BIOLOGY, MEDICINE, & NATURAL PRODUCT CHEMISTRY ISSN 2089-6514 (paper)
Volume 15, Number 1, April 2026 | Pages: 731-738 | DOI: 10.14421/biomedich.2026.151.731-738 ISSN 2540-9328 (online)

Population Estimation and Habitat Characteristics of Anoa (*Bubalus* sp.) in Mount Kondoruang, Central Sulawesi

Dirham[1], Ongky[2]*, Manap Trianto[3], Yunita Messe[4]
[1]Department of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.
[2]Tropical Biodiversity Conservation Study Programme, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia.
[3]Department of Biology Education, Faculty of Teacher Training and Education, Tadulako University, Central Sulawesi, Indonesia.
[4]Department of Tropical Biology, Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Corresponding author*
ongkiforester14@gmail.com

Manuscript received:01 March 2026. Revision accepted: 11 May 2026, Published: 30 May 2026.

Abstract

The anoa is a dwarf buffalo endemic to the Indonesian island of Sulawesi and several surrounding offshore islands. Despite its relatively small body size compared to other wild cattle, it is the largest wild terrestrial mammal native to Sulawesi. This study aims to estimate the population size and density of the anoa (*Bubalus* sp.) in Mount Kondoruang, Central Sulawesi, and to analyze the habitat characteristics that influence its distribution and occurrence. This project began with an information survey conducted from 8–15 June 2024 involving nature enthusiast groups (university student nature clubs) and local communities regarding the presence of the anoa on Mount Kondoruang. Data collection was carried out from 17–28 August 2024. Mount Kondoruang, also known as Kandela in Tojo Una-Una Regency, Central Sulawesi, Indonesia. Mount Kondoruang has an elevation of 2,870 meters above sea level and features diverse topography, ranging from hilly areas to mountainous terrain with slopes exceeding 15^{o}, and is therefore designated as a Protected Forest area. The ecosystem types of Mount Kondoruang include savanna, lowland forest, lower montane forest, and upper montane forest. Mount Kondoruang remains an important habitat for the anoa, with individuals predominantly found in sub-montane forests. Habitat characteristics, particularly vegetation structure, elevation, temperature, and humidity, strongly influence its distribution. The limited population size and low juvenile detection indicate potential vulnerability, highlighting the need for continued monitoring and strengthened conservation efforts to ensure the species' long-term survival.

Keywords: Anoa; Endangered; Endemic; Mount Kondoruang; Sulawesi.

INTRODUCTION

Anoa is a dwarf buffalo endemic to the Indonesian island of Sulawesi and several surrounding offshore islands. Despite its relatively small body size compared to other wild cattle, it is the largest wild terrestrial mammal native to Sulawesi (Priyono et al., 2018; Priyono et al., 2024). Taxonomically, two distinct species are currently recognized: the lowland anoa (*Bubalus depressicornis*) and the mountain anoa (*Bubalus quarlesi*). These two species differ in morphology, habitat preference, and certain behavioral characteristics. The lowland anoa generally inhabits lowland forests, swamps, and riverine areas, while the mountain anoa is more commonly found in upland and montane forests at higher elevations (Rozzi, 2017; Priyono et al., 2022; Ongky et al., 2025).

The anoa's relatively small body size and predominantly solitary lifestyle represent important ecological adaptations to dense tropical forest environments (Moreno-Arias et al., 2020). Forest ecosystems in Sulawesi are characterized by complex geological structures, steep terrain, and heterogeneous topography. In such habitats, large-bodied animals or species living in large social groups may face difficulties moving efficiently through thick vegetation and rugged landscapes (Reynolds et al., 2016; Rozzi, 2017). Therefore, a smaller body size and solitary behavior enhance mobility, reduce competition for limited food resources, and increase survival chances in fragmented or topographically challenging forest habitats (Priyono et al., 2024).

From a conservation perspective, the anoa holds exceptional ecological significance. As the largest endemic mammal on Sulawesi, it plays a crucial role in maintaining forest ecosystem dynamics, including seed dispersal and vegetation structure (Arini et al., 2025). However, its population has experienced a severe decline due to two primary threats: habitat destruction and illegal hunting. Deforestation, driven by agricultural expansion, logging, mining, and infrastructure development, has significantly reduced and fragmented anoa habitats (Rija et al., 2020). In Central Sulawesi, including Tolitoli District, deforestation between 1990 and 2016 reached approximately 73,223 hectares, with an average annual

loss of 2,816 hectares and a deforestation rate of 1.19% per year (Karin et al., 2023). Such habitat loss not only reduces available living space but also isolates populations, increasing their vulnerability to genetic decline and local extinction (Lino et al., 2019).

In addition to habitat degradation, hunting pressure remains a major threat. Reports indicate that at least 283 individual anoas were hunted or captured within a single year. The highest hunting rates were recorded in North Sulawesi (34%), followed by Southeast Sulawesi (30%) and Central Sulawesi (22%) (Sulo et al., 2024). In several regions, anoa are hunted not only for subsistence purposes but also as commodities for trade, generating income for local communities. This unsustainable exploitation further accelerates population decline. Recognizing these serious threats, the Government of Indonesia has granted full legal protection to the anoa (Polidoro et al., 2011. Internationally, the species is classified as Endangered (EN) on the IUCN Red List of Threatened Species, indicating a very high risk of extinction in the wild. Furthermore, it is listed in Appendix I of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), which prohibits international commercial trade in specimens of the species except under exceptional circumstances (Arini et al., 2020).

Although comprehensive and up-to-date population data remain limited, current estimates suggest that the combined population of both anoa species is fewer than 2,500 mature individuals. It is believed that no single subpopulation contains more than 250 mature individuals, even within large protected areas such as Lore Lindu National Park and other extensive forest blocks. This fragmented and relatively small population structure increases the species' susceptibility to environmental changes, disease outbreaks, and continued human pressures (Erkens et al., 2023; Aninta et al., 2025).

To prevent extinction, various conservation initiatives have been implemented. Beyond legal protection, the Indonesian government has designated several conservation areas to safeguard critical anoa habitats (Al-Husna et al., 2025). One important protected area is the Dako Mountain Nature Reserve, established under the Decree of the Minister of Forestry and Plantations Number 238/Kpts-II/1999 dated April 27, 1999. This reserve covers approximately 19,590.20 hectares and serves as a vital refuge for anoa populations and other endemic wildlife (Sulo et al., 2024). Continued habitat protection, strengthened law enforcement, community-based conservation programs, and scientific research are essential to ensure the long-term survival of this unique and ecologically important species (Brichieri-Colombi et al., 2018). This study aims to estimate the population size and density of the anoa (*Bubalus* sp.) in Mount Kondoruang, Central Sulawesi, and to analyze the habitat characteristics that influence its distribution and occurrence.

MATERIALS AND METHODS

Study area

This study began with an information survey conducted from 8–15 June 2024 involving nature enthusiast groups (university student nature clubs) and local communities regarding the presence of the anoa (*Bubalus* sp.) on Mount Kondoruang. Data collection was carried out from 17–28 August 2024. Mount Kondoruang, also known as Kandela, is geographically located at (01°17'56.20" S – 121°32'33.80" E) in Tojo Una-Una Regency, Central Sulawesi, Indonesia. Mount Kondoruang has an elevation of 2,870 meters above sea level and features diverse topography, ranging from hilly areas to mountainous terrain with slopes exceeding 15°, and is therefore designated as a Protected Forest area (Figure 1).

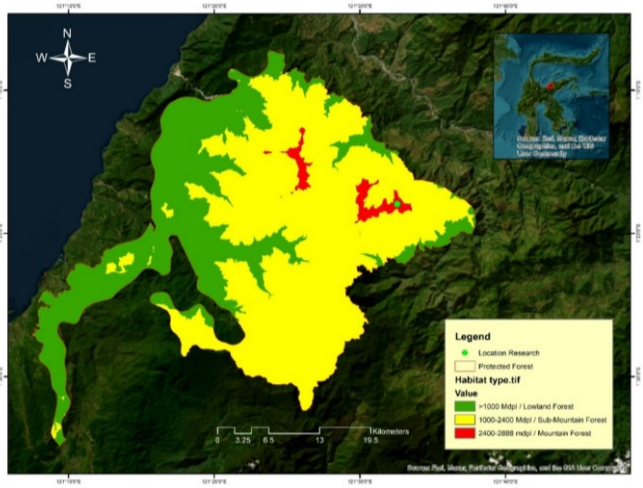

Figure 1. Map of the research location in Mount Kondoruang, Central Sulawesi, Indonesia.

Procedures

Preliminary Survey and Site Determination

The study was initiated by determining observation sites within two primary ecosystem types, namely sub-montane forest and montane forest, in Mount Kondoruang. Site selection was conducted using a purposive approach, based on preliminary information regarding the presence of the anoa (*Bubalus* sp.) and the identification of potential habitat suitability. Areas showing signs of anoa activity, accessibility for fieldwork, and representation of different elevation gradients were prioritized. This step was essential to ensure that the selected study sites accurately reflected the ecological conditions relevant to the species and allowed for comprehensive data collection across habitat types.

Direct and Indirect Observation of Anoa

Observations of mountain anoa were carried out through both direct and indirect methods to increase detection probability. Direct observations were conducted during active periods, specifically from 07:00 to 11:30 and 13:00 to 17:00 (WIB), when wildlife activity is generally higher. Researchers systematically surveyed the study area while recording any visual encounters with anoa. Indirect observations focused on identifying field signs indicating the presence and behavior of the species. These signs included footprints, feces, wallowing sites, horn-scouring trees, drinking sites, and feeding or browsing traces. Each sign was carefully documented, photographed when possible, and georeferenced to support spatial analysis. This combined approach enhanced the reliability of presence data in dense forest environments where direct sightings are relatively rare.

Population and Abundance Estimation

Population size and relative abundance were estimated using a combination of exploratory surveys, line transect methods, and camera trapping. The exploratory survey allowed researchers to broadly assess the distribution of anoa signs across the study area. The line transect method involved systematically walking predetermined transect lines and recording footprints encountered along the path. Footprint measurements were used as an indicator of individual presence and activity patterns. In addition, four camera traps were strategically installed in locations with high signs of anoa activity, such as near trails, water sources, and wallowing sites. Camera traps operated continuously during the study period to capture photographic evidence of anoa presence, frequency of occurrence, and activity times. The integration of these methods provided complementary data to improve the accuracy of population estimation.

Habitat Vegetation Analysis

To assess habitat characteristics, vegetation analysis was conducted using a nested sampling (plot-based line) method. A total of 12 observation plots were established using purposive sampling to represent variations in habitat structure and elevation. Within each plot, vegetation data were collected and categorized into different growth stages, including trees, poles, saplings, and seedlings. Parameters such as species composition, density, dominance, and canopy cover were recorded to describe forest structure and plant diversity. This analysis aimed to identify key vegetation components that may influence habitat suitability for mountain anoa, including the availability of food plants and shelter.

Measurement of Abiotic Environmental Factors

In addition to biotic components, several abiotic environmental variables were measured directly in the field to provide a comprehensive description of habitat conditions. These variables included elevation, slope gradient, air temperature, and relative humidity. Elevation and slope were recorded to understand topographic influences on habitat use, while temperature and humidity measurements helped describe the microclimatic conditions within each observation site. Collecting these physical environmental data allowed for further analysis of the relationship between habitat characteristics and the distribution of mountain anoa within the study area.

Data analysis

Data were analyzed quantitatively and descriptively to estimate population parameters and evaluate habitat characteristics of the anoa (*Bubalus* sp.) in Mount Kondoruang. Population size and relative abundance were calculated using encounter rates from line transects, footprint records, and camera trap capture rates, while spatial distribution was mapped based on recorded coordinates of direct and indirect signs. Abiotic factors such as elevation, slope, temperature, and humidity were analyzed using mean and range values, and their relationship with anoa presence was examined to identify habitat preferences and ecological requirements of the species.

RESULTS AND DISCUSSION

Population Size and Abundance of Anoa

The estimated population size of the anoa (*Bubalus* sp.) in Mount Kondoruang was determined based on footprint measurements, line transects, exploratory surveys, and camera trap data. A total of 28 footprints were recorded and identified as representing 14 individuals, consisting of 12 adults, 1 juvenile, and 1 calf. The highest number of individuals (12 individuals) was recorded in the sub-montane forest habitat at elevations ranging from 1,576–1,759 meters above sea level. Footprint measurements in this habitat ranged from 6–9.2 cm in length and 4.6–7.5 cm in width. In contrast, only 2 individuals were identified in the montane forest habitat at elevations between 2,567–2,769 meters above sea level, with footprint sizes ranging from 4.1–9.1 cm in length and 4–8.2 cm in width. These findings indicate that the sub-montane forest supports a higher relative abundance of mountain anoa compared to the higher elevation montane forest habitat (Table 1; Figure 2).

Table 1. Population size and abundance of anoa.

Location	Transect/ Exploration Line	Footprint Size			Age		
		Length	Width	Depth	Calf	Juvenile	Adult
Sub-Montane Forest	1	-	-	-	-	-	-
Sub-Montane Forest	3	9	7	1	-	-	√
		9	7	1.5	-	-	√
		9.2	7.5	4.5	-	-	√
		8,4	6.6	2.5	-	-	√
		7,5	4.6	2.1	-	-	√
		6	5.8	1.4	-	√	-
		7,7	6.2	2.4	-	-	√
		8	7.5	1.5	-	-	√
		10	9	2.3	-	-	√
Sub-Montane Forest	4	7.5	6.8	3.1	-	-	√
		8.2	6.5	3.1	-	-	√
		9.6	6.8	1.2	-	-	√
Montane Forest	2	-	-	-	-	-	-
Montane Forest	5	4.1	4	0.9	√	-	-
		9.1	8.2	4.2	-	-	√
Total					**1**	**1**	**12**
Population Total					**14 individuals**		

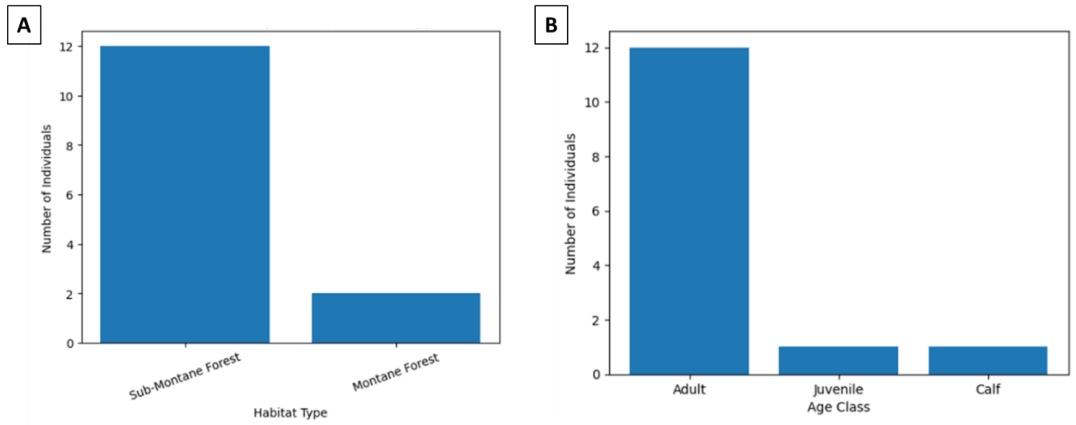

Figure 2. Population size and abundance of anoa. A. Anoa population per habitat type and B. Age structure of anoa opulation.

Camera Trap Records

Four camera traps were installed for 10 days, with three units placed in the sub-montane forest and one unit in the montane forest. The purpose of camera trap installation was to obtain direct photographic evidence, considering that mountain anoa are shy and highly sensitive to human presence. Out of the four cameras deployed, only one camera located in the sub-montane forest (1.267065 S, 121.550178 E) successfully recorded the presence of mountain anoa. One adult individual was captured on 08 August 2024 at 07:17 WIB. No photographic records were obtained from the montane forest habitat. This result further supports the footprint-based findings that indicate higher activity levels in the sub-montane forest (Figure 3).

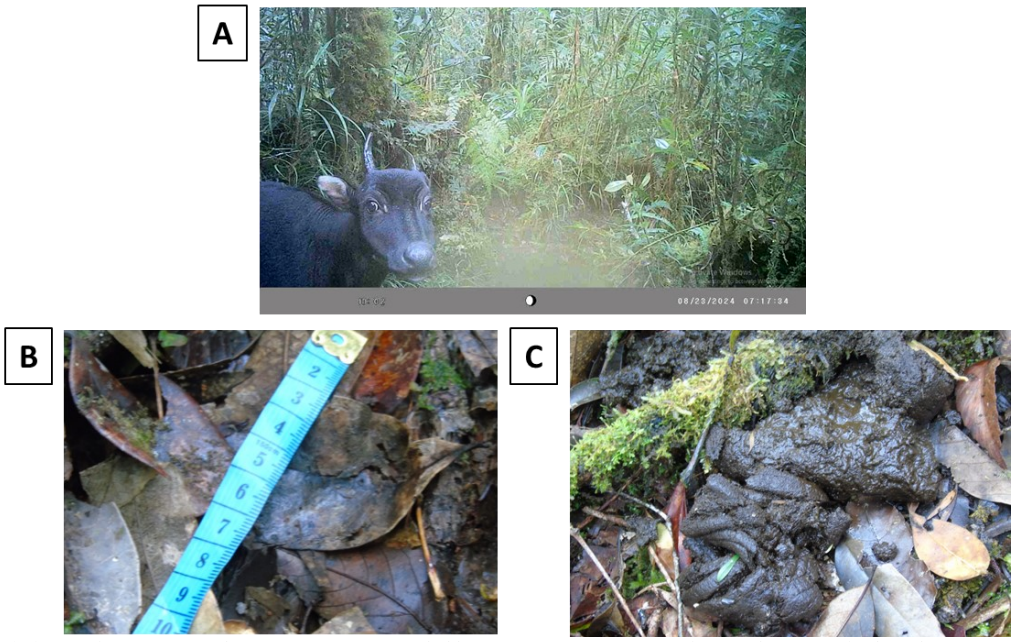

Figure 3. Anoa (*Bubalus* sp.) in Mount Kondoruang. A. Anoa recorded by a camera trap, B. Footprints, and C. Feces in the sub-montane forest.

Habitat Distribution and Vegetation Characteristics of Anoa

Mountain anoa were recorded in two ecosystem types: sub-montane forest and montane forest. However, their presence was more frequently detected in the sub-montane forest. In the sub-montane forest, anoa were found at elevations between 1,576–1,759 meters above sea level, while in the montane forest they were detected at elevations between 2,567–2,769 meters above sea level. The distribution pattern suggests that mountain anoa show a stronger habitat preference for mid-elevation forest ecosystems (Figure 4).

Vegetation analysis revealed distinct differences between habitat types. The sub-montane forest habitat was characterized by a forest floor covered with leaf litter, tree trunks partially covered with moss, and moderately dense canopy cover. Dominant plant species identified in this habitat included *Syzygium* sp., *Calamus* sp., *Lithocarpus celebicus*, and *Areca* sp. In contrast, the montane forest habitat exhibited thick moss covering both the forest floor and tree trunks. Vegetation was generally shorter and more adapted to cooler and more extreme climatic conditions. Plant species commonly found in this habitat included *Rhododendron* sp. These vegetation differences likely influence food availability and habitat suitability for mountain anoa.

Figure 4. Habitat distribution of anoa. A. Sub-Montane Forest and B. Montane Forest.

Abiotic Characteristics of Anoa Habitat

Abiotic measurements showed variation between habitat types. In the sub-montane forest, temperatures ranged from 16.9–19.4 °C, humidity ranged from 90–99%, slope ranged from 8–25%, and elevation ranged from 1,576–1,759 meters above sea level. In the montane forest, temperatures ranged from 16.0–17.2 °C, humidity ranged from 95–98%, slope ranged from 8–15%, and elevation ranged from 2,567–2,769 meters above sea level. These environmental conditions indicate that mountain anoa inhabit cool, humid, and moderately steep environments, with a greater concentration observed in sub-montane forest conditions (Table 2).

Table 2. Abiotic characteristics of anoa habitat.

Abiotic Characteristics	Habitat Type	
	Sub-Montane Fores	Montane Forest
Temperature (°C)	16.9-19.4 °C	16.0-17.2 °C
Humidity (%)	90-99 %	95-98 %
Slope (%)	8-25 %	8-15 %
Elevation (m asl)	1576-1759 m asl	2567-2769 m asl

Discussion

As one of Sulawesi's endemic large mammals, the anoa represents a unique component of the island's biodiversity and plays a significant ecological role within montane forest ecosystems. Its elusive behavior, solitary lifestyle, and strong sensitivity to human disturbance make it inherently difficult to observe directly in the wild. These behavioral traits, combined with the rugged and densely vegetated mountainous terrain of Central Sulawesi, create substantial challenges for accurate population estimation (Priyono et al., 2018; Priyono et al., 2024). Direct sightings are rare, and individuals often avoid areas with signs of human presence. Consequently, integrating indirect indicators such as footprints, feces, feeding signs, and wallowing sites with camera trap documentation provides a more reliable and comprehensive method for assessing presence and estimating relative abundance (Rozzi, 2017). Such a multi-method approach reduces detection bias and is particularly suitable for studying cryptic ungulates in remote tropical forest ecosystems (Moreno-Arias et al., 2020).

The stronger occurrence of mountain anoa in sub-montane forest compared to higher montane forest suggests that mid-elevation habitats may function as core areas supporting essential ecological activities such as foraging, resting, thermoregulation, and movement (Street et al., 2016). Sub-montane forests generally exhibit greater structural complexity, stratified vegetation layers, and higher floristic diversity than upper montane forests. The presence of plant genera such as *Syzygium*, *Lithocarpus celebicus*, *Calamus*, and *Areca* reflects a relatively productive and resource-rich ecosystem (Sainge et al., 2019). Many of these taxa contribute to understory density and provide edible plant parts, including leaves, shoots, and fallen fruits, which are important components of the anoa's diet. As a browsing herbivore, the mountain anoa depends heavily on understory vegetation rather than tall canopy foliage. Forests with moderate canopy openness allow sufficient sunlight penetration to stimulate understory growth, thereby increasing forage availability. In addition, thick leaf litter layers may support nutrient cycling and maintain soil moisture, further promoting vegetation productivity and habitat quality (Moreno-Arias et al., 2020).

In contrast, upper montane forests are typically characterized by cooler temperatures, persistent mist or cloud cover, thicker moss accumulation, and shorter, stunted vegetation adapted to nutrient-poor soils and harsher climatic conditions. These ecological conditions often result in lower plant diversity and reduced biomass compared to sub-montane zones (Salinas et al., 2021). Although mountain anoa are physiologically capable of occupying high-elevation environments, these areas may represent secondary habitats used for temporary refuge, predator avoidance, or seasonal movement rather than primary foraging grounds (Martin et al., 2011). The slower rate of vegetation regeneration and limited understory diversity at higher elevations may reduce carrying capacity, thereby supporting fewer individuals. Elevational gradients therefore play a fundamental role in shaping habitat suitability by influencing both vegetation structure and microclimatic stability (Pepin et al., 2022).

Abiotic factors further contribute to habitat selection and distribution patterns. The cool temperatures and consistently high humidity recorded in the study area are characteristic of tropical montane forests and align with the ecological preferences of mountain anoa (Salinas et al., 2021). High humidity may help maintain hydration balance and support thermoregulation in large-bodied mammals inhabiting steep and shaded forest environments. Additionally, moderate slope gradients indicate that the species is well adapted to uneven and mountainous terrain, reflecting long-term evolutionary adaptation to Sulawesi's complex geological landscape (Culmsee et al., 2011). However, extremely steep slopes or exposed ridgelines may increase energetic costs of locomotion and reduce accessibility to forage resources, thereby influencing fine-scale habitat use and spatial distribution (Ashton, 2017).

The predominance of adult individuals in the detected population has important demographic implications. A relatively low proportion of juveniles may indicate limited recent recruitment, seasonal breeding dynamics, or potential juvenile mortality (Biagioni et al., 2015). Anoa are known to have low reproductive rates, typically producing a single offspring after a long gestation period, which limits rapid population growth. Consequently, even small increases in mortality whether due to natural causes or anthropogenic pressures such as hunting can significantly affect long-term population stability. This demographic pattern underscores the vulnerability of small and isolated populations and highlights the importance of safeguarding reproductive habitats and minimizing disturbance in core areas (Culmsee et al., 2011).

Comparisons with previous studies conducted in other protected forests in Central Sulawesi suggest that mountain anoa populations are generally fragmented and occur at low densities. Habitat fragmentation resulting from agricultural expansion, infrastructure development, and small-scale logging continues to threaten forest connectivity across the species' range (Rozzi, 2017). Although Mount Kondoruang is designated as a

protected forest, legal status alone does not automatically ensure effective conservation. Remote mountainous areas may still experience encroachment or opportunistic hunting activities. Therefore, conservation strategies must integrate habitat preservation with consistent law enforcement, ecological monitoring, and collaborative engagement with local communities to reduce anthropogenic pressures (Culmsee et al., 2011).

The limited camera trap detections observed in this study further reflect the secretive nature of the species and its low detectability. Mountain anoa are highly cautious animals and may alter movement patterns in response to even minimal disturbance. Such behavioral plasticity complicates density estimation and requires extended monitoring periods and broader spatial coverage of camera traps to improve detection probability (Priyono et al., 2018; Priyono et al., 2024). Future studies may benefit from incorporating non-invasive techniques such as fecal DNA analysis to identify individuals and assess genetic diversity, thereby enhancing population assessment accuracy (Ramírez-García et al., 2025).

CONCLUSIONS

Mount Kondoruang remains an important habitat for the anoa (*Bubalus* sp.), with individuals predominantly found in sub-montane forests. Habitat characteristics, particularly vegetation structure, elevation, temperature, and humidity, strongly influence its distribution. The limited population size and low juvenile detection indicate potential vulnerability, highlighting the need for continued monitoring and strengthened conservation efforts to ensure the species' long-term survival.

Acknowledgements: The authors would like to express their sincere gratitude to the Mohamed bin Zayed (MBZ) Species Conservation Fund for the facilities provided during the conduct of this research.

Authors' Contributions: Conceptualization, Dirham and Ongky; methodology, Dirham, Ongky, and Manap Trianto; analysis, Ongky and Yunita Messe; writing original draft preparation, Dirham, Ongky, and Manap Trianto; writing review and editing, All authors.

Competing Interests: The authors declare that there are no competing interests.

Funding: This research was funded by the Mohamed bin Zayed (MBZ) Species Conservation Fund under Project Number 232532327.

REFERENCES

Al-Husna, S., Wiriya, M., & Mongga, A. E. (2025). Conservation Science in Indonesia: Protecting the Endangered Species of the Archipelago. *Indonesia Discourse*, *2*(1), 85-106.

Aninta, S. G., Drinkwater, R., Carmagnini, A., Deere, N. J., Priyono, D. S., Andayani, N., ... & Frantz, L. (2025). The importance of small-island populations for the long-term survival of endangered large-bodied insular mammals. *Proceedings of the National Academy of Sciences*, *122*(26), e2422690122.

Arini, D. I. D., Christita, M., Sheherazade, Mayasari, A., Suryaningsih, R., & Simamora, A. T. A. J. (2020, August). A review of anoa conservation efforts in Sulawesi, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 533, No. 1, p. 012003). IOP Publishing.

Arini, D. I. D., Kuswanda, W., Kinho, J., & Irawan, A. F. (2025). Strengthening anoa (Bubalus spp.) conservation based on social and cultural community values in Wallacea Bioregion, Indonesia. *Ethnobiology and Conservation*, *14*.

Ashton, P. S. (2017). Patterns of variation among forests of tropical Asian mountains, with some explanatory hypotheses. *Plant Ecology & Diversity*, *10*(5-6), 361-377.

Biagioni, S., Wündsch, M., Haberzettl, T., & Behling, H. (2015). Assessing resilience/sensitivity of tropical mountain rainforests towards climate variability of the last 1500 years: The long-term perspective at Lake Kalimpaa (Sulawesi, Indonesia). *Review of Palaeobotany and Palynology*, *213*, 42-53.

Brichieri-Colombi, T. A., McPherson, J. M., Sheppard, D. J., Mason, J. J., & Moehrenschlager, A. (2018). Standardizing the evaluation of community-based conservation success. *Ecological Applications*, *28*(8), 1963-1981.

Culmsee, H., Pitopang, R., Mangopo, H., & Sabir, S. (2011). Tree diversity and phytogeographical patterns of tropical high mountain rain forests in Central Sulawesi, Indonesia. *Biodiversity and Conservation*, *20*(5), 1103-1123.

Erkens, R. H., Blanpain, L. M., Carrascosa Jara, I., Runge, K., Verspagen, N., Cosiaux, A., & Couvreur, T. L. (2023). Spatial distribution of Annonaceae across biomes and anthromes: Knowledge gaps in spatial and ecological data. *Plants, People, Planet*, *5*(4), 520-535.

Karin, B. R., Krone, I. W., Frederick, J., Hamidy, A., Laksono, W. T., Amini, S. S., ... & McGuire, J. A. (2023). Elevational surveys of Sulawesi herpetofauna 1: Gunung Galang, Gunung Dako Nature Reserve. *PeerJ*, *11*, e15766.

Lino, A., Fonseca, C., Rojas, D., Fischer, E., & Pereira, M. J. R. (2019). A meta-analysis of the effects of habitat loss and fragmentation on genetic diversity in mammals. *Mammalian biology*, *94*(1), 69-76.

Martin, P. H., Fahey, T. J., & Sherman, R. E. (2011). Vegetation zonation in a neotropical montane forest: environment, disturbance and ecotones. *Biotropica*, *43*(5), 533-543.

Moreno-Arias, R. A., Bloor, P., & Calderón-Espinosa, M. L. (2020). Evolution of ecological structure of anole communities in tropical rain forests from north-western South America. *Zoological Journal of the Linnean Society*, *190*(1), 298-313.

Ongky, Mustari, A. H., & Prasetyo, L. B. 2025. Habitat suitability modeling for anoa (*Bubalus* spp.) in Mountain Sojol Nature Reserve, Central Sulawesi, Indonesia. *Biodiversitas, 26*, 1395-1404.

Pepin, N. C., Arnone, E., Gobiet, A., Haslinger, K., Kotlarski, S., Notarnicola, C., ... & Adler, C. (2022). Climate changes and

their elevational patterns in the mountains of the world. *Reviews of geophysics*, *60*(1), e2020RG000730.

Polidoro, B. A., Elfes, C. T., Sanciangco, J. C., Pippard, H., & Carpenter, K. E. (2011). Conservation status of marine biodiversity in oceania: an analysis of marine species on the IUCN red list of threatened species. *Journal of Marine Sciences*, *2011*(1), 247030.

Priyono, D. S., Solihin, D. D., Farajallah, A. C. H. M. A. D., & Arini, D. I. D. (2018). Anoa, dwarf buffalo from Sulawesi, Indonesia: Identification based on DNA barcode. *Biodiversitas*, *19*(6), 1985-1992.

Priyono, D. S., Solihin, D. D., Farajallah, A., & Purwantara, B. (2024). Biogeographic history of the endangered dwarf buffalo, subgenus Anoa (Bovidae: *Bubalus quarlesi* and *Bubalus depressicornis*): a perspective based on mitochondrial DNA phylogeny. *Evolutionary Systematics*, *8*, 311-321.

Priyono, D. S., Solihin, D. D., Farajallah, A., & Purwantara, B. (2022). Genetic diversity of the endangered endemic Anoa (Bubalus spp): Implication for conservation. *HAYATI Journal of Biosciences*, *29*(5), 586-596.

Ramírez-García, J. G., Maciel-Torres, S. P., Hernández-Rodríguez, M., Arenas-Báez, P., Orzuna-Orzuna, J. F., & Granados-Rivera, L. D. (2025). Non-Invasive Sampling for Population Genetics of Wild Terrestrial Mammals (2015–2025): A Systematic Review. *Diversity*, *17*(11), 760.

Reynolds, R. G., Collar, D. C., Pasachnik, S. A., Niemiller, M. L., Puente-Rolón, A. R., & Revell, L. J. (2016). Ecological specialization and morphological diversification in Greater Antillean boas. *Evolution*, *70*(8), 1882-1895.

Rija, A. A., Critchlow, R., Thomas, C. D., & Beale, C. M. (2020). Global extent and drivers of mammal population declines in protected areas under illegal hunting pressure. *PLoS One*, *15*(8), e0227163.

Rozzi, R. (2017). A new extinct dwarfed buffalo from Sulawesi and the evolution of the subgenus Anoa: An interdisciplinary perspective. *Quaternary Science Reviews*, *157*, 188-205.

Sainge, M. N., Mbatchou, G. P., Kenfack, D., Peterson, A. T., Nchu, F., & Lyonga, N. M. (2019). Vegetation, floristic composition and structure of a tropical montane forest in Cameroon. *Bothalia-African Biodiversity & Conservation*, *49*(1), 1-12.

Salinas, N., Cosio, E. G., Silman, M., Meir, P., Nottingham, A. T., Roman-Cuesta, R. M., & Malhi, Y. (2021). Tropical montane forests in a changing environment. *Frontiers in Plant Science*, *12*, 712748.

Street, G. M., Fieberg, J., Rodgers, A. R., Carstensen, M., Moen, R., Moore, S. A., ... & Forester, J. D. (2016). Habitat functional response mitigates reduced foraging opportunity: implications for animal fitness and space use. *Landscape Ecology*, *31*(9), 1939-1953.

Sulo, Y., Mallombasang, S. N., Rosyid, A., & Saleh, S. (2024, January). Estimating the Anoa (*Bubalus* spp.) Occupancy Area and Enviromental Factors Effect In Dako Mountain Nature Reserve, Central Sulawesi, Indonesia. In *2nd International Interdisciplinary Conference on Environmental Sciences and Sustainable Developments 2022 Environment and Sustainable Development (IICESSD-ESD-22)* (pp. 50-55). Atlantis Press.