of camera traps was a significant constraint, resulting in some of the cameras lacking imagery in most months. More expensive brands tended to last longer than cheaper ones. Most importantly, we found that small numbers of videos are far superior to large numbers of still images in terms of acquisition of useful information. Video imagery captured a greater proportion of a herd (so that estimating numbers and composition is easier), the subtle differences between individuals that are usually unclear in still images could usually be seen in videos, deciding on individual BCS was more accurate, and interactions could be seen between individuals, providing further clues on age, relatedness and dominance.

Identification and body condition scores
We found that perineal markings were visible in about 30% of all individuals from as early as six months of age (Figure 4), with size, shape and

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**Identification and body condition scores**
We found that perineal markings were visible in about 30% of all individuals from as early as six months of age (Figure 4), with size, shape and
configurations of the markings unique to each individual and not changing with time.

Prior to grass-planting interventions, the BCS of all Tomanggong road banteng ranged between 1 and 3. A year after the habitat enrichment began, the

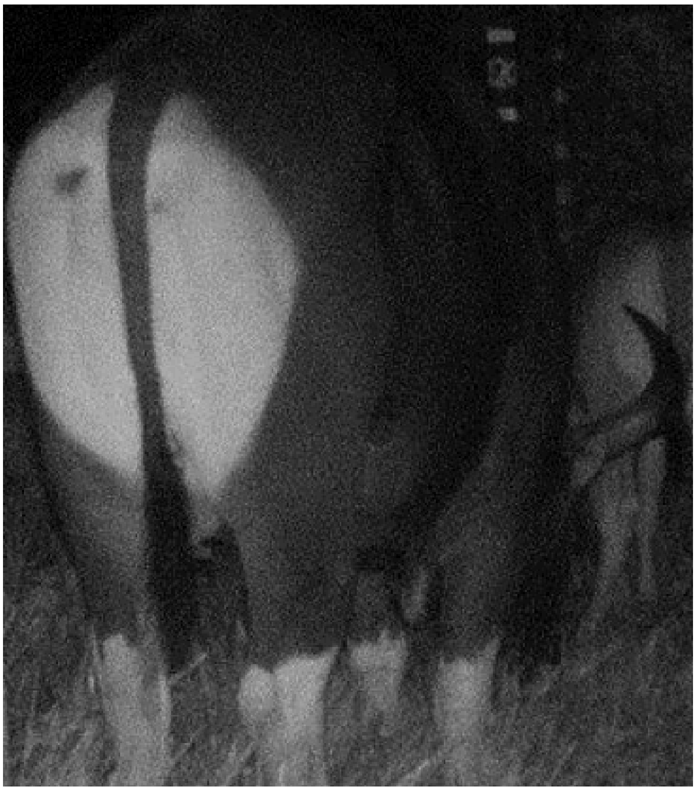

**Figure 4:** Perineal marking on the rear of a bull

average BCS improved, but was variable through time and between age groups at the same time, with juveniles, sub-adults and cows still tending to having a BCS of 1 or 2. Cows with calves tended to lose condition as the calves grew older, and as the calves required more intense suckling prior to weaning. Even after weaning, growing calves were observed on video images to keep harassing cows for milk, thereby interrupting her grazing. In addition, sub-adults were constantly harassed by adults of both sexes at favoured feeding sites and mineral blocks.

The only evidence of calf mortality was one calf in year 2024, where circumstantial evidence suggested shooting of the mother outside Tabin Wildlife Reserve.

## Reproductive performance and herd demography

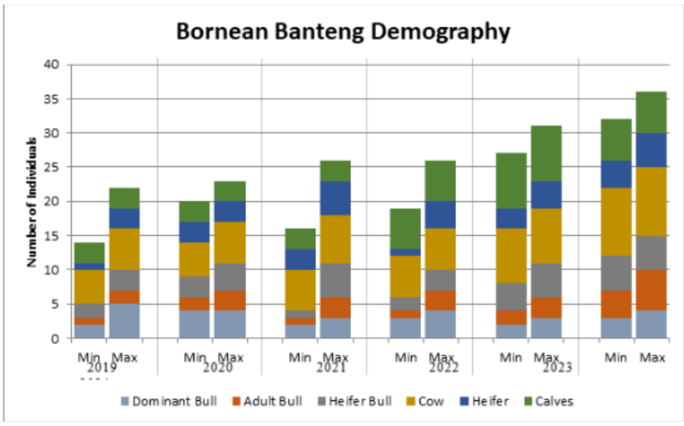


**Figure 5:** Bornean banteng demography, Tomanggong road, Tabin Wildlife Reserve, 2019-2024

## Discussion

Previous studies of wild banteng or banteng introduced into wild habitats have identified various factors associated with observed habitat preferences including proximity to salt licks (Thailand; Chaiyarat et al 2023), methods of logging (Sabah; Gardner, 2019) and presence of a mix of grass and forest (Northern Territory, Australia; Bowman & Panton, 1991).

The increase in number of births in the herd in years 2022 and 2023, also 2024 compared to previous years suggests that the interventions on Tomanggong road are likely to have boosted nutrition for the cows.

No reason can be suggested for the drop in calving rate in 2024 compared to 2023, other than random annual fluctuations that can also be observed in domestic cattle. The absence of a control site precludes a definitive conclusion. However, no alternative interpretation seems plausible. Also, there is no means to ascertain whether the increase in fresh grass availability or the provision of mineral blocks was the more important factor or whether the combination of both resulted in increased frequency of births. In the absence of further research, probably needing the formation of a captive herd, this point cannot be assessed.

Banteng growth rates at Tomanggong road were observed to be lower than expected for well-managed cattle in Southeast Asia (e.g. Takdir Saili 2020; Norsyamimi et al, 2023). Numerous studies of Bali cattle (the closest relative to Bornean banteng amongst domesticated bovids) have demonstrated that nutrition is the key factor influencing growth rate (e.g. Marestyo et al, 2012). Based on videos examined in this study, the period of greatest stress for individual banteng appears to be for all calves until they are weaned, and for their mothers. Forceful attempts by older or weaned calves to nurse from a young mother banteng were noted. Whether allo-nursing occurred could not be ascertained. It was observed that bulls in the Tomanggong road herd beyond about 3 years of age (which would be classed as adult in domestic cattle) were not necessarily able to act as an adult sexually. Due to their slow growth rate and stunted size, presumably linked to poor nutrition, they were constantly harassed not only by older, larger bulls but equally by mature cows. It was estimated that at Tomanggong road, bulls started to show dominance over cows only after age five years. Similarly, some of the Tomanggong road banteng classed here as heifers were probably more than three years old, but their growth rate was seen to be slow. Some bulls left the herd after age about three years. Many factors influence cows' fertility and milk production, including nutrition, stresses other than those related to nutrition, pesticides and disease (e.g. Wrzecinska et al. 2021). The possibility of pesticide contamination of plants eaten when the Tomanggong road herd enters the adjacent oil palm plantation cannot be ruled out. Apart from that, no other forms of non-nutritional stress are evident in the study area. The only signs of disease in the herd over five years were occasional fungal skin lesions in a few individuals.

Even with enrichment for banteng, the tentative explanation for these observations is that the Tomanggong road habitat is rather marginal for banteng in terms of nutrition (Figure 6) The poor quality of the substrate on which the grass grows is likely to be a significant contributory factor in slow growth rate (productivity) of the favoured food plants. In Tabin, Napier grass planted on the Tomanggong road grew so slowly that estimation of its productivity could not be made. In contrast, at a separate site in Tabin Wildlife Reserve on fertile alluvial soil where banteng are absent, Napier grass from the same source materials was grown and produced an estimated 80 tonnes of fresh biomass per hectare annually. Unfortunately, the prevailing global fashion of planting trees in damaged tropical habitats has resulted in reluctance and opposition to developing grasslands in protected areas.

After absence of policy support for habitat manipulation in protected areas, the biggest challenge and major use of funds and manpower lies in sustaining the removal of weeds to allow grasses to predominate. Forbs, shrubs and woody plants tended to out-compete grasses on Tomanggong road throughout the study period. The reverse appeared to be true on alluvial soil in Tabin. After two years of effort, weeding of every part of the grassland on Tomanggong road proved to be necessary at two-three-month intervals. After four years, the amount of time needed to maintain grasses as the dominant plants decreased, but did not end entirely. We anticipate that the more often the banteng feed on the pasture, the less weeding will be needed. If banteng visit frequently, weeding may not be necessary after six years. Ideally, any further work to develop managed pastures for wild bovids in equatorial sites should be done on fertile soils.

### Author contributions

Study design: ZZZ, AHA; camera traps and supervision of weeding: AE; data analysis, ZZZ: writing: ZZZ, JP.

### Acknowledgements

Thanks go to Mellinda Jenuit for creating the Figures, and to Sabah Wildlife Department, Sabah Forestry Department and Sabah Biodiversity Centre for providing necessary support; to Sabah Forestry Department's Forest Research Centre herbarium for assistance in food plant identification; to the BORA staff who have participated in creating and maintaining the grasslands in Tabin; to oil palm grower KLK for in-kind assistance, notably the initial clearing of fallen trees, bridge repair and supplementary labour. Financial support from WWF-Malaysia / Beiersdorf from October 2021 to September 2023 and September to December 2024 allowed monthly work to continue.

**Conflicts of interest** None

**Figure 6.** Tomanggong road two years after pasture development work started

### Ethical standards

The research was conducted to high ethical standards. Governmental approval was granted by the Sabah Biodiversity Council via access licence reference number JKM/MBS.1000-2/2 JLD. 16(75).

### Data availability

Data upon which the Results presented here are not available in public domain. The corresponding author is willing in principle to share specific data if requested for the purpose of Bornean banteng conservation, subject to government approval.

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# AUTHOR GUIDELINES

## Aim & Scope

*BULLetin* is the official, peer-reviewed publication of the IUCN/SSC Asian Wild Cattle Specialist Group. It aims to provide information on all aspects of natural history for the relevant species (Anoa, banteng, gaur, kouprey, saola, tamaraw, water buffalo and yak), with a particular focus on their conservation and management, both *in* and *ex situ*.

*BULLetin* accepts manuscripts of original research findings that have not been published or submitted simultaneously to other journals, and with a minimal overlap of contents with other published papers. As well as these, *BULLetin* also accepts and encourages submission of other relevant news, thesis abstracts, book reviews, summaries from workshops and meetings as well as a "notice-board" to publicise relevant upcoming conferences, funding opportunities etc.

## Subscription and processing of manuscripts

We prefer manuscripts in English. If English is not your first language, then please have your text thoroughly reviewed by a native speaker before submitting. Abstracts must also be in English, but we encourage an additional abstract in the language of the country where the project has been conducted. We will consider manuscripts in other languages; speed of publication in that case depends on availability of reviewers. If the article is not in English, then an English abstract must be provided.

Manuscripts should be submitted in MS Word and sent to James Burton (jamesaburton@yahoo.co.uk) or Corinne Bailey (c.bailey@chesterzoo.org). Submitted manuscripts will initially be evaluated by the editors. Manuscripts which fail to meet the editorial requirements will be returned to the author without review. Research articles and reviews will be sent to one or two independent reviewers. We aim for less than two months between initial submissions until final acceptance for publication.

## Types of contributions and requirements

News and field notes
Relevant news and notes from the field that may contain figures and tables (up to 2,500 words)
Book reviews
Short evaluations of recently published books and monographs of interest to the AWCSG (up to 1,500 words)
Review papers
Unbiased reviews of the existing knowledge on a specific topic, providing novel insight and synthesis are welcomed (up to 6,000 words)
Research papers
Original research articles (up to 8,000 words including all text, references and legends). Manuscripts should adhere to the following structure:

- Title
- Author details (names, affiliations and contact details for corresponding author)
- Abstract (not more the 250 words)
- 4-8 key-words (additional key-words not appearing in the title – if any)
- Introduction
- Materials and methods
- Results
- Discussion
- Acknowledgements (optional)
- References (Harvard style)
- Figures and tables, presented alongside individual captions (please also send photos and figures in separate files in the highest available resolution)

## Numbers and units

The metric system should be used for all measurements and weights with a space between the number and the unit of measurement. Temperature should be expressed as degrees Celsius (°C). Numbers from one to nine should be spelled out except when used with units; e.g. one anoa but ten banteng and 3 km.

## Nomenclature

Please use common English names of plants and animals, and adhere to the taxonomy used in the IUCN Red List. At first mention in the main text, give both the common and scientific names (in italics). If possible, also add the local name of the species in the area where you work.

## Figures and tables

Figures and tables should be cited in the text in the order that they should appear. Figures and images should be in one of the following file formats:
· Encapsulated PostScript (EPS)
· Tagged Image File Format (TIFF)
· Portable Network Graphics (PNG)
Portable Document Format (PDF)
JPEG (Joint Photographic Experts Group) should be avoided where possible, as these are compressed formats. Enough detail should be included in figure legends so that the figure can be understood without reference to the text. Figures should be referred to in the text as Fig. 1, Fig. 2 etc. Tables should be numbered and with a title above, and referred to in the text as Table 1, etc. The same data should not be presented in both table and figure form.

## References

We use the Harvard style and the name-year method of citing and listing references. Citation to work by one or two authors should give the author names in full, e.g. (Smith 2017) or (Smith & Miller 2017). Citation to work with three or more authors should be abbreviated with the use of et al. (e.g. Smith et al. 2017). Citations in the text should be separated by a semicolon and listed in chronological order. Works with the same first author and date should be coded by letters (e.g. Smith 2017a). The reference list should be organised alphabetically by first author, punctuation should be minimised and journal names should be unabbreviated. The minimum reference information required is as follows:

- Journal article: Author(s) in full, year of publication, article title, journal title (not abbreviated), volume number, issue number, page range. References to online research articles contain the same information, but have a DOI instead of volume, issue and page range.

- Book: Author(s) in full, year of publication, book title, place of publication, publisher, number of pages.

- Book chapter: Author(s) in full, year of publication, chapter title, book author/editor, book title, place of publication, publisher, page range.

- Thesis: Author in full, year of publication, thesis title, type of thesis (e.g. MRes, PhD etc.), awarding institute.

- Online resources: Author/organisation, year of publication, link, date on which the resource was accessed.