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Cover: A digital art of water birds of Noyyal River and its wetlands in Coimbatore District by Megha A. Kashyap.

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COMMUNICATION

Wallowing site observations of the Philippine Tamaraw *Bubalus mindorensis* Heude, 1988 (Artiodactyla: Bovidae) using camera trap data

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Abstract: Due to the combination of anthropogenic and natural stressors, the endemic Philippine Tamaraw *Bubalus mindorensis* was divided into four distinct subpopulations. Currently, the largest population is found within the protected Mts. Iglit-Baco Natural Park. Wallowing is one of the most important behavioral adaptations of *B. mindorensis* to address heat stress but it has remained understudied. With the species facing a continuous threat of extinction, the future conservation plan for the species needs to be carefully strategized, bringing attention to further understand its wallowing behaviour in the wild. Using camera trap technology, the wallowing activity of Tamaraws was photo-captured in a wallowing site of Mts. Iglit-Baco Natural Park. The site was continuously monitored for three years utilizing two sets of cameras capturing opposite sides for a total of 517 independent wallowing events over 1096 sampling days. The photographic data reveal a solitary and diurnal behaviour of Tamaraw wallowing. The correlation of detections with climate variables reveals temperature as a direct driver of *B. mindorensis* wallowing. This study presents the baseline data of the wallowing behavior of the otherwise data deficient species and brings attention towards its management and conservation practices.

Keywords: Endemic, ethology, habitat use, mammalogy, protected area, wildlife monitoring, thermoregulation.

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INTRODUCTION

The Philippine Tamaraw *Bubalus mindorensis* is the largest endemic land mammal in the Philippines, and it is found only on the island of Mindoro, Philippines. The species is listed as Critically Endangered under the Department of Natural Resources (DENR) Administrative Order 2019–09, the Philippine Red List Committee, and The International Union for Conservation of Nature (IUCN) and is also listed in the Appendix I of the Convention on International Trade in Endangered Species (CITES) (Maala 2001). Historically, it was believed to be widespread on the island; however, the combination of anthropogenic (land conversion, illegal logging, migration, and hunting) and natural (rinderpest outbreak) stressors caused a significant decrease in its numbers from an estimated 10,000 individuals in 1900 to 154 individuals by 2000 (Ishihara et al. 2007; Boyles et al. 2016; Tabaranza et al. 2022; Schütz et al. 2023). At present, the *B. mindorensis* is reported to be confined within four sites (Image 1A) on the island: (1) Aruyan-Malate Tamaraw Reservation Area, (2) Upper Amnay watershed region, (3) Mt. Patrick region, and (4) Mts. Iglit-Baco National Park (MIBNP) (Gil et al. 2021; Schütz et al. 2023).

Mts. Iglit-Baco Natural Park (MIBNP) is a protected area proclaimed under the National Protected Areas System (NIPAS) act in 1992 and was recognized as an ASEAN heritage site in 2003 due to the rich biodiversity of native and endemic species inhabiting the mountain (Bonenfant et al. 2023). It is located in the south-central portion of the island, which coincides with the ancestral domain of the Taobuid indigenous communities (Schütz et al. 2023). The park is known for holding over 80% of the entire Philippine Tamaraw population and has been the focal point of the Tamaraw conservation efforts since its establishment (Long et al. 2018; Bonenfant et al. 2023). One instance is the established agreement between the wildlife managers and the indigenous communities that prevents the hunting of Tamaraws, harvesting of resources, or establishment of settlements within a 16 km^2 area inside the Park which they refer as the "2016 IP No Hunting Agreement Zone" which became the Strict Protection Zone when the Protected Area Management Plan was formulated, deemed vital for conserving the species in the mountain (Bonenfant et al. 2023; Schütz et al. 2023). Although protection against killing by poachers and traditional hunting from indigenous communities was enhanced, the confinement of this endemic mammal has led to several problems; one of which is the increase in hunting pressure, especially at the border of the strict protection zone where residing indigenous communities are allowed to set traditional traps (Bonenfant et al. 2023). Another challenge for the confined species is the overgrowth in population, resulting in crowding, slowing the population growth, as well as forcing a source-sink dynamic due to the limited habitat range that may be detrimental to future conservation efforts (Bonenfant et al. 2023).

Wallowing is a behavioural adaptation displayed by several mammals including bisons, pigs, and buffaloes which is done by submerging their bodies in mud/water puddle to cover a thick coat of mud on their body (Coopedge & Shaw 2000; Bracke et al. 2011). This behavior is mainly done to alleviate heat stress, improving the overall well-being in buffaloes. In fact, wallowing was shown to be the most effective cooling strategy of buffaloes, significantly increasing skin temperature, milk production, and overall productivity under heat stress (Aggarwal & Singh 2008; Petrocchi et al. 2023). Despite its ecological significance to the species, wallowing behavior remains understudied since most of *B. mindorensis* studies have been focused on population estimates, distribution and occurrence (Ishihara & Kanai 2010; Ishihara et al. 2015; Gil et al. 2021; Bonenfant et al. 2020, 2023), while behavioral studies remain outdated, and limited (Custodio et al. 1996; Cebrian et al. 2014; Tabaranza et al. 2022). The only study of the species' wallowing is primarily described from a small population of captive Tamaraws (Momongan & Walde 1993). Little is known about the Tamaraw wallowing in the wild besides the earlier descriptions (Custodio et al. 1996; Cebrian et al. 2014; Tabaranza et al. 2022).

Given these challenges, understanding behavioral ecology in response to the rapid shift in climate is critical in preserving natural behaviours and ensuring the species' survival. Especially in MIBNP where intense drought remains a recurring threat to the bovine (Perez et al. 2022). Hence, we report the wallowing observations from comprehensively monitoring a wallowing site in the wild through a camera-trap survey conducted in Mts. Iglit-Baco Natural Park from 2016–2018. The objective of the study is to (i) determine the *B. mindorensis* daily and monthly wallowing patterns and (ii) correlate climatological variables with the wallowing patterns observed. The results of the study will pioneer a descriptive study for the species' wallowing behavior in the wild, as well as highlight its importance to their natural ecology.

MATERIALS AND METHODS

Study site

Here, we report the observed activities of *B. mindorensis* from a three-year comprehensive camera trapping survey (2016–2018) by monitoring a wallowing site (849 m) within the safe zone of the MIBNP (Images 1B, 1C). Here the study area is the wallowing site found at the edge of the grasslands and forest within the 16 km² of SPZ, which contains two mud puddles and is surrounded by shrubs and tall grasses (Image 2). The camera trap survey utilized two cameras, capturing opposite sides of the site.

Camera-trap survey

The initial camera-trap survey was conducted from 04 March 2016 to 24 October 2018 by The World Wide Fund for Nature (WWF-Philippines) in collaboration with the Hubbs-SeaWorld Research Institute (HSWRI), the MIBNP- Protected Area Management Office (MIBNP-PAMO), and Tamaraw Conservation Program (TCP) under the Department of Natural Resources (DENR), and the Far Eastern University (FEU). Due to the critical status and limited distribution of the species, the team opted for targeted sampling in a forest within the no-hunting zone of MIBNP to understand its behavior.

The survey used two camera models at two different angles: the Bushnell camera capturing one side of the site, which recorded the date and time from 12 March 2016 to 30 July 2017. The Reconyx Ultrafire XR6 camera captured photos from 01 August 2017 to 24 October 2018, which recorded the time stamp, date, temperature, and moon phase on the opposite side of the site. The camera was strategically placed in tree trunks, 1.5 m above ground, ideal for capturing large-sized mammals. Image retrieval and maintenance were conducted once

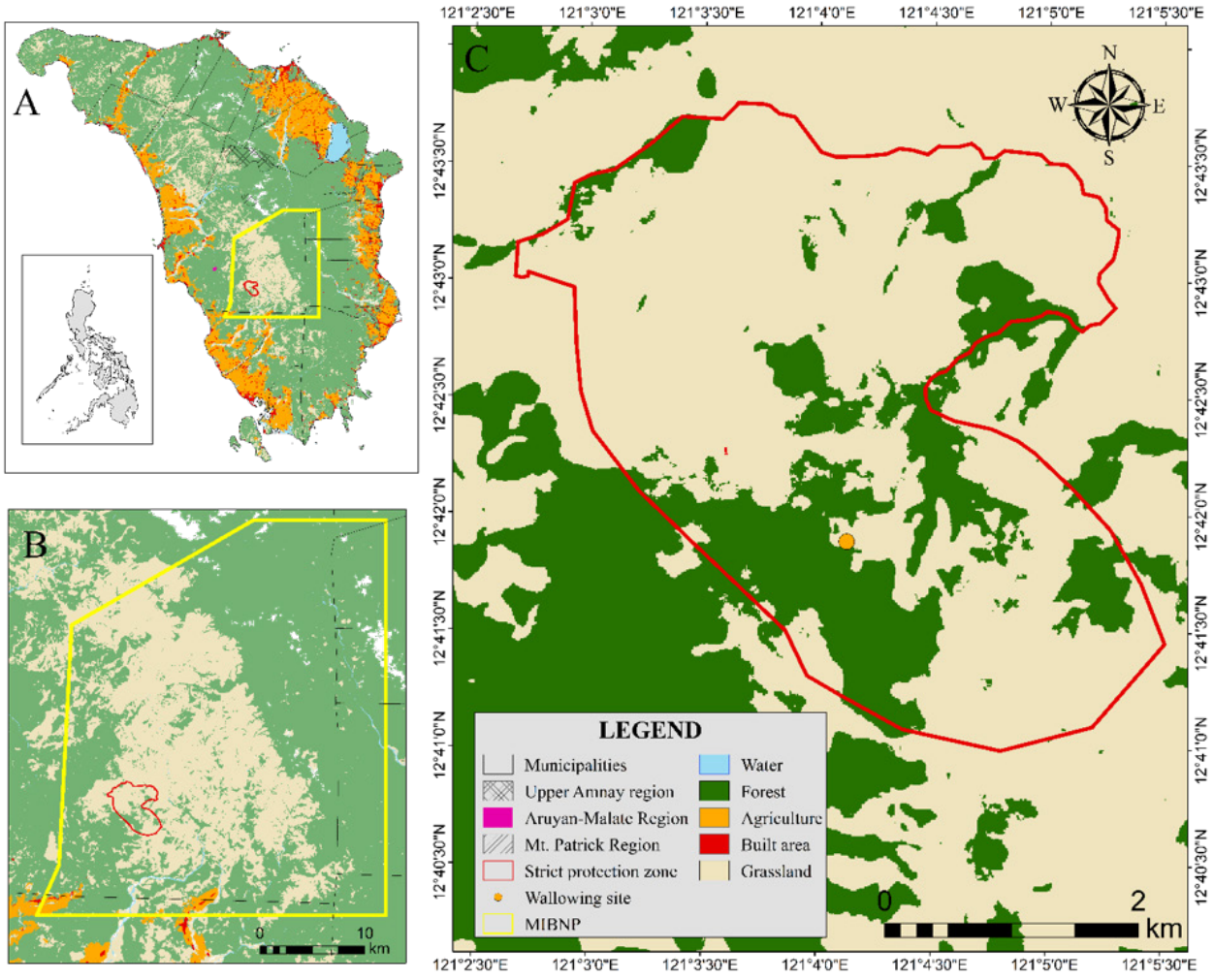

Image 1. Study site map showing: A—Tamaraw reserves within Mindoro Island | B—land cover maps for MIBNP | C—the camera trapped wallowing site within the agreed no-hunting zone.

every month by the WWF-Philippines staff, the TCP & the MIBNP-Park Area Management Office (PAMO) rangers. The cameras were set on high sensitivity, which captures three photographs per trigger and a one-second interval per picture. Photographs were recorded with an image size of 5 megapixels and a 640x480 image resolution.

Image processing

The camera trap data was organized per year, with subfolders arranged by months to determine the seasonality of the observations. The photos were tagged in the metadata using DigiKam ver. 8.4.0. To minimize potential errors in identification, data on the age class & sex were excluded from the image tagging, and only activity, species wallowing behaviour & number of individuals per wallowing observations were tagged. The detection of the images was defined at a 30-minute interval, which is estimated based on the time spent for each Tamaraw activity before moving away from the detection radius of the camera. This ensures that independent events are captured, and it also minimizes potential duplicate counts of individuals and behavior recorded. The statistical analysis was done through R software version 4.4.1 (Kumar & Tiyagi 2024). The function "recordTable" of *camtrapR* package (Niedballa et al. 2016) was used to extract the metadata from the images into a CSV file. The metadata includes the *timestamp*, the *tags*, the *minDeltaTime*, and the *camera station*.

Climate data

The nearest available meteorological station of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) to MIBNP is located in San Jose City, south of the island. The elevation, geographic, and topographic difference between the available station and the study site may reflect different conditions, potentially affecting the outcome of the analysis. The climatological data of San Jose, Mindoro station, spanning from 01 January 2016 to 31 December 2018, was requested from The Climate and Agrometeorological Data Section (CADS) of PAGASA. The three-year data include the minimum, maximum, and mean temperature, rainfall, humidity, and wind speed.

Statistical analysis

The statistical analysis and visualization were done through the R software using the reshape2, ggplot2, and corrplot packages. A correlation heatmap was used to determine the correlation of wallowing observations with the available climate data which includes rainfall, relative humidity, max temperature, minimum temperature, mean temperature, wind speed, and wind direction.

RESULT AND DISCUSSION

Tamaraw ethogram

The survey lasted for 1,096 days, capturing a total of 9,560 photographs. Using 30-minute intervals, a total of 517 independent wallowing detections were observed. The image tagging revealed 18 different activities exhibited at the wallowing site (Table 1). The activities were further classified into six distinct categories including (1) feeding & drinking, (2) movement & navigation, (3) social interactions, (4) rest & relaxation, (5) wallowing transition, and (6) hygiene maintenance.

Table 1. A constructed ethogram of *Bubalus mindorensis* observed activities.

Activity	Description
Feeding and drinking	
1. Foraging	The head is lowered, chewing food
2. Drinking	The head is lowered in front of a body of water, consuming water
3. Suckling	Juvenile feeding from adult mammary glands
Movement and navigation	
1. Traversing	The head is straightforward, traveling across the landscape
2. Investigating environment	Standing, the head is held up high, either moving left or right
3. Running	Traversing rapidly
Social Interactions	
1. Mounting	A male, positioned on top of a female
2. Nose-to-nose touching	Standing, physical contact between the noses of two individuals
3. Sparring	Two individuals, heads are lowered, physical contact of horns
4. Mock aggression	One or two individuals, heads are lowered, no physical contact of horns
Rest and relaxation	
1. Idling	Individual/s standing, stationary
2. Resting	Individual/s lying down on the grass, stationary
3. Wallowing	Individual/s submerged/standing on top of a mud puddle,
4. Stretching	Extending limbs or entire body
Wallowing transitions	
1. Enter wallow	Moving into a mud puddle
2. Exit wallow	Moving out of a mud puddle
Hygiene and Maintenance	
1. Scratching	Rubbing or scraping the body against a surface or its feet
2. Urinating	Releasing urine, usually in a different stance

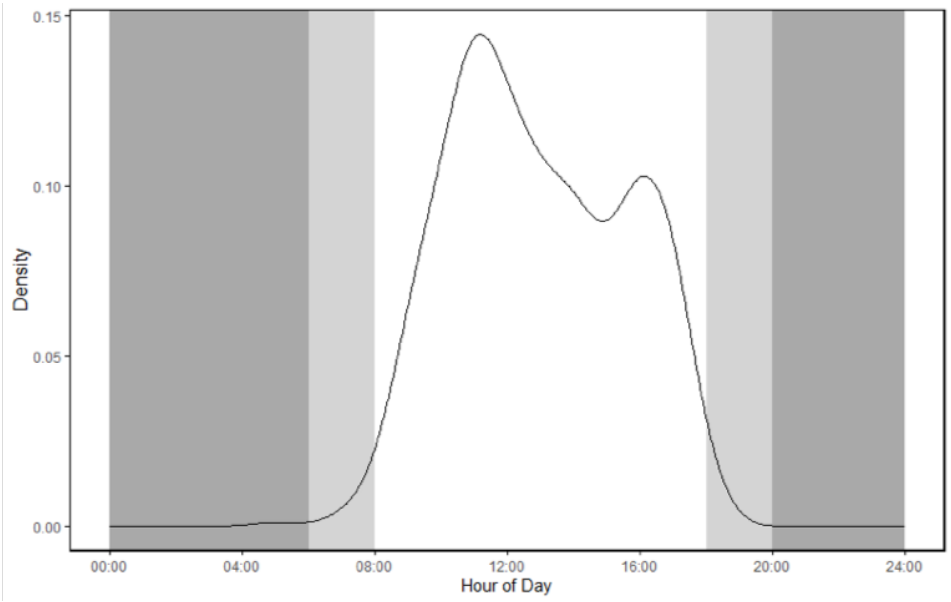

Figure 1. Kernel density estimate of *Bubalus mindorensis* wallowing patterns. The darker shaded area represents nighttime, while the lighter shaded area represents dusk and dawn, respectively.

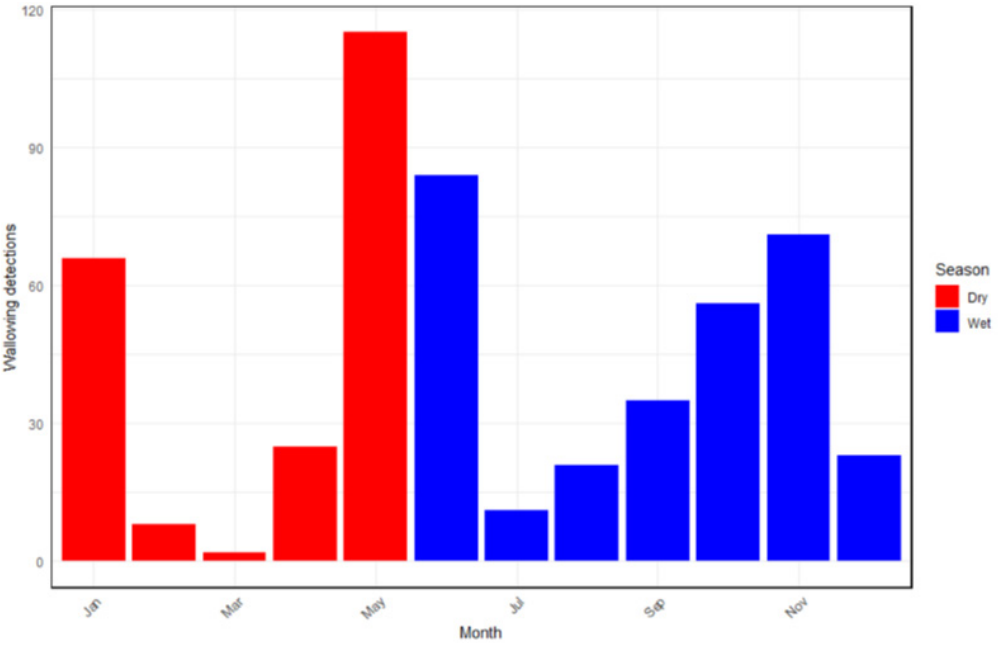

Figure 2. Monthly Philippine Tamaraw wallowing detections differentiated by red (dry season) and blue (wet season) bars (Total records, n = 517).

This preliminary ethogram provides the basic activities that are observed from *B. mindorensis* at wallowing sites which should be considered when strategizing conservation plans for the species. For example, the observed wallowing behavior denotes the importance of mud holes for their natural ecology; therefore, such landscape features must be present in their potential expansion ranges to ensure their survival and overall well-being. Furthermore, the ethogram reports behaviors that have never been described for the species such as sparring and mock aggression, which are commonly observed between juveniles, and bulls with their juveniles.

Image 2. The *Bubalus mindorensis* wallowing observations (© WWF-PHILS): A—one side of the site from the Reconyx camera | B—another side from the Bushnell camera.

Wallowing site activity patterns

Photo analysis revealed a distinct diurnal pattern (Figure 1). Tamaraw wallowing was primarily observed at 0700–1800 h, with two peak periods at mid-day, at 1000–1200 h, and another at 1500–1700 h. No wallowing was observed at night, contrasting the observations of Momongan & Walde (1993) on captive *B. mindorensis* individuals, which reported wallowing during midnight. This suggests that thermoregulation is the primary purpose of wallowing and not ectoparasite protection.

The monthly observations reveal higher counts of wallowing during the longer wet season compared to the dry season (Figure 2). Wallowing was observed to peak in May, when the dry season transitions to the wet season, which was further confirmed by the high correlation between minimum temperatures, and wallowing detections (Figure 3). The observation suggests that perhaps *B. mindorensis* wallowing is induced by the availability of mud puddles, which are limited when these mud puddles are sometimes dry during the hotter months of January to early May. Low wallow observations during the dry season may indicate that these bovines search for other wallowing site instead or rather seek shade in forest during hotter hours when the mud holes dry up, which are normally observed behavior of buffaloes (Katwal et al. 2024)

The correlation of climatological variables detections reveals temperature (minimum temperature, maximum temperature, and mean temperature) as the primary driver of wallowing. This can simply validate the

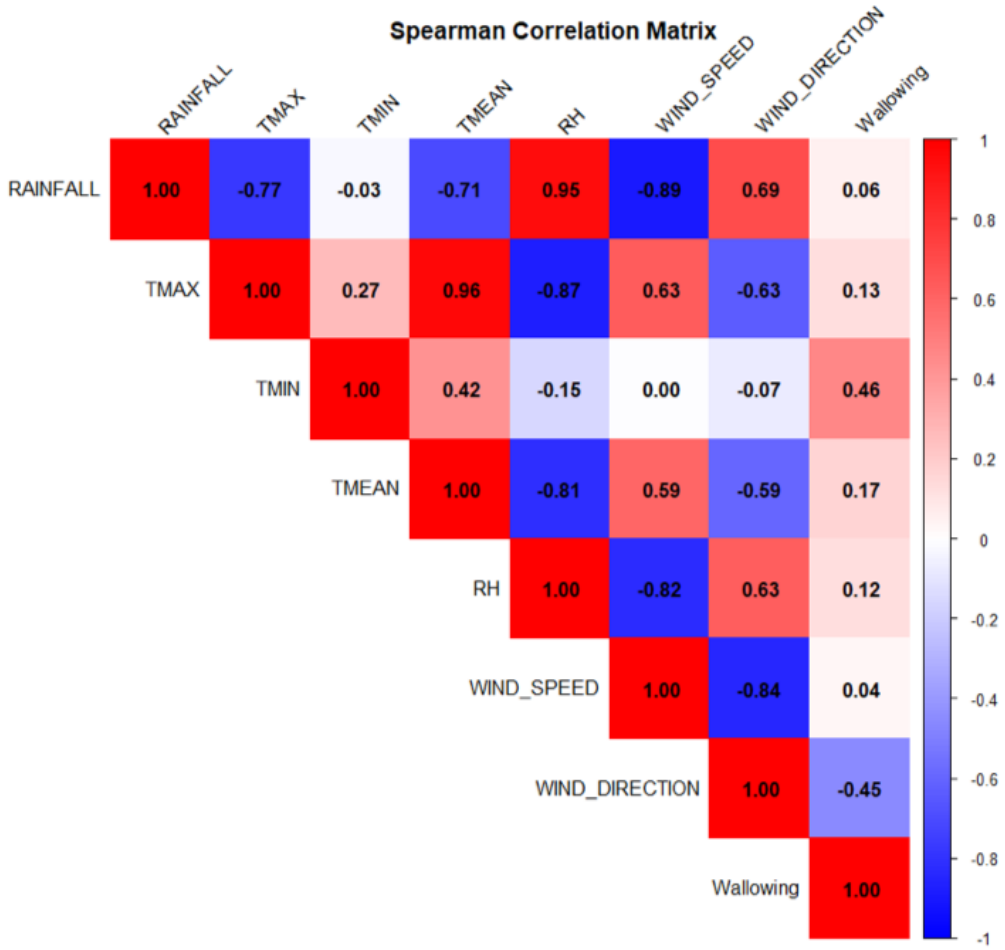

Figure 3. Spearman correlation heatmap of Philippine Tamaraw wallowing occurrences with the climatological variables. TMAX—maximum temperature | TMIN—minimum temperature | TMEAN—mean temperature | RH—relative humidity | WIND_SPEED—wind speed | WIND_DIRECTION—wind direction.

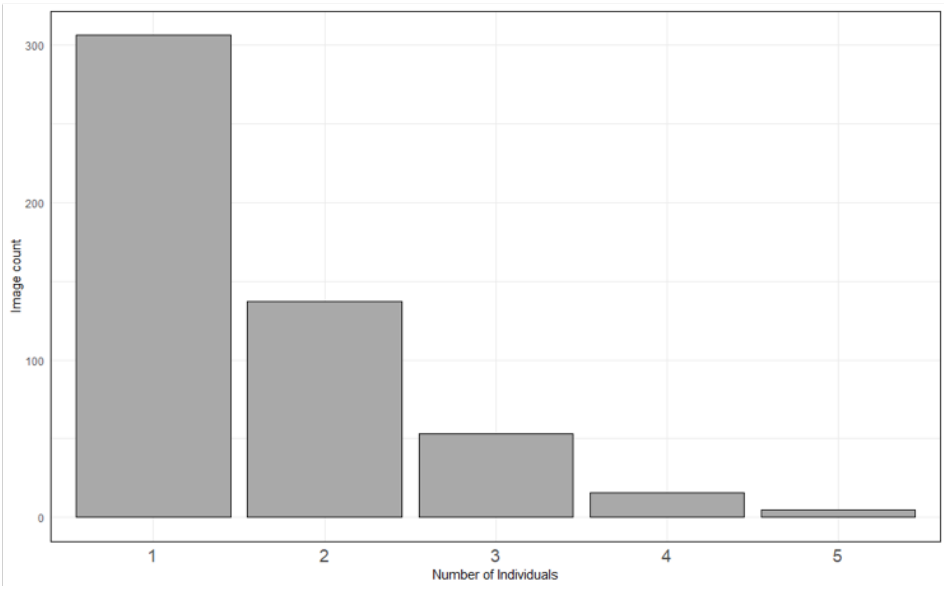

Figure 4. Tamaraw individuals observed at wallowing events over 517 independent records from 1096 days of observation in the strict Tamaraw protection zone of Mts. Iglit-Baco Natural Park.

importance of wallowing as a thermoregulatory mechanism in *B. mindorensis*, inferring that increase in ambient temperature induces the wallowing behavior as long as the mud puddles are readily available in their habitat.

Further analysis of individuals during the Tamaraw wallowing (Figure 4) events reveals a preference for solitary wallowing. This is in line with the solitary nature of Tamaraws, where both adult bulls and cows are observed to be lone individuals (Custodio et al. 1996). Occurrences of wallowing with multiple (3–5) individuals were rare, which may also be attributed to the agonistic behavior between bulls, resulting in the competition for mud puddles. However, this behavior was only associated with breeding season where bull fights are common in order to assert dominance in a herd and displace the losing individual (Custodio et al. 1996)

CONCLUSION

The study provides a preliminary descriptive information regarding the wallowing pattern of *B.* mindorensis on a single wallowing site in MIBNP. It is highly recommended for future that Philippine Tamaraw behavioral studies be conducted on multiple sites to extrapolate its general wallowing patterns in the wild. Nevertheless, the present results highlight the importance of wallowing on the behavioral ecology of *Bubalus mindorensis*, particularly wallowing as their primary thermoregulation during heat stress as suggested by its diurnal pattern. The seasonal patterns show the importance of mud puddle availability to induce the behavior, which should be immediately identified and preserved by the park managers. The preservation of these landscape features should be considered when expanding their range as well as translocating to ensure their survivability. The correlation of climate variables further validate temperature as the primary driver that induces wallowing behaviour and is a critical consideration for future conservation planning of *B. mindorensis.*

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