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Estimation of tamaraw population size at Mts Iglit-Baco Natural Park: a comparison between the simultaneous multi-vantage points count method and the double observer point count estimator

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Executive summary

Mts Iglit-Baco Natural Park (MIBNP), in Mindoro, Philippines, hosts the largest population of the endemic and Critically Endangered tamaraw (*Bubalus mindorensis*). The annual tamaraw population count operation carried out by local authorities for the past two decades has been valuable in measuring population trends and protection success. Nevertheless and as with any approach that does not account for imperfect detection probability, the traditional annual counts only return a proxy of tamaraw numbers and not an absolute population size. Thence, the actual number of animals remains unknown. In addition, thorough observation of the protocol used during the annual count suggest many biases resulting in an official total number of tamaraw which could be misleading our understanding of the real number of animals actually present.

To address these issues, we first critically assessed the traditional annual count of tamaraws, its protocol and results. We then compared these results with those obtained using a more rigorous estimator of population abundance called the double observer count. Unlike the traditional annual count approach, this method estimates the detection probability of animals and the population size with confidence limits. The main outputs and findings of this work suggest that the number of tamaraws might be half what the traditional annual count would claim. The following sections attempt to explain why.

<u>Overestimation of the number of animals by the annual tamaraw population count</u>

- *<u>Biologically unrealistic density of animals returned by the annual tamaraw count</u>*

  Official results of the annual count suggest a problem of overestimation of the number of tamaraw present inside the count zone (2200ha). This is evidenced by the fact that the calculated density of animals in the count zone is much higher than any other value found in the literature for ruminant species of similar body size (Table.1). Based on results of the count for the period 2019-2022, around 400 animals appear to share an area of 2000ha. This corresponds to a density of 20 animals per km², which is rare for a wild herbivore species of this size and ecology. Estimated numbers become even more unrealistic when focusing on vantage points located at the center of the count zone, where most sightings are recorded. For instance at Bayokbok and Bato Fidel, two adjacent vantage points with a total area of approximately 300ha, the estimated density is >50 animals per km², which is similar to densities typical of the domestic cattle ranching industry. Such numbers are not reflected in observations of tamaraw during regular patrols.

- *The cumulative nature of the multi-vantage point count estimator*

  Analyses from previous counts suggest that the higher the number of count sessions, the larger the final number of different animals apparently present in a count area. A likely explanation is the increasing difficulty in differentiating between individual tamaraws as population size increases. Moreover, when analyzing the consolidated data sheets from previous counts, we observe a substantial variability in the proportion of animals discounted because of supposed multiple counts. Over the past 5 years, the "total number of animals sighted" seems to decrease while the number of "actual number of individuals sighted" has increased.

- *The intrinsic subjective nature of the simultaneous multi vantage point count method*

  The analysis of the annual tamaraw population count operation highlights partial subjectivity of the multi-vantage point method during all phases of the operation, from observations in the field (variability in segregation of sexes and age classes, skills in spotting of animals, considering if animals are newly seen or not) up to the consolidation step (choice of consolidation method, removing of possible double counts, people leading the operation). This means that changing observers or repeating the data consolidation process would probably lead to different numbers of tamaraws each time.

The issues raised above imply that:

- The annual tamaraw population count has likely been overestimating the number of tamaraw present in the count zone since the beginning of the operation, but to an unknown extent.
- The method used to estimate population abundance cannot be considered reliable while the consolidation step is not repeatable. The time series data is not thorough over the two decades of operation.

Double observer estimator experiment suggesting a population half the size previously claimed

A multi-vantage point count operation using the double observer method was carried out in April 2022 just a week after the traditional annual tamaraw population count, so as to benefit from similar weather and habitat conditions (the grassland burning being done a few weeks prior to the count). We built five teams of two people and divided them into two sub-teams each (observer A and observer B), so as to survey 15 vantage points out of the 19 used during the annual population count. We carried out eight (8) 15 minute-long sessions with two overnights per vantage point. The design and protocol enables reducing the problem of double counting by avoiding the teams to be in adjacent vantage points at the same time.

- *Imperfect detection of animals*

  The operation sheds light on the difficulty in detecting animals in the field by rangers. The double observer method estimated an average detection rate of tamaraws inside the count zone estimated of **p = 0,7** on average. This corroborates the variability in observations during the annual tamaraw population count.

- *A more robust and realistic estimation of tamaraw abundance using the double observer estimator*

  The double observer method returned an **estimated population size of tamaraw to N = 181.0 individuals [163-200]**. With a density of 10 animals per km², the newly estimated abundance appears more realistic and supports our concerns about a long-standing over-estimation of the tamaraw number at MIBNP.

- Slight underestimation of the double observer experiment

  Unforeseen military presence during the operation likely led to disturbance within the count zone, with animals adjusting their behavior (hiding longr in the vegetation or moving to more quite area. In addition, an unusual low atmospheric pressure has hindered visibility. Yet, the impact on the animals' availability for spotters or movement within vantage points cannot be measured. Nevertheless, the very small number of tamaraws estimated at Magawang vantage point (n=18) suggests that observers did miss some animals actually present, lowering the estimation returned by the model. Therefore, we can consider the upper estimation of the confidence interval (n=200) to be more realistic, and the tamaraw population at MIBNP to be around that number or even a bit higher.

Consequences for conservation and management policies

This unexpected result has important implications for the assumptions used for the Population and Habitat Viability Assessment workshop of 2018, and the subsequent conservation strategies and list of actions formulated in the **Tamaraw Conservation and Management Action Plan** (TCMAP 2021-2030). In addition, it does not alleviate the problem of density dependence already highlighted and the fact that the species requires more space at MIBNP.

Finally, it challenges the reliability of the annual count and the need to switch to an indicator of abundance rather than focusing on an absolute number of tamaraws. These points becomes even more relevant in a perspective of phasing-out the use of fire prior to the annual count, as stated in the **Protected Area Management Plan for Mts Iglit-Baco Natural Park** (2021) and which will make the current method obsolete.

Acknowledgment

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Introduction & context

Mts Iglit-Baco Natural Park (MIBNP) hosts the largest population of the Critically Endangered tamaraw (*Bubalus mindorensis*), a species of dwarf buffalo endemic to the island of Mindoro in the Philippines. For nearly two decades, local authorities have been carrying out a population count, on a yearly basis, to estimate the number of tamaraw still present in the protected area. This operation is confined to a limited area within the so called "Core Zone of the Monitoring" (CZM) where most of the patrolling effort by the rangers occurs. The time series of tamaraw abundance has been valuable in measuring population trend and assessing the effectiveness of protection measures (Bonenfant al. 2022). Nevertheless, thorough observation by international partners of the historical method used to estimate tamaraw abundance and the way it is conducted suggest several biases underlying any method based on simple visual observation of unmarked animals. In addition, the need to conduct grassland burning prior to the count operation has led to further criticisms of the current method due to its negative impact on the habitat and local fauna.

As a consequence, local authorities have engaged in a process of transition to phase-out burning and develop alternative monitoring methods of tamaraw abundance that do not require intrusive habitat intervention.

In this context, it is crucial to get a more accurate idea of the number of tamaraws currently living in the CZM, in order to first, re-evaluate conservation strategies and second, base new monitoring methods on a more robust population abundance estimate. On that purpose, the D'ABOVILLE Foundation and Demo Farm Inc., together with its international partners, have proposed to evaluate the annual tamaraw population count, its results and to test a specific method able to provide a stronger measure of tamaraw abundance. This report summarizes the main findings and their meaning in terms of conservation and management.

This work has been conducted in the frame of the actions and objectives as defined in the ***Tamaraw Population and Management Action Plan*** (TCMAP 2021-2030) and the ***Protected Area Management Plan for Mts Iglit-Baco Natural Park*** (PAMP MIBNP 2021).

1. General overview about the estimation of population abundance

In population ecology, the term abundance refers to the number of animals of a certain species present in a certain area.

Animal abundance lies at the heart of conservation biology as most protection policies and the establishment of conservation status are based on how many animals are left in the wild. Estimating abundance of wildlife populations is a challenging task and this ecological problem has been continuously debated for more than a century (Anderson 2001). Several hundreds of methods have been proposed in the literature (see Seber 1982 for a review) although many of them are *ad hoc* with no proper statistical formalization.

A major advance in the estimation of abundance has been the acknowledgment of imperfect animal detection (Petersen 1954). When counting animals in the field, some of them are missed by the observer because of poor visibility, or because of the cryptic behaviour of animals. A famous experiment on roe deer (*Capreolus capreolus*) in Denmark (Strandgaard 1967) clearly shed light on this underestimation issue when simply counting wildlife. Managers were asked to count roe deer in a fenced park using their traditional census method.

Once done, hunters undertook an unlimited harvest of roe deer in order to clear the park of large herbivores. At the end of the experiment almost three times more animals were shot by hunters than were counted in the “census”. This early experiment came as the first empirical example that any method of population abundance estimation, not considering detection probability, would be biased and return an underestimated number of animals.

In most instances the proportion of missed animals is unknown to practitioners if not estimated and is likely to vary in space and time with observation conditions (e.g., weather conditions, vegetation cover, observer’s experience and motivation). A raw number of animals counted in the field confounds true abundance and detection. For instance, if 100 animals are seen during a count, it could result from a population of 200 animals detected with a probability of 0.5, or from a population of 100 under the unrealistic assumption of perfect detection. Teasing apart abundance from detectability is therefore a central theme to the estimation of wildlife abundance. To date only two main classes of **abundance estimators** can disentangle abundance from detection probability: capture-recapture (Petersen 1954, Lincoln) and distance sampling (Buckland et al. 2001). Since the publication of these seminal papers, the development of new methods flourished but most rely on these two fundamental principles[1] (Schwartz and Seber 1999).

While still the most reliable and accurate methods to estimate population abundance, implementation of capture-recapture and distance sampling through direct observation remains challenging when applied on very large areas or on endangered species. Capturing and marking animals such as large herbivores requires major logistics and manpower, while the associated physical risk to the animal must be clearly evaluated and balanced. To reduce the practical costs of the population abundance estimation, many practitioners make use of methods that are easier to implement but do not quantify detection probability. This is the case for basic aerial counts, the number of animals seen per kilometers covered, or snow track density for instance. Although those counts are given as a number of animals or population density, they are only proxies of the true abundance because detection is not estimated (also referred to as “**relative abundance**”). As a consequence, a large confusion arises in the literature between real estimations of population abundance (using capture-recapture or distance sampling) and the computation of a proxy of abundance such as pellet density or the crude number of animals seen per km or unit area.

2. Evaluating the annual tamaraw population count method to estimate tamaraw abundance at Mts Iglit-Baco Natural Park

2.1. On the use of the multiple vantage point method

The abundance of the tamaraw population at MIBNP has been monitored on a yearly basis since 2000 with a method called the multiple vantage point estimation. Each year tamaraws are simultaneously counted from 19 different vantage points (we split Loibfo vantage point into Loibfo A and Loibfo B) distributed over an area covering around 2000ha (the count area) within the “core zone of the monitoring” (Appendix 1). Vantage points are located on high spots where observers are assigned a specific portion of the count zone to assess. Counts are repeated 8 times (four consecutive mornings and evening sessions of 90 minutes each at dusk

1 Additional methods were proposed to estimated population abundance from unmakred animals in the last decade (random encounter, N-mixture…) but its relevance and robustness are heavily discussed. For instance, the N-mixture estimator (Poisson-Binomial) applied to the tamaraw counts in 2019 yielded an estimate of >1000 tamaraws. This value is obvioulsy wrong and should be given no further consideration.

and dawn), following which observers attempt to remove multiple counts of animals between vantage points and from one count session to another. The process of removing multiple counts is called the **consolidation of tamaraw numbers**. . It enables to return an actual number of individuals by discounting assumed multiple counts from the total number sighted. Thereby the estimated population abundance is the total number of animals considered as different by observers over the 8 x 19 = 152 counts. Rangers from the PAMO and TCP perform this consolidation step all together after the end of all counts.

This number (Fig.1) is the official tamaraw population size considered left alive at MIBNP, used and published by authorities, and conservation organizations.

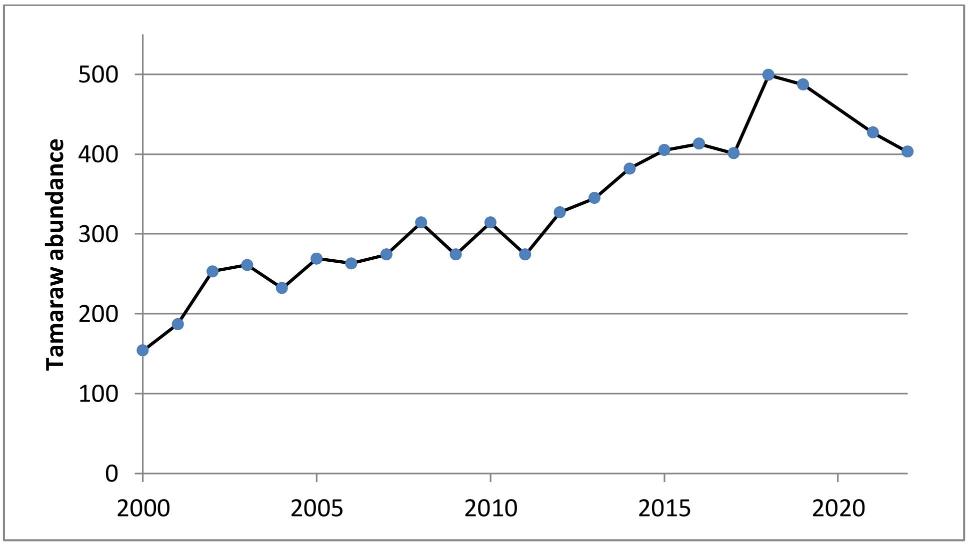


Fig.1: Historical results of the annual tamaraw population count showing the total number of animals estimated after consolidation each year. Note that there was no count in 2020 because of the pandemic

The design of the multiple vantage-points method is similar to other census methods used for various wildlife species around the globe. But because detection probability is seemingly not estimated – from our understanding of the methodology and our observation of the consolidation step – this estimation of tamaraw population size falls into the category "**relative abundance"** from **abundance estimators**.

It means that the annual tamaraw population count operation shares the well-known problem that it cannot return an absolute number or density of tamaraws but only the trends in population abundance over the years (in other words increase or decrease; Morellet et al. 2007). Because no method using reference estimators of population abundance, such as capture-recapture or distance sampling, were conducted prior to start the simultaneous multi-vantage point count method in year 2000, it was not possible to assess the performance and properties of this method, neither to calibrate it (see Pellerin et al. 2019 for an example on roe deer and the kilometric index of abundance).

As such, the multi-vantage point count method cannot estimate population abundance and in practice the real number of tamaraws roaming at MIBNP remains unknown still. This is the primary reason for why the double observer protocol was proposed to be tested and was carried out at the counting area, especially in the perspective of phasing-out the use of grassland burning and the need to establish alternative methods. Nevertheless, it is important to note that the annual count has been pivotal in building a time series and quantify the population growth rate of the species in the past two decades (Bonenfant et al. 2022).

2.2. Overestimation of population abundance by the simultaneous multiple vantage points count method

A detailed investigation of the historical and more recent data suggests that tamaraw counts at MIBNP suffer from many uncontrolled biases. We describe below some of the main constraints that observers are facing and then consider why the current number of tamaraws is also biologically unrealistic. We also provide some evidences suggesting that the protocol in the field as well as the data processing for double counts has changed significantly over the years, affecting our current idea of how many tamaraws are left in the wild.

General constraints and issues of the method observed at MIBNP

The first limitation of the multiple vantage point counts lies in the fact that the method relies on direct sightings of animals in the field and therefore on the capacity of the observer to see the animal and differentiate individuals from each other. To facilitate observations, grassland burning has been used over the count zone prior to each annual count: after a fire event, the grass vegetation is reduced to zero, hence making animals easier to spot. We can suppose that this intrusive habitat management generates behavioral adjustment by the tamaraw as it boosts the regrowth of youg vegetation at the peak of the dry season, a critical period when grass species are normally less nutritious. One could expect the tamaraw to use its habitat differently in absence of fire regime, thus changing the pattern of distribution and local abundance at this time of the year. This assumption is verified by the fact that tamaraws are regularly seen beyond the count zone at other period of the year during patrols, meaning that the overall distribution of the species is larger than what the annual count would suggest. In addition, the amount of animals that would naturally use forested areas on a longer basis in absence of fire, to find shade or look for substitute resources, but are now attracted to the open to feed on new grass shoots and therefore visible to observers cannot be measured.

The overall count zone is divided into 19 smaller count zones for each vantage point. Nevertheless, and despite the experience of rangers and existence of landmarks, it appears difficult for each observer team to clearly state where their assigned count zone starts and ends. This issue is amplified by the fact that staff turnover at PAMO MIBNP and TCP don't enable to have sufficient experienced rangers for each vantage point, while many participants at the count have barely an idea of the area and method in use. Thereby, vantage points have the tendency to overlap and defining if one animal spotted in the boundary area shall be included in one or another vantage point's data sheet remains at the discretion of the relevant observers. In addition, tamaraws are often moving, either within a single vantage point, or between vantage points. While it is not always easy to clearly follow each animal during the 90 minutes of an observation session, it appears even harder to differentiate individuals that have moved between two sessions, with a possible difference of days between them.

Another issue is the difficulty in clearly identifying sexes and age classes of observed animals; the difference in judgment between observers leads to variability in the data collected on the raw data sheets. This is amplified by the fact that each team is not equipped the same way (binoculars, telescope or nothing) and that the VP count zones are of different sizes. This problem was tested on the field during the preparation of the Double Observer Point Count, showing a great variability of age and sex detection among experienced viewers.

The issues raised above highlight the problem of multiple counts of the same individuals, which seems a singular aspect of the annual tamaraw population count operation.

The way the consolidation process is conducted and the decisions taken during this phase impact on the estimation of tamaraw abundance (for instance if one individual is recorded as a female sub-adult by one observer and as a male juvenile by another observer spotting it at an adjacent VP, they will be considered as two different animals instead of one). However, the error induced by double counts is not quantified and hence, unknown since the beginning of the monitoring.

Finally, there is no confidence interval measured by the multiple vantage-points estimation of abundance. In other words, the precision and uncertainty in the number of tamaraw estimated is unknown. This limits our ability to test for temporal trends in abundance. The reason for this lies in the empirical design of the abundance index, which lacks probabilistic framework and statistical theory. As a consequence, population viability analyses for instance, are likely to be too optimistic as they do not consider the lower limit of population size estimates in their models.

Table.1 in Appendix 5 summarizes the limits, constraints and biased inherent to the method implemented in the context of tamaraw at MIBNP.

Unrealistic tamaraw density at MIBNP

A first striking observation about the multiple vantage-points method is the rather large estimated number of tamaraws. Overall, up to 400 animals are assumed to be living on a 2,000 ha surface. This yields a density of 20 tamaraw per km², which seems very high for a large herbivore species (~200-300kg). The only ungulate species of the Bovidae family and similar size that harbors equivalent density is the African blue wildebeest (*Connochaetes taurinus*) (Table.1). This gregarious species forms large herds following seasonal climatic cycles along specific migratory routes. This is very different than tamaraw which is considered rather solitary and not migratory.

When focusing on Bayokbok and Bato Fidel (Appendix.1), two contiguous vantage points covering a 300ha of open grassland dominated by cogon (*Imperata cylindrica*) and talahib (*Saccharum spontaenum)*, the abundance averages 150 animals since 2019 (Appendix.2), meaning a density of 50 animals per km². Densities that high would inevitably trigger density-dependent demographic responses such as low juvenile survival and major reduction of female reproduction (Bonenfant et al. 2009). Yet, calves and yearlings make a substantial proportion of the annual tamaraw counts in those sites, which does not match with animal densities close to 50 animals per km² (for instance, in 2022, juveniles and yearling represent respectively 40% (n=36) and 30% (n=18) of the total number of animals estimated at Bayokbok (n=89) and Bato Fidel (n=69)). Further, such a high density of large wild herbivores was never reported elsewhere (Table 1) making such values rather questionable from a biological viewpoint. Besides, with that many animals, the encounter of rangers or visitors with tamaraws should be constantly high, while in practice the sighting of tamaraws remains occasional and sporadic.

It could be argued that the high number of animals seen in this location at that time of the year is a consequence of adjustment in animal's behaviors induced by the burning event, temporarily attracting tamaraws in the regenerating grassland. In other words, animals seen during the count at Bayokbok and Bato Fidel partly come from surrounding areas and especially areas benefiting from lower patrolling effort. If true, this could explain the low number of animals counted in the neighboring vantage points. For instance only 21, 8, 8 and 5 animals were counted in average in respectively Lanas 1, Lanas 2, Talafo West and Talafo East in the past three counts (Appendix 2).

Although this phenomenon could partly play a role, reports from patrols doesn't support a sufficient number of animals in these peripheral vantage points to explain such a migration pattern, while burning also occur there, producing the same ecological bias. At the end, the number of animals reported at the periphery of the count zone is simply not sufficient to supply the Bayobok and Bato Fidel areas to an amount as suggested by the annual count.

These biological comparisons of abundance among large herbivore species and the evidence from the field tend to suggest an over-estimated tamaraw abundance at least at the core zone of the monitoring and especially in the center.

Species	**Location**	**Body mass (kg)**	**Density (/km²)**	**Reference**
Okapia johnstoni (Okapi)	Afro-tropical region	250	0-4	Fa & Purvis (1997)
Tragelaphus spekeii(Sitatunga)	Afro-tropical region	100	55	Fa & Purvis (1997)
*Sincerus caffer nanu*s (African forest Buffalo)	Afro-tropical region	285	1-4	Fa & Purvis (1997)
	Ma-an National Park (Cameroon)		0,03	Bekhuis, De Jong & Prins (2008)
Sincerus caffer (African buffalo)	Virunga National Park (Congo)	500	12,3	1959 (Cited by Bourlière 1962)
	Queen Elizabeth National Park (Uganda)		7,2	Bere (1960) (Cited by Bourlière 1962)
	Serengeti (Tanzania)		0,2	Grzimek (1958) (Cited by Bourlière 1962)
Kobus ellipsiprymnus (waterbuck)	Virunga National Park (Congo)	150	1,26	1959 (Cited by Bourlière 2022)
	Queen Elizabeth National Park (Uganda)		1,4	Bere (1960) (Cited by Bourlière 1962)
	Nairobi National Park (Kenia)		1,1	Bere (1960) (Cited by Bourlière 1962)
Connochaetes taurinus (Blue wildebest)	Nairobi National Park (Kenia)	200	23,8	Bere (1960) (Cited by Bourlière 1962)
	Serengeti (Tanzania)		9,9	Grzimek (1958) (Cited by Bourlière 1962)
Taurotragus oryx (Eland)	Nairobi National Park (Kenia)	300	0,5	Bere (1969) (Cited by Bourlière 1962)
	Serengeti (Tanzania)		0,2	Grzimek (1958) (Cited by Bourlière 1962)
Tragelaphus strepsiceros (Greater Kudu)	Southern Rhodesia (Zimbabwe)	250	1,3	Dasmann & Mossman (Cited by Bourlière 1962)
Bos gaurus (Gaur)	Kuiburi National Park (Thailand)	1000	2,5	Tanasarnpaiboon (2016)
Bubalus depressicornis (Anoa)	Tanjung Peropa Wildlife Preserve (Indonesia)	225	0,9	Mustari (2003)
Bubalus bubalis (feral watter buffalo)	Norther territory (Australia)	800	up to 34	Australia government (2011)

Table.1: Comparison of the density of various species of ungulates related to their body size

Variability in the consolidation process

Another relevant point is the comparison between the total number of seen tamaraws and their actual numbers since the beginning of the monitoring in 2000. These two quantities are linked by the consolidation process. Obviously total and actual numbers should increase together as the real population size of tamaraws increases. Assuming the consolidation is a repeatable and objective data processing by rangers, we should expect a similar proportion of discounted animals in time. For instance, if actual numbers made 40% of the total number in the early 2000, it should be the same in 2022. Otherwise, it would mean that the consolidation is affected by abundance itself. In other words, the more the number of animals in the count zone, the harder to distinguish that two individuals are different and recorded as such, leading to underestimate the amount of multiple counts. Similarly too high a variability could be the consequence of changes in the decision rules to state that an animal has been seen previously or not.

In this sense and when investigating the relationship between actual and total number of tamaraws since 2000, a first striking observation is the great variability in the total number of animals sighted versus the actual number of individuals after consolidation (R = 0,45) and the lack of proportionality in the number of animals removed (Fig.3.a). It means that the consolidation process is responsible for nearly 50% of the variability in determining the total number of animals. In other words the consolidation step can generate 50% more or less animals than was recorded in the raw count.

In addition, we notice a gradual decrease in the proportion of discounted animals because of supposed multiple counts, most notably in the last two years (Fig.3.b). Such a temporal heterogeneity in the proportion of removed animals during consolidation could be the consequence of heterogeneous rules of decision intrinsic to the methodology, when observers decide whether a given group of animals has been detected already or shared with another vantage point. Differences in decision rules may result from changes in the people involved in the count and consolidation phase with, for instance, new observers or the discontinuation of others, or from changes in the protocol and rigor in the consolidation step itself.

As a matter of fact, it seems very difficult for an observer (if possible at all) to state if an unmarked tamaraw has been previously seen or not in the field without being able to clearly identify individuals. Only a few exceptional cases are plausible (for example an individual with a particular fur pattern or horn shape) but inferring on multiple counts from the group size and composition, and the time and direction of the observation will undoubtedly lead to many errors and mis-identifications of individual tamaraw. For instance, our trial with rangers to distinguish individuals from camera trap pictures proved the difficulty of the exercise. (see Appendix 3 for examples of tamaraw photos)

The above demonstration highlights the decisive importance of the consolidation step in generating the final result of the annual tamaraw population count. The important point here is the partial but clear subjectivity of the methods making results not repeatable. Were the consolidation performed again, the estimated results would be different each time, despite the same raw count data, making the method unreliable. An additional consequence is the uncertainty brought by this consolidation step to the estimated population abundance.

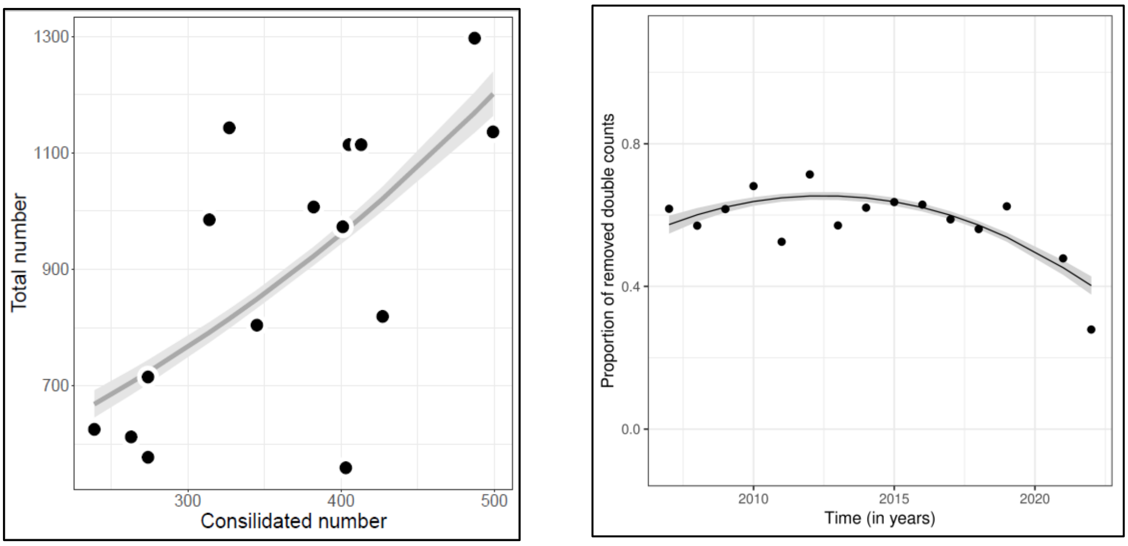


Fig.3a and 3b: Consolidated number versus total number seen; R=0,45 meaning that less than 50% of the variance of the consolidated data are explained by the total number of animal sighted (left). Yearly variation in the proportion (p_t) of tamaraw number removed from the raw annual counts because they are considered as previously observed by rangers, either at another vantage point, during a previous count session or both. This data processing is known as the consolidation step of the multiple vantage point estimation of tamaraw abundance which aims at obtaining an unbiased estimation of tamaraw abundance. We detect a statistically significant decrease in this proportion with time (Logistic regression: logit(p_t) = beta0 + beta1 x year + beta2 x year^2; beta1 = -45.8 (SE = 4.0), P < 0.001; beta2 = 0.14 (SE = 0.01), P < 0.001. This result is evidence (right).

The above statements are corroborated by the fact that the count operation has indeed seen several changes in its design since its beginning in year 2000: adding of two new VP in 2007 (Saligue East and Malibayong); removing of the Saligue East VP in 2017, replaced by Tangle VP located at the exact opposite side of the count zone; moving of the location of the observation spot at Bato Fidel and Lanas 2 VPs; these variation influencing the consolidation process. In addition, the consolidation step and calculation of the actual number of different animals (the count result) has indeed seen variation in its rules over time and between the people involved by either looking at the session with the highest number of animals seen, or by summing the assumed new animals seen session after session. It seems that these changes occurred based on *ad-hoc* decisions from the people in charge of the annual count process over the years. The section below emphasizes how this last aspect has undoubtedly played a crucial role in overestimating the true number of animals.

<u>Influence of the number of count sessions</u>

A unique feature of the multiple vantage point counts methodology lies in the summation of seen animals over the eight repetitions of the counts. Instead during the consolidation step, a link is established between successive count sessions by attempting to remove multiple counts. As a consequence of this link, any error in the state of an animal (previously seen or not) at any given session will cascade into the remaining count sessions. Errors hence add up within a vantage point but also across vantage points to affect the actual number of tamaraws to an unknown extent. More importantly, we believe this error accumulation is the main reason for the overestimated abundance of tamaraws we observe, especially in the latest years.

To illustrate our purpose, let us focus on the estimated number of tamaraws in 2022. Year 2022 is particular and interesting: because only five sessions were carried out instead of the usual eight (due to human disturbance at that moment). A consequence of this lower number of count sessions is a substantial drop in the actual population abundance that year (403 animals) compared to previous years (427 in 2021 and 487 in 2019) (17%, see Fig.1). Given the positive dynamics of the last 5 years, such a decrease in abundance is surprising. While a true population decrease is plausible as suspected by the field rangers (possible increase of poaching during the COVID-19 pandemic, lower reproduction success because of density dependence effect taking place…), this result might also highlight an intrinsic bias in the method. Indeed, a likely interpretation for this low abundance in 2022 is that the multiple vantage-points estimator is sensitive to the number of count session conducted during a counting operation.

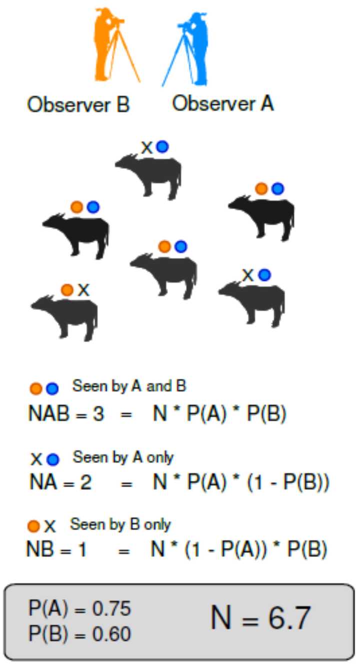
The major pitfall of the multiple vantage point count methods is that the more count sessions, the higher is the result of the count operation. For example, if 10 or 12 count sessions were used during the annual tamaraw population count operation, we could assume that the estimated number of tamaraws would be 2.5 greater. Similarly, it could be halved if only 2 or 3 count sessions were carried on. If true, this property is problematic because it would point out the cumulative nature of the estimator. So to say that accounting only for the animals considered newly seen is prone to a high risk of error leading to increase the chance to record the same animals at multiple times in the course of the eight count sessions.

As a conclusion it seems that the multi vantage point count method used at MIBNP has led to the tendency to over-estimate the number of animals present inside the count zone. The later choice of a cumulative manner to record and consolidate field data has amplified this aspect. A sensible alternative would have been to make an average of the eight sessions in order to reduce the risks or error accumulation.

4. The double observe point count method as an attempt to provide a robust tamaraw population estimate

4.1. Description of the double observer principle

The choice of a population abundance estimator for tamaraw is a difficult one because of the species conservation status and the many local constraints. At present, the capture and marking of animals is not an option. Thus it is not possible to use standard capture-recapture methodologies and estimators (e.g. Petersen-Lincoln estimator and derivatives). We did not consider distance sampling through direct observation of animals either because in practice, walking transects in fully grown grassland habitats would result in very low detection rates of tamaraws. In addition, the risk of close encounter can lead to the animal charging people, hence the habits of making noise when walking in the tall grass, which is in contradiction with the need to increase chance of spotting animals by reducing noise. This is for these reasons that distance sampling using indirect signs of presence was rather selected and is proving a relevant monitoring method in the context of the tamaraw in MIBNP (see the report on the results of the double observer distance sampling using dung transects). For instance, during the four replications of the distance sampling of dung operations, the teams didn't spot many tamaraws along the transect lines, but spotting more tamaraws in between transects when crossing elevated landmarks.



Principle of the double observer methodology to estimate population size of wildlife.

In this case, we suppose two observers A and B are searching the same area for tamaraws. Those two observers should not interact because we assume independence of the observations.

The recorded data consists in the number of animals detected by the two observers (NAB), by the observer A only (NA) and by observer B only (NB).

The different numbers of detected animals by observer A and B are the product of the number of tamaraw present at a vantage point (N) and the detection probability associated to each observer (P(A) and P(B).

From these three quantities, we can derive the estimated population size and detection probabilities and their respective variance (uncertainty, not presented here). Detection probability for observer A is P(A) = 3/5 = 0.6, for observer B P(B) = 3/4 = 0.75. From there, population size is N = 6.7 tamaraws, and the overall detection rate P = 0.77 by observer A and B. In this simplistic example, only one animal (0.66 exactly), have been missed by the two observers.

Box 1: the double observer method explained

Thereby the idea to test the double observer estimator of population abundance (Nichols et al. 2000) at MIBNP. Put it simply, if two observers record animals at the same time and place, they should count the same number of animals at the end if we assume a perfect detection rate of 100% for both of them. If the detection of animals is not perfect (the most likely cases in the wild), observers will not report the same number of animals because of slight deviation in sighting conditions and ability. Nichols *et al.* (2000) published a statistical model to estimate population size and detection rates from three numbers recorded in the field: how many animals were commonly seen by the two observers, the number of animals missed by the first observer and seen by the second, and the number of animals missed by the second observer but seen by the first (see Box 1 for details). The method is therefore quite simple as it only requires identifying the number of animals seen by each observer.

4.2. Carrying out the double observer point count at MIBNP

Here we developed a statistical model based on the double observer estimator but generalized to the overall count zone by combining the 19 vantage points into one single estimator.

A first experiment, conducted in May 2021, proved useful in highlighting the difficulties for the field teams to implement the protocol from theory to practice. As a consequence, the protocol was simplified, and several exercises were carried out to help refine the data collection procedure and train the rangers to properly understand the protocol and the way data should be collected.

We conducted the second operation in April 2022, just a week after the traditional annual tamaraw population count so as to benefit from similar weather and habitat conditions (the grassland burning being done a few weeks prior to the count). Five teams of two people were formed and divided into two sub-teams each (akin to the observer A and observer B, see Box 1), so as to survey 15 vantage points among the 19 vantage points used during the annual population count (Loibfo I, Loibfo II, Magawang, Bayokbok, Bato Fidel, Inubon, Mibluan, Nagbobong, Fangandatan, Anyayos, Lanas I, Talafu East, Talafu West, Malitwang and Lanas II). We removed the vantage points with the fewer number of tamaraws reported during the previous three tamaraw counts (Tangle, Malibayong, Tarzan, Iyan) (Appendix 2)) as a consequence of the difficulty to mobilize rangers for a longer period of time.

The survey route and vantage point assignment was organized so as to avoid the teams to be on contiguous vantage points on the same date, thus removing the need for a consolidation step between VPs and therefore reducing the problem of multiple counting of same animal.

We set the duration of observations in the field to 2x15 minutes to avoid long movement of the animals that could lead to multiple counting within a single vantage point's zone or between two different vantage points. The two sub-teams searched for tamaraws in the same direction, side by side, but were trained to do so with the least amount of interaction because the model assumes independence of counts. In addition, we asked the teams not to look at the landscape during the 45 minutes gaps between the two 15min sessions, so as to ensure that the two counts were independent. Both sub-team of observers compared their results immediately after the 15 minutes of observation; the short period of spotting time (15min) enabling observers to remember and show to each other where they spotted animals in the landscape and thus making it easier to determine which one were seen commonly or not. We replicated the two sessions of counts 4 times over two days at each vantage point (split into morning and evening observations) to increase our sample size and get reliable results.

The data sheet was similar to the one used for the annual count but the number of category was reduced to reproductive animals (adults and sub-adults male, female, unidentified) and non-reproductive animals (juvenile, yearling and calf in a single column).The columns "seen by observer A only" "seen by observer B only" and "seen by observers A and B" were added for the teams to facilitate the consolidation of their data after each 15min sessions.

In practice, we could not complete the design as planned due to logistic issues and human disturbance in the area during the operation. Three teams could not complete the eight sessions assigned to them (Appendix 4 – Table.A).

4.3. Estimation of the absolute abundance of tamaraws inside the Count Zone

Once the data collected, we implemented a double observer statistical model to estimate the number of tamaraw in the population (i.e., Bayesian model in a JAGS framework.) In the model, we accounted for space and time variation in detection rate of tamaraws by implementing different random variables. We also accounted for weather (good or bad) while we were running the experiment. We also allowed for different detection probabilities for adult male, adult female and all other individuals mainly composed of calves and juveniles. The computer code is available on-line at: https://github.com/cbonenfant/tamaraw-abundance-estimation.

Detection rate of tamaraws inside the count zone was definitely lower than 1 (imperfect detection) (Appendix 4 - Table.B), being estimated to be **p = 0,70** on average. We detected marked variation in detection probabilities among the teams, some of them detecting all animals present on their vantage points (p = 1) while others missed half of the available animals (p =0.40).

Changing weather conditions did alter detection probability by observers, tamaraws being nearly 50% less likely to be spotted when the weather was foggy and rainy compared to sunny and clear sky conditions (estimated parameter = -0.725 [-1.350; -0.175]).

The estimated population size of tamaraw as returned by the double observer method and corrected with the four vantage points not included in the experiment was **181 individuals with a credibility interval ranging from 163 to 200**. This is nearly half the number of animals estimated by the annual tamaraw population count with the standard multiple vantage point approach.

When looking at the estimate for each vantage point (table.2), we observe the same overall pattern of spatial variation in relative abundance compared to the annual point count, with fewer tamaraws at the periphery of the count zone than in the vantage points located in the center near base camps. This is even more obvious by looking at the count per session (Appendix 4 – Table.A).

Vantage Point	CI_Low	Median	CI_Up	Observed 2022
Anyayos	1,21	1,66	3,25	8
Bato Fidel	29,80	32,35	40,11	69
Magawang	17,00	18,71	23,93	89
Malitwang	0,10	0,34	1,28	8
Inubon	18,00	20,52	28,23	28
Bayokbok	20,12	21,96	27,48	89
Lanas I	6,92	8,26	12,43	24
Loibfo I	37,96	41,28	51,49	29
Nagbobong	2,53	4,67	15,07	0
Talafu East + West	2,05	2,76	4,95	11
Fangandatan	1,23	1,93	4,4	2
Lanas II	2,04	3,38	8,92	5
Loibfo II	2,47	3,55	7,58	8
Mibluan	9,67	10,99	15,02	19
4 missing VPs		10		7

Table.2: Estimated number of tamaraw per vantage point returned by the double observer estimator model confidence interval, in comparison with the result of 2022 annual tamaraw population count

5. Discussion

We provide here the first estimation of the absolute abundance of tamaraw at Mts Iglit-Baco Natural Park using a well-established and robust statistical method: the double observer estimator (Nichols et al. 2000). With 181 animals (all age- and sex-classes pooled), the tamaraw abundance we find is much lower than all the results of the annual tamaraw population count of the last decade. This result raises several questions and concerns in terms of population monitoring and conservation.

5.1 Limits of the simultaneous multi0vantage point count method

Our result raises several questions about the multiple vantage points method which, noticeably, has led to a general overestimation of tamaraw numbers since a decade at least. More surprisingly, it highlights an unusual conundrum. On the one hand direct visual counts should lead to an underestimation of animal abundance because of imperfect detection, as revealed by many other examples of underestimation of wildlife populations elsewhere (see Schwarz and Seber 1999). On the other hand, results of our experiment using the double observer estimator suggest a population size half of that which the annual population count returns. It is likely that this discrepancy arises because of the issues related to the consolidation steps (see previous discussion).

Problems may hence arise from both the protocol itself over the four days count duration and the subsequent data consolidation session, most likely when observers try to differentiate between different animals across vantage points and count sessions. Obviously, the historical multiple vantage point method generates a lot of multiple counts of the same animals because of duration of the counts (1.5 hours) and the field implementation period (4 nights); and the overlap of fields of view between adjacent vantage points. The goal of the consolidation step is to reduce those multiple counts as much as possible. By summing the number of different animals over the 8 count sessions, however, any errors in the decision to state if an animal has been previously detected or not will cascade into the other sessions. In other words, errors accumulate with the number of count sessions during the consolidation stage, leading in turn to a strong overestimation of the overall tamaraw abundance. It can be assumed that the influence of such errors would be greatly limited by using the mean value of the eight sessions instead of the sum in the calculations, or the use of the sessions with the highest numbers of anima seen.

The problem faced during the consolidation phase is one of the many issues inherent to the method as summarized in Appendix 5. It stresses the need to reconsider the use of this method to monitor tamaraw population or the search for an exact number of animals.

5.2. Model limitation and problem faced during the operation – underestimation of the experiment of the double observer estimator

The model assumes independence between observers, while this may not be entirely happening at all-time despite the training of observers. The consequence of a partial independence of the observation is that the estimated detection probabilities are higher than what they should be (*e.g.* observer B detects more animals because he noticed observer A writing down a record thus increasing the number of animals considered as seen by A and B).

Such bias leads to an underestimation of the tamaraw population size. Further analyses could help refining this.

Another issue was the presence of a military platoon during the operation, with men moving within the count zone and stationing at different vantage points. This has undoubtedly created disturbance to tamaraw, although its consequence on the number of animals counted cannot be measured. Yet, we can assume that animals might have either hidden longer in the vegetation, reducing chances for observers to spot them during their 15min laps time, or moved to more quiet areas, thus changing the usual pattern of distribution of tamaraw across the CZM at that time of the year. In addition, the weather conditions, with an unusual low pressure, resulting in fog and regular rainfalls, has indeed affected the detection capacity of observers; probably by reducing the potential distance of observation. Both issues could explain why the number of tamaraws returned by the double observer estimator is quite low at Magawang vantage point with only 19 tamaraws estimated there (Table.2) against 99 animals reported by the annual count in 2022. Indeed, Magawang is the largest VP (around 220ha) and low visibility would surely affect observers more than in a smaller VP to survey, such as Lanas II (36ha) or Mibluan (77ha). Besides, the military platoon has been staying several nights at Magawang station, with daily excursion in the CZM, thus probably affecting the animals' daily behavior. It can also explain the quite surprising high number of tamaraw estimated at Loibfo 1 (n= 41) compared to the annual count a week earlier (n=37), if we assume that disturbance created by the military at the east side of the CZM has pushed animals to temporarily move westward.

For the above reasons, we can assume that our model is returning a slightly underestimated population size, especially at Magawang; where we know by experience that more than 19 animals can be seen on a daily basis or during a single session of observation during the annual tamaraw count. .

Therefore, we can consider the upper level of the confidence interval (n=200) more likely and round the total number of tamaraw inside the count zone to around 200 animals or slightly more. This estimated abundance substantiates the perception shared by many rangers that the number of tamaraws within the count zone is lower than what the annual count is suggesting.

5.3 Density of animals within the core zone of the monitoring and population dynamic

The estimated number of tamaraws as returned by the double observer estimator yields a density of 10 animals per km^2 within the 2000ha of the count zone at MIBNP (considering the upper level of the confidence interval). Such a density for tamaraw already lies at the upper range of previously published densities for species of comparable size and ecology (Table.1). Nonetheless this relatively high population density corroborates the recent evidence of density-dependence in the tamaraw population dynamics (Bonenfant et al. 2022). The annual population growth rate is indeed gradually decreasing with time as tamaraw density rises, being currently at 70% of the estimated carrying capacity of the study site (K). From the absolute density we have now, the carrying capacity for tamaraw at the Core Zone of Monitoring would be around K = 16 animals.km^{-2} (~ 300 tamaraws). Although high, the newly estimated density is biologically realistic for a large herbivore (~ 300kg) living in a protected area.

Nevertheless, we observe that the distribution of tamaraw as returned by the double observer estimator through the local abundance measured at each VP (Table.2) doesn't differ from the distribution pattern returned by the annual point count; animals concentrate at the center of the CZM and become scarcer at the periphery. In such context and repeating the calculation made at section 2.2, the density at Bayokbok and Bato Fidel combined is now 22 animals per km². Such a high population density of tamaraw remains certainly not sustainable in a natural situation, recalling values observed for the feral water buffalo (*Bubalus bubalis*) (Tanle.1) in Northern Territory, Australia (up to 34/km²), where the species has been imported and is now considered as a major environmental disaster (Australian Government, 2011). This highlights the peculiar situation of the tamaraw population at MIBNP.

For instance, the fact that the Anoa *(Bubalus depressicornis)*, the closest relative of the tamaraw, that leaves in dense tropical forest on the Island of Sulawesi, Indonesia, shows a density of around 1 animal per km² (Table.1) emphasizes the specific case of the CMZ at MIBNP. Indeed, such a low density rather recalls the situation of the tamaraw sub-population that was re-discovered at the Upper Amnay watershed region, a densely forested area at the border of Occidental and Oriental Mindoro, in 2018. Results of field surveys suggest a similar density (60+ animals on 6000ha) to the Anoa (Schütz, IUCN AWCSG BULLetin Issue 2 July 2019).

These observations emphasize the fact that the tamaraw is expressing a very particular adjustment of its ecology at MIBNP, because of the burning regime of the grassland that retain animals within a limited zone, with high concentration where rangers are patrolling more regularly near base camps, then becoming scarce towards the periphery and virtually absent beyond the CZM. This situation is analogue to a context of semi-captivity with animals retained within a quite well delineated invisible border.

5.4 On the long term conservation of the species

In terms of conservation, our results have important implications. A population size closer to 200 animals inside the CZM draws a very different picture compared to the base line population that was used to run population models and plan actions during the Population and Habitat Viability Analyses (PHVA) that was held in Mindoro in December 2018.

The first consequence of a much lower tamaraw population size than what was envisioned is that the projected long-term trajectory and viability of the species at MIBNP is likely over-optimistic. Based on previous estimations and the data available at that time, the population viability analyses published by the PHVA assumed an initial population size of 400–500 animals and an annual growth rate of 0.04 (Lee et al. 2019). In reality, we re-evaluated the long-run population growth rate of the tamaraw to 0.06 (Bonenfant et al. 2022), with an initial population size of approx. 200 instead of 400. The time to extinction being a direct function of initial population size, we fear the projected extinction time is substantially shorter than the previously estimated of >100 years (Lee et al. 2019). In such context, it would be relevant to run again the population models used at the PHVA. In any case, our findings reinforce all the concerns that were raised at the PHVA and stress the need to urgently implement the measures and strategies that were formulated in the subsequent Tamaraw Conservation and Management Action Plan (TCMAP 2021-2030).

Another consequence of our results relates to the feasibility study for an *ex-situ* program for the tamaraw. One option which will be investigated is the feasibility of translocating some tamaraws from the core zone of the monitoring to create a conservation breeding center, establish a new population or to reinforce other sites with very small populations or proper conditions/habitat (Aryuan-Malati, Mt Calavite Wildlife Sanctuary). With a population size close to 200 tamaraws, the envisioned number of animals that could be removed without jeopardizing the main population of Mindoro is necessarily much smaller than with the previously though 400 individuals. It means that the current potential level of reinforcement for other populations is rather modest, thought proper dedicated simulations and analyses are needed to come with a more quantitative estimate.

Finally, the fact that the density dependence effect is still at play with only 200 animal stresses the need to increase the space available for the species so as to enable it to reproduce safely and to see a population increase up to a more viable number of animals.

6. Conclusion

The conclusion of our experiment suggests that the number of tamaraw is closer to 200 animals than to the 400 returned by the annual tamaraw population count. However, this does not mean that 200 animals have disappeared in the past few years because of more intensive poaching, illegal activities, density dependence effects or singular situations during the last count operation, although all these factors may be playing a role in a possible population decreasing trend. It rather reveals that the population size has been generally overestimated during the twenty years of annual counts due to the problems inherent to the method used. In that sense the people involved are not responsible for the shortcomings of the method, and the ability to conduct more or less the same protocol over a long period of time has been crucial in assessing the true increase of the tamaraw population since 2000 and hence the success of protection effort at MIBNP by local authorities. In addition it reveals the distribution pattern of the species in the area, thus guiding patrolling effort.

Despite the fact that the tamaraw population might be much smaller than thought, the density-dependence effect concurrent to the progressive decrease of the population growth rate already documented for the MIBNP population (Bonenfant et al), is still at work. In other words, the population size may differ, but the population dynamic remains largely unchanged. Consequently, the need to increase the tamaraw range at MINBP so as to enable animals to have more space, as stated in the TCMAP, remains crucial for the long-term viability of the species. Expanding the tamaraw range therefore remains a primary target in order to avoid density dependence effect and restore reproductive potential of the tamaraw population in MIBNP.

In the perspective of phasing-out the grassland burning that has been in used for the purpose of the annual multi-vantage point count, new methods, not relying on direct visual sightings, and with methodologies less prone to bias, are being developed. From an annual population estimate wrongly considered as the true number of tamaraw present in the core zone of the monitoring, we will progressively move to indicators of abundance. Therefore, being able to rely on the most robust population estimate at early stage of this transition becomes crucial. In this matter, conducting another operation using the double observer estimator in 2023 could be relevant so as to validate the results of 2022, so far as the conditions are appropriate and that it doesn't hinder the transition phase.

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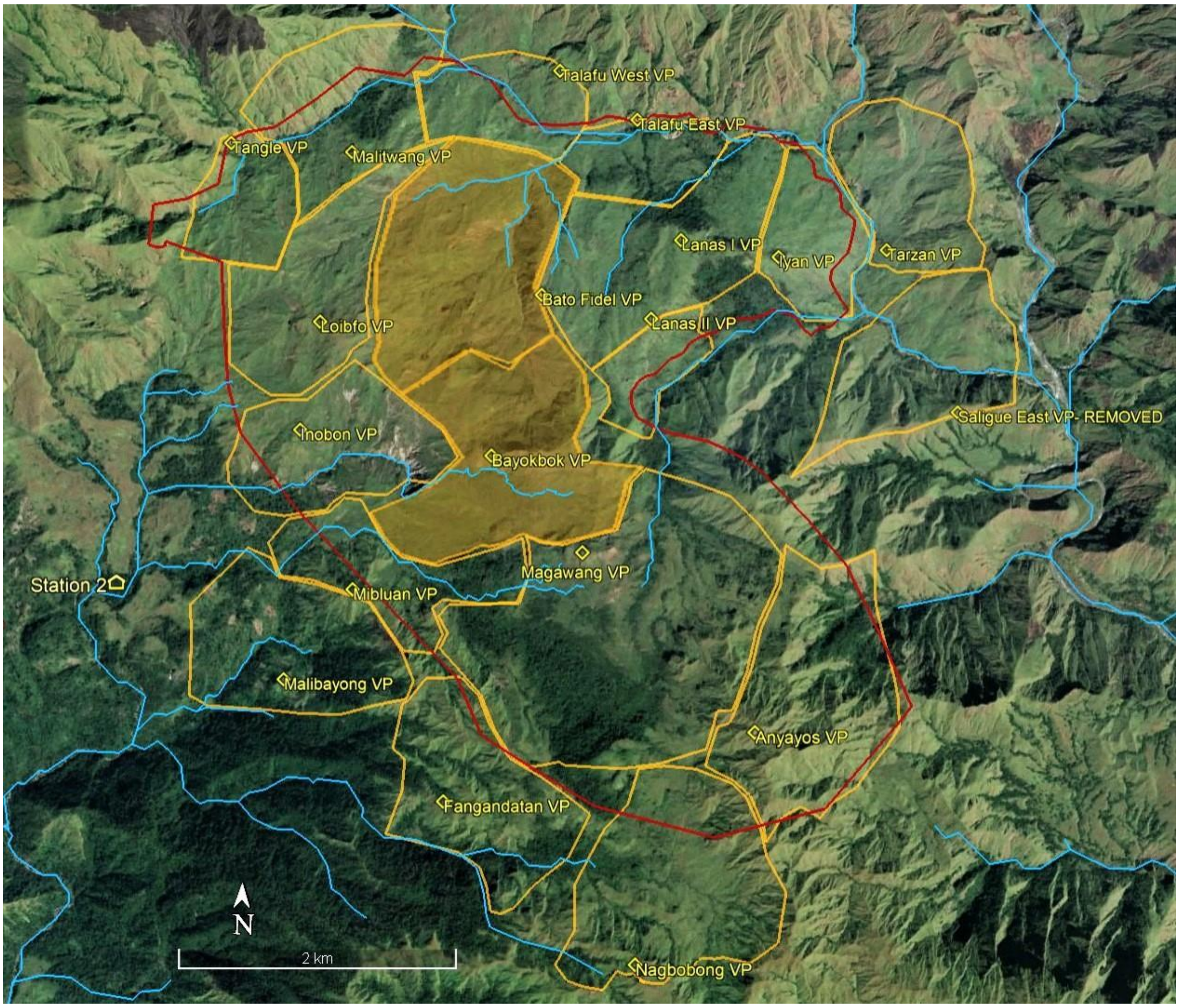
Appendix 1.A

Physical map of the Core Zone of the Monitoring inside Mts Iglit-Baco Natural Park showing the location of the different vantage points used during the annual tamaraw population count with a highlight on the Bayokbok and Bato Fidel vantage points



Appendix 2

Table of the results of the past three operation of the annual tamaraw population count per vantage point showing the expected surface of observation of each vantage point and the corresponding density of animals

Vantage point	2019	2021	2022	Average	Surface (ha)	Animal/km²
1. Loibfo	49	45	37	44	74,4	59
2. Magawang	98	95	99	97	218	45
3. Bayokbok	83	73	89	82	152	54
4. Bato Fidel	59	83	68	70	164	43
5. Inubon	38	29	28	32	99,6	32
6. Mibluan	34	17	19	23	77,2	30
7. Nagbobong	6	5	0	4	142	3
8. Fangandatan	5	7	2	5	110	4
9. Anyayos	31	27	9	22	148	15
10. Lanas I	26	14	24	21	141	15
11. Iyan	2	0	0	1	64,4	1
12. Tarzan	0	0	2	1	86,3	1
13. Talafu East	6	8	2	5	51,1	10
14. Talafu West	13	6	6	8	62,5	13
15. Malitwang	11	7	8	9	98	9
16. Lanas II	11	7	5	8	36,4	21
17. Tangle	8	4	4	5	53	10
18. Malibayong	7	0	1	3	123	2
Total	**487**	**427**	**403**			

Appendix 3

Photos of tamaraws captured with photo cameras in MIBNP and by camera traps at Aruyan-Malati site showing the difficulty to distinguish individuals and individualize animals from each other

Appendix 4

Table.A: Total number of animals seen per session and per vantage points by the two sub-teams during the double observer point count operation

	Session (15minutes each)	1	2	3	4	5	6	7	8
1	Loibfo I	10	16	9	11	4	23	14	14
2	Loibfo II	0	3	0	0	5	0	0	0
3	Magawang	8	22	6	3	5	0	7	5
4	Bayokbok	5	13	6	13	7	13	6	3
5	Bato Fidel	13	5	12	15	18	21	3	2
6	Inubon	NA	NA	2	3	2	6	13	11
7	Mibluan	3	11	0	3	0	12	0	4
8	Nagbbong	4	0	0	0	0	0	3	0
9	Fangandatan	0	0	5	0	0	0	0	0
10	Anyayos	5	0	0	0	0	0	0	0
11	Lanas I	0	5	7	0	0	1	6	3
12	Talafu East	0	3	2	2	NA	NA	NA	NA
13	Talafu West	0	7	0	0	1	0	0	0
14	Malitwang	0	1	0	0	0	1	0	0
15	Lanas II	0	1	3	0	0	1	NA	NA

Table.B: Proportion of sighting for each sub-teams for the whole operation of the double observer point count operation

	Only by A	Only by B	A and B	Total per team	%A	%B
Team 1	1	1	153	155	99.35	99.35
Team 2	47	29	70	146	80.14	67.81
Team 3	3	5	8	16	68.75	81.25
Team 4	23	21	72	116	81.90	80.17
Team 5	2	5	10	17	70.59	88.24

Appendix 4

Summary of the limitations of the simultaneous multi-vantage points count method

Observed constraints / limits	Consequence
Based on direct sightings of animals	Animals need to be visible by observers – problem of imperfect detection of animals (forest, blind spots, tall grass…)
Requires to burn grassland prior to the count to increase detectability of animals in low grass	Artificially maintain tamaraw in open areas attracted by new grass shoots at peak of dry season (behaviour bias) Impact on other biodiversity Freeze the ecological succession to few dominant pioneer grass species
Animals observed from far, 18 different teams of different people, not all teams have binocular and/or telescope	Variability in quality of observation between observers (skills, motivation, experience, equipment)
Count zone of around 2000ha contiguous area	Good to avoid gaps but animals that may be roaming beyond the count zone at the time of the operation are not recorded, while belonging to the same sub-population
Species displaying little physical characteristics	Impossibility to properly differentiate individuals Subjectivity in segregating sexes and class ages (heterogeneity between observer's appreciation)
18 contiguous vantage point's count zones	Difficulty for observers to clearly state delimitation between different VP count zones (overlap of area being surveyed)
Animals moving within and between vantage point's count zones during the 90 minutes observation session	Prone to recording same animal on same VP or different VP during same session
Animals moving between vantage points' count zones between sessions	Prone for multiple counts if not considered different individuals from one session to another, if the consolidation process is cumulative (addition of new animals only)
Possible multiple counts being removed a posteriori during consolidation process	Variability in consolidation process (observers, supervisor, protocol adopted (overall average, maximum observation, cumulative counts)) will lead to very different results each time (annual result) and over time (time series becoming not reliable)