RESEARCH

Four years after the Population and Habitat Viability Assessment, what do we know about the status of tamaraw (*Bubalus mindorensis)* in Mindoro?

Status of research and findings and implication for conservation.

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Introduction

The tamaraw (*Bubalus mindorensis*), or Mindoro dwarf buffalo, is endemic to the island of Mindoro in the Philippines and was once widespread across the island (Custodio et al. 1996). However, the species is now restricted to only a few isolated locations and is listed as Critically Endangered on *The IUCN Red List of Threatened Species* (Boyles et al. 2016). The **Tamaraw Conservation Program (TCP)**, a flagship program of the Philippine Department of Environment and Natural Resources (DENR), is in charge of coordinating and consolidating efforts in the implementation of the **Tamaraw Conservation and Management Action Plan (TCMAP)** that was formulated following a Population and Habitat Viability Assessment (PHVA) in 2018. The TCMAP provides a road map outlining actions for each of the four sub-populations known to persist on the island at the time of the PHVA workshop. Here, we present new information on the status of each population as of 2023 and discuss how finding or changes in recent years may impact tamaraw conservation more broadly.

Mts Iglit-Baco Natural Park – A population that is smaller than previously thought and contracting in range.

Mts Iglit-Baco Natural Park (MIBNP) was first created as a game refuge in 1969, and then proclaimed as National Park the following year in order to protect the tamaraw. Domestic cattle ranching was phased out prior to protected area gazettement. The protected area covers 106,655.62 hectares of difficult terrain in the south central part of the island. The current tamaraw population of MIBNP, the largest of all known sub-populations, is entirely located within the territories of the Taobuid indigenous peoples whose ancestral domain shares boundaries with

the Park. By-catch and intentional killing for traditional purposes from Taobuid remain one of the causes of death of tamaraw, while poaching from outsiders has been a long-standing threat to the species.

The tamaraw population at MIBNP has been monitored on a yearly basis since 2000 with a method referred to as multiple vantage point estimation. Each year tamaraw are simultaneously counted from 19 vantage points distributed over a 2,200 ha area (called the "count zone"). The count zone is part of a core area that is regularly patrolled by rangers and where all tamaraws are confined. Vantage points are located in strategically located areas that give good field of view, and each observer is tasked with recording tamaraw within a specific area of the count zone. Because the multiple vantage point estimation method is based on direct observations, this approach requires observers to be able clearly to see tamaraw – which is difficult under natural conditions in MIBNP, due to the high grass that covers most of the count zone. As a result, every year the local authorities burn the grassland within the sampling area, with the primary aim of increasing visibility so that tamaraw can be sighted, and a secondary aim to attract animals to new grass shoots that sprout following burning. Counts are repeated eight times (four consecutive mornings and evening sessions of 90 minutes each at dusk and dawn). At the end of the counting process, counts of the same animals between vantage points and different sessions are removed from the total count. The process of removing multiple counts is called the consolidation of tamaraw numbers. The final estimated population abundance from this approach is therefore the total number of animals counted during the consecutive sessions minus animals that were "double counted" during all sessions and considered different. The final number (Fig.1) is presented as the official tamaraw population size in MIBNP, and is used by authorities and conservation organizations.

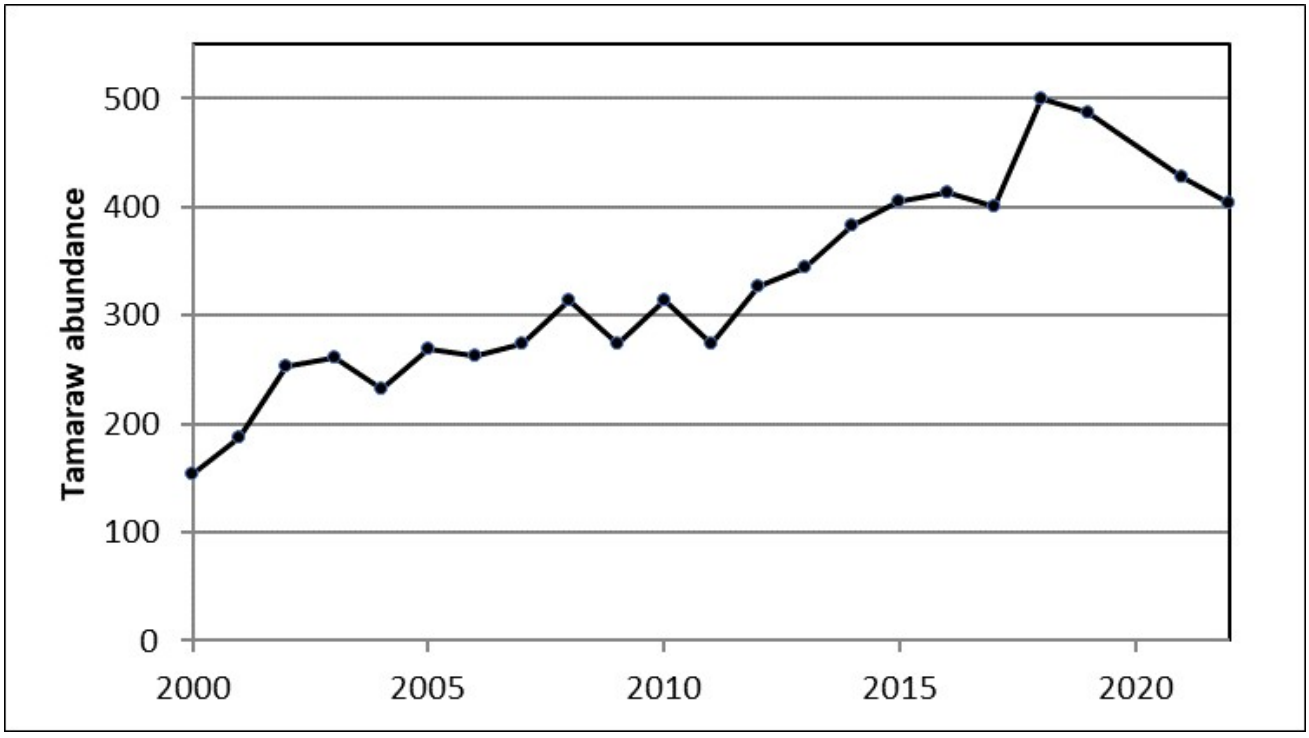

Figure 1. *Historical results of the annual tamaraw (Bubalus mindorensis) population count showing the total number of animals estimated after consolidation each year at Mounts Iglit-Baco Natural Park on Mindoro Island, Philippines. Note that there was no count in 2020 because of the COVID-19 pandemic.*

The multiple vantage point time series of tamaraw abundance has been valuable in measuring the population trend in MIBNP and assessing the effectiveness of protection measures. Bonenfant et al. 2023 used this data to estimate an average growth rate of 0.06% over the past 22 years. Moreover, analysis of the annual count data from 2003 to 2022 showed strong spatial structuring within the count zone, with the population growth close to +10% in the central vantage points located nearby ranger's base camps, and a growth rate of −5% at the periphery of the count area (Bonenfant et al. 2023). These results provide insights into the progressive contraction of the tamaraw distribution in the cores zone of MIBNP – an observation that has also been suggested by rangers working in the park. It is likely that tamaraw range is contracting because anthropogenic pressures are forcing the species to concentrate in high densities in areas where the presence of rangers is more deterrent to poachers and where Taobuid IPs have no permanent activities, creating a source sink dynamic (Fig.2). Despite a general increase of the population since the beginning of the census (163 in 2000, 396 in 2022), the multiple vantage point data highlights a progressive decrease of the average growth rate in time, suggesting significant density-dependence at the population level. If true, this means that the current abundance is close to the carrying capacity, with animals competing for space and resources in a smaller and smaller area.

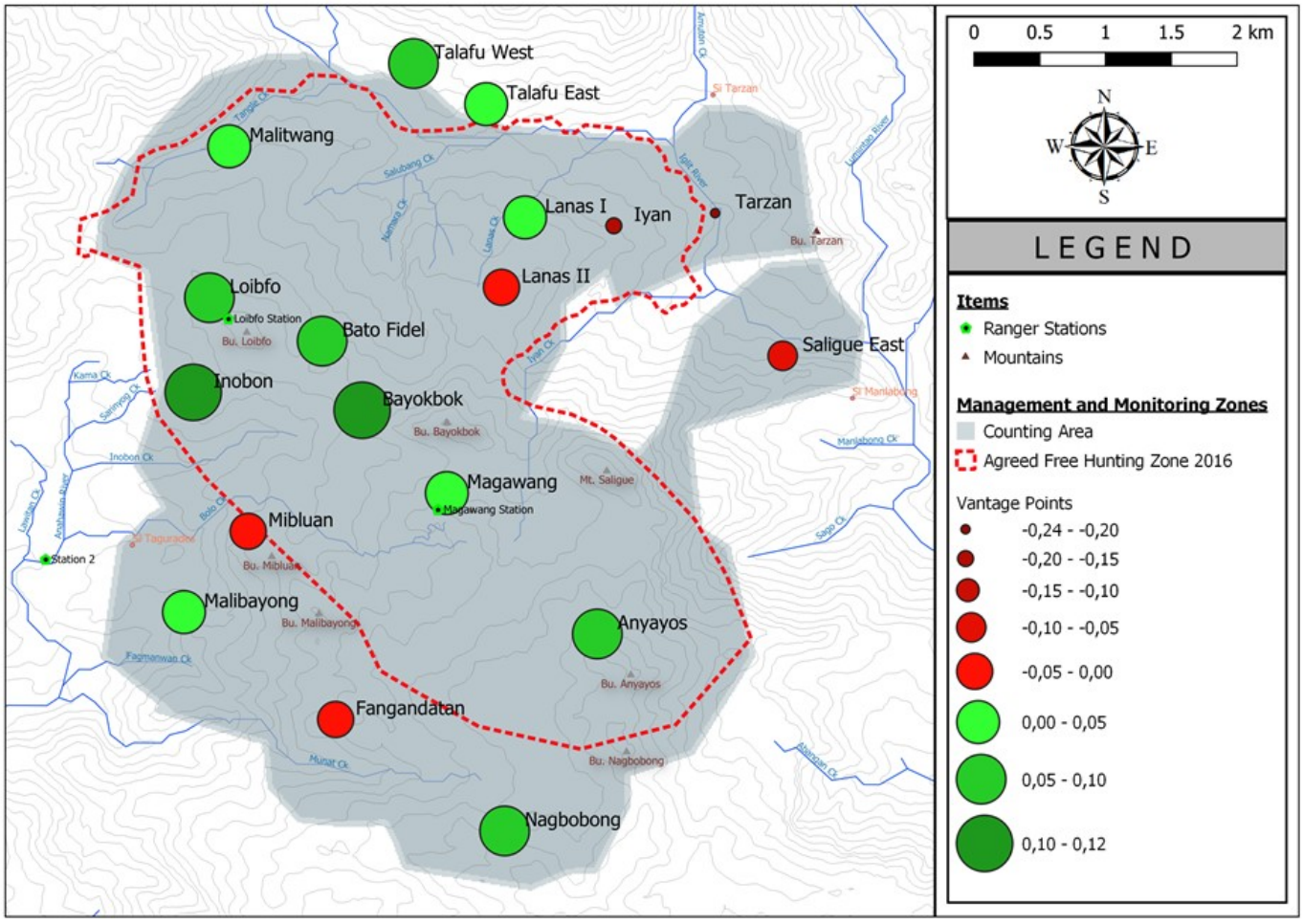

Figure 2. *Spatial variations in the local growth rate of tamaraw (Bubalus mindorensis) abundance in Mounts Iglit-Baco Natural Park on Mindoro Island, Philippines, from years 2000 to 2021 (taken from Bonenfant et al, 2023).*

The design of the multiple vantage points method is similar to other census methods used for other wildlife species around the world. However, because detection probability is not estimated, the annual tamaraw population count operation is unable to provide an absolute number or density of tamaraw, but instead provides an indicator of relative abundance. In practice, this means that it can provide trends in population abundance over time, but not the number of tamaraw in the MIBNP population.

A closer look at the multiple vantage points method and its protocol reveals several issues:

First, the density of animals returned by the annual tamaraw count raises some questions. Official results of the annual count suggest 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, p27). Based on results of the count for the period 2019-2022, more than 400 animals would live in an area of 2200 ha. This corresponds to a density of around 20 animals per km², which is rare for a wild herbivore species of this size and ecology. Estimated numbers in the vantage points located at the center of the count zone, where most sightings are recorded, return an even more biologically unrealistic density estimate of more than 50 animals per km², which is similar to densities found in the domestic cattle ranching industry.

Second, there are problems with the cumulative nature of the multiple vantage point count estimator, where participants attempt to sort out new tamaraw from animals observed in previous sessions. Such protocol means that the probability of errors increases with the number of sessions, while the total number of animals becomes directly impacted by the number of sessions conducted; the more the number of count sessions, the larger the final result.

Third, the intrinsic subjective nature of the simultaneous multiple vantage point count method creates sources of variability at all phases of the operation, from observations in the field (variability in segregation of sexes and age classes, skills in spotting of animals between observers, determining whether animals have been previously recorded or not) to the consolidation step (choice of consolidation method, removing of possible multiple counts, people leading the operation). It is likely that changing observers or repeating the data consolidation process would lead to a different abundance estimation of tamaraws each time, thus limiting the ability to compare count years between each other.

As a result of these issues, it has been suggested that the annual tamaraw population count could have been overestimating the true number of tamaraw present at MIBNP, possibly hiding a long-standing stagnation of the population or a more concerning decline in recent years. Indeed, an overview of the raw data shows that the total number of animals sighted, before consolidation, seems actually to have reached a peak in the mid-2010s (Fig.3). The last annual count conducted in April 2023 goes in that direction with a substantial drop in the number of animal counted after consolidation with only 325 this year compare to 396 animals in 2022. The overestimation of the tamaraw population in MIBNP is corroborated by the results of a recently implemented and robust population size estimation analysis using the independent double observer estimator method carried out in 2022 and 2023 by the D'ABOVILLE

Foundation and Demo Farm Inc. (DAF) together with the TCP and the park office. The method, which aims to correct the bias of the multiple vantage point approach by calculating the probability of detection of tamaraw, suggests a population nearly half the size of the results of the annual count (2022: [163-200], 2023: [135-180]).Interestingly, the ratio between the results of the double observer estimator and the annual count for both years are similar (2022: [0.41 – 0.5]; 2023: [041 – 0.55]). This is suggesting that both methods, hence imperfect in estimating the true number of animals, are consistent in sustaining that the decrease in the number of animals observed reflects a true decline of the population in the recent years.

From a conservation perspective, a much lower tamaraw population size than what was envisioned means that the long-term viability of the species at MIBNP has probably been over-optimistic. Based on previous estimations and the data available at that time, the population viability analyses published by the Population and Habitat Viability Analysis (PHVA) assumed an initial population size of 400–500 animals and a conservative annual growth rate of 0.04 (Lee et al. 2019). Because the estimated time to extinction in PHVA models is a direct function of initial population size, it is likely that, with an initial population size of approximately 200 instead of 400, the projected extinction time is substantially shorter than the >100 year result that was previously estimated (Lee et al. 2019), even with a corrected growth rate reevaluated at 0,06. We recommend that the PHVA models are re-run with the updated population size information. In general, the new population size estimate strengthens the concerns raised at the PHVA workshop in 2018 about the viability of the MIBNP population, and stresses the urgency of implementing the measures and strategies outlined in the Tamaraw Conservation and Management Action Plan.

Another consequence of the revised population estimate in MIBNP is that it may cause conservationists to reassess the feasibility of

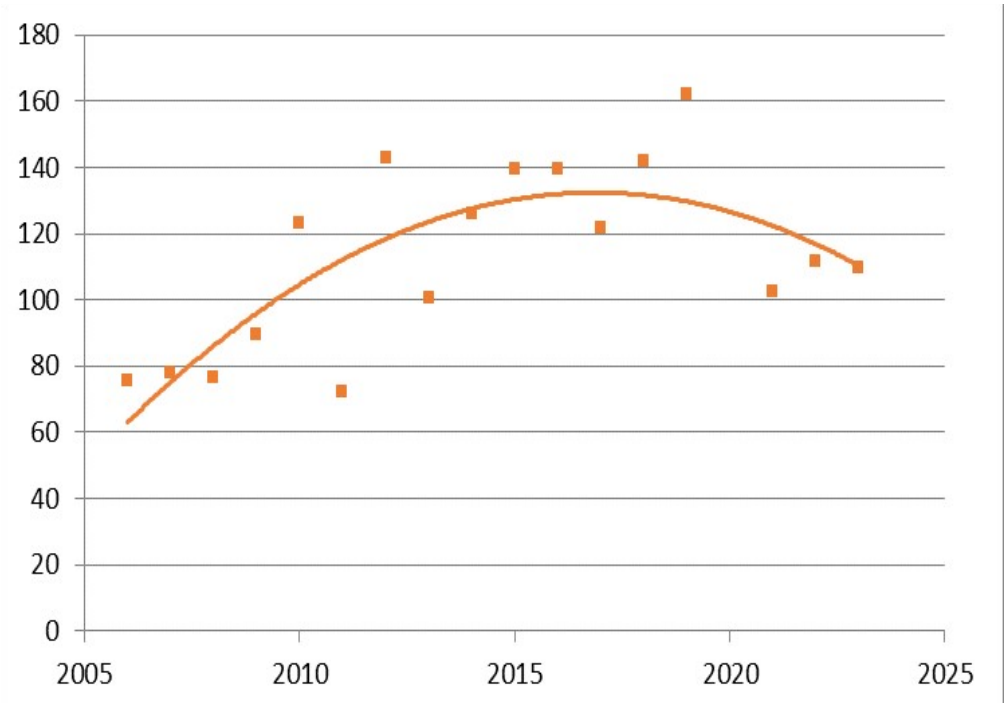

Figure 3. *Evolution of the average number of sightings per session from the raw data (total number of tamaraw sighted) during the annual tamaraw population count between 2006 and 2023, Mts Iglit-Baco Natural Park on Mindoro Island, Philippines.*

using this population as a potential source for translocation or *ex situ* intervention. The number of animals that could be removed without jeopardizing the viability of the MIBNP population will be smaller with a population of 200 rather than 400 individuals. This, in turn, may impact the ability of using the MIBNP population as a source for reinforcement of smaller populations such as Aruyan-Malati. However, any decisions about *ex situ* interventions in the MIBNP population will require robust analyses and in-depth discussions with local stakeholders.

Finally, the fact that negative density dependence is still occurring within such a small population highlights the need to increase the space available for the species where it could disperse and reproduce safely so as to see the population increase up to a more viable number of animals. As a matter of fact, the 1600ha "No Hunting Agreement Zone" of 2016, where Taobuid and TCP agreed that no traps would be set inside, is far too small to secure a viable population with full reproduction potential. An expansion of such agreement would be crucial for the conservation of the species.

Aruyan-Malati – A small population in decline

The Aruyan-Malati forest area, in the municipality of Sablayan in Occidental Mindoro, has long been known to hold tamaraw. The Aruyan-Malati region is believed to have harboured a substantial number of tamaraws in the 1980s; indeed, 20 animals were captured there between 1982 and 1994 to establish the tamaraw gene pool farm. The goal of the gene pool farm was to create an insurance population for the species, but ultimately this was unsuccessful, due to difficulties with managing and breeding the species. Kalibasib, the only captive-born tamaraw reaching adult age, died in 2021 without leaving any decedents. In 1998, a maximum of 26 tamaraws was estimated in Aruyan-Malati during a rapid population assessment conducted by TCP using indirect signs of presence and direct sightings. (TCP records, unpublished). By 2015, the population was estimated to be no more than 15 animals by using a similar method (DENR TCP report, 2015). As a consequence of this finding, local authorities initiated the filing of 3,000 ha within the Aruyan-Malati region to be declared as "critical habitat", a protection category under Philippine laws that provides some level of resource and protection (albeit less than what is given under full protected area status). The TCMAP supported this initiative, calling for urgent actions in Aruyan-Malati before the tamaraw population declined further. As a first step, it was recommended to conduct a proper baseline survey on the small population.

From 2020-2022, DAF and the TCP conducted a systematic camera trap survey in Aruyan-Malati with the goal of assessing tamaraw population status. The survey followed a grid-based design, with stations spaced approximately 300m apart

Tamaraw captured on camera trap in Aruyan– Malati

across the core forest area of Aruyan-Malati, and active in the field for 4-5 weeks. Twenty camera traps were first deployed for five months in 2020, covering 80 locations and 700ha, undertaking four rounds. It was followed by another deployment of twenty devices for another five months in 2021-22 to complete the sampling area, based on information collected during the first phase. A total of 1000ha was sampled over the two years, defined thanks to prior foot surveys and consultation with Taobuid communities residing in the region and sharing their living space with the species. In seven stations the cameras malfunctioned or were stolen, providing a total of 73 active stations and 1,889 camera trap nights. Tamaraw were recorded in only six stations, with 51 events (independence threshold = one hour) (Fig. 4). At least four different individuals can be distinguished from the photos, based on physical characteristics and age.

Although the camera-trapping survey was unable to provide an estimate of tamaraw abundance, the findings are, overall, in accordance with the TCMAP estimates of no more than 15 animals – and the number may be in the single digits. Equally alarming is the fact that tamaraw were only recorded over an area of restricted range of approximately 170 ha at the time of the study. Together, the small population size and small area of occurrence reinforce the notion that the Aruyan-Malati population is currently not viable and will disappear in the near future without urgent conservation actions that will likely involve *ex situ* reinforcement. We also urge local officials to accelerate the approvement of the proposal to declare Aruyan-Malati as critical habitat.

Mt Calavite Wildlife Sanctuary – Still no evidence of tamaraw

Historically, tamaraws were also present in Mt. Calavite Wildlife Sanctuary (MCWS), a protected area in the Municipality of Paluan in the extreme northern part of Occidental Mindoro. In 1987,

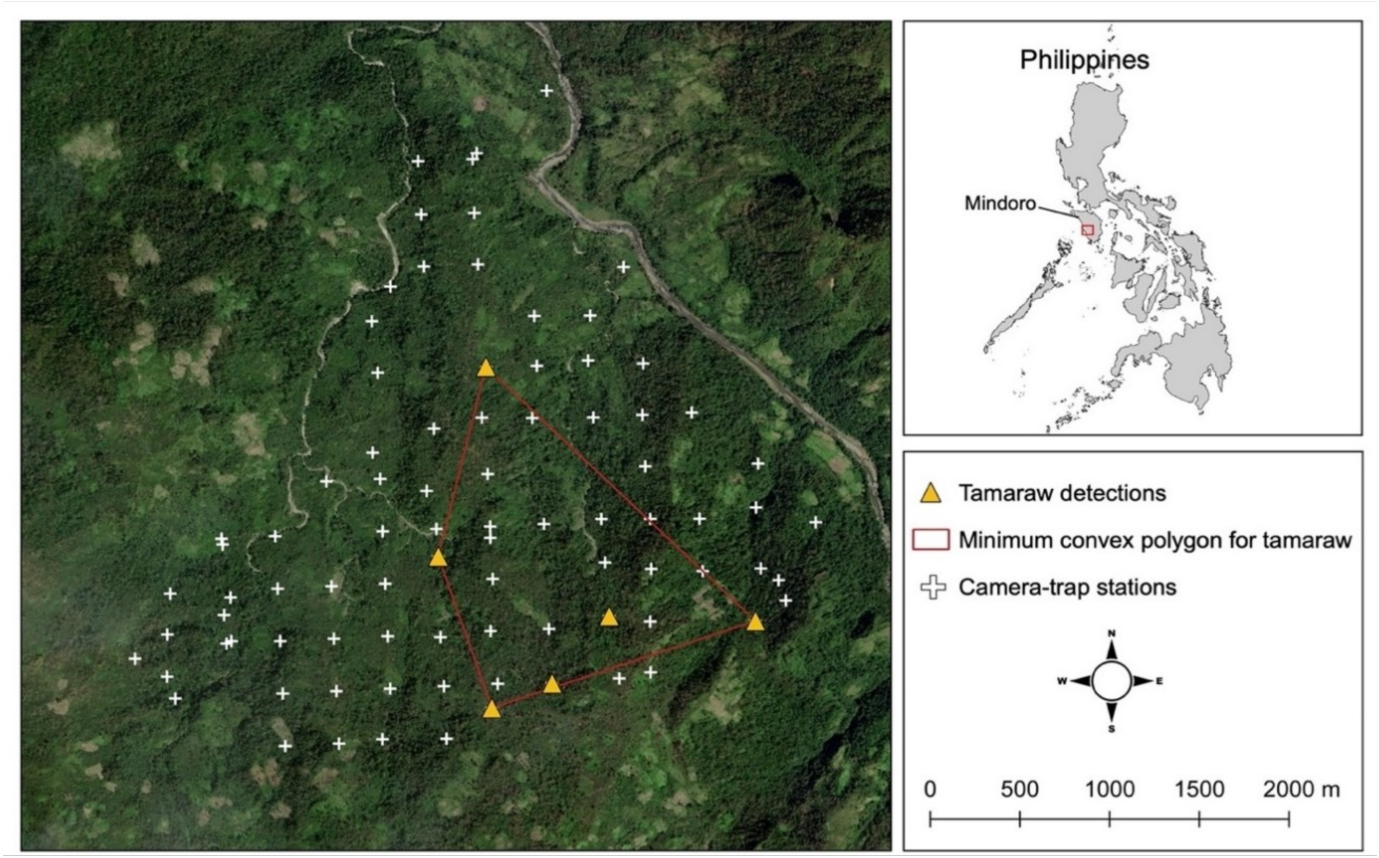

Figure 4: Aruyan Malati camera trap results: detections of tamaraw 2020-2022

Petocz (1989) estimated the tamaraw population in MCWS to be 45 individuals (though the method used is unclear). However, during surveys conducted in 1994, only a single animal was sighted, with some additional evidence of tamaraw from tracks and dung (de Leon et al. 1996). More recent surveys conducted in 2013 and 2014 failed to record tamaraw sightings or sign (Balete et al. 2013; Ishihara et al. 2014). The tamaraw population in MCWS was considered possibly extirpated until 2019, when a tamaraw survey conducted by the Mindoro Biodiversity Conservation Foundation Inc. (MBCFI), in collaboration with the DENR TCP and DAF, reported signs of tamaraw presence based on dung and tracks, and a sighting of a possible juvenile male. Based on this preliminary information, researchers estimated that the number of tamaraw in the site could be between 4 and 6 individuals (MBCFI 2019, Tabaranza et al., 2021), though this was little more than a guess. However, no sign of tamaraw presence could be photo documented, while the possible presence of feral carabaos or water buffalo (*Bubalus bubalis*) in the protected area brings doubt to these conclusions.

It is imperative to conduct robust and intensive surveys to assess whether tamaraw occur in MCWS, and if so, its population size and distribution. The project MATAPAT (**M**ultidisciplinary **A**pproaches for **Ta**maraw **P**rotection **A**gainst **T**hreat) is a collaborative research work between the University of Santo Tomas (UST), DAF, PAMO MCWS and the DENR-TCP. The main purpose of the project is to establish information on the tamaraw population of MCWS using foot surveys, camera-trapping, and habitat suitability analysis. In addition, the project also aims to obtain data on other threatened medium to large-sized mammals such as the Mindoro warty pig (*Sus oliveri* VU; Schütz 2016) and the Philippine brown deer (*Rusa marianna* VU; Mackinnon et al. 2015).

From July to November 2021, two foot surveys were conducted to (1) obtain information on the likely current distribution of tamaraw through direct and indirect indications of presence, and (2) to identify areas to be included in subsequent camera trapping. In total, the surveys covered 32 kilometres walked with a sampling area of approximately 543ha size. No actual sightings were reported, but possible indirect signs of tamaraw were recorded, which includes hoof and dung (Fig. 1).

Feral carabao captured on camera trap in Mt. Calavite

Follow-up camera-trapping was conducted between December 2021 and will be completed by third quarter 2023 (one round is missing at time of this article). The sampling area for the camera trapping is covering 1,300 hectares or 7% of the total protected area. The survey design is following the protocol used in Aruyan-Malati, with stations spaced approximately 300m apart in a grid, and cameras deployed in successive phases (Fig. 2). In total, the survey will cover 120 camera stations across six phases. At the end of the fifth phase, no tamaraw were recorded, but feral carabaos were captured on multiple occasions (image on previous page).

Could tamaraw still exist in MCWS? Our results, although not definitive, suggest that the species is either extirpated or, if present, then occurs at extremely low numbers. The presence of feral carabaos is adding further doubt to the findings of most recent surveys, while local IP communities confess that they haven't seen the species for many years now (personal communication). However, some extremely remote areas of the park remain unsurveyed, and future work should target these areas and adjacent mountainous areas of the Park to understand if a remnant tamaraw population could survive in MCWS.

Meta-population research across the Mindoro central spine – new evidence of tamaraw found in 2022-23

The rediscovery of the tamaraw in the upper Amnay watershed region in 2018, on the border between both Occidental and Oriental provinces (Schütz, 2019), provided hope that the species could still persist outside of the three populations mentioned above. Spurred on by this finding, conservation stakeholders formalized a goal to locate all remaining sub-populations that could survive within the island's central spine, and link additional sub-populations to the wider meta-population conservation approach defined in the TCMAP.

Several additional tamaraw surveys were organized in the Mindoro inner region between 2021 and 2023 with the objective of assessing potential tamaraw sites. Prior to field verification survey, Interviews with local indigenous people communities were conducted and completed with a rapid remote sensing data analysis to locate most potential areas based on socio-ecological parameters (land cover, IP settlement, land-use type and fire event). Although these surveys did not result in any direct sightings, tamaraw tracks were observed outside of the previously confirmed areas of 2018 in at least two different locations. More interestingly, a group of 5 hoofmarks was spotted in a remote region located nearby the Northern border of MIBNP. In addition, convincing recent tamaraw sighting reports were obtained from indigenous peoples whose ancestral domain stretches across these remote upland areas of inner Mindoro, while several of them, living in the upland, suggest the presence of tamaraws in areas not yet visited by the team.

Taken together, this information suggests that the distribution of the tamaraw population within the upper Amnay region could cover a much larger distribution than previously thought, extending across much of the island's central mountain spine, including MIBNP (fig. 5), or be composed of several subpopulations. Additional efforts are needed to understand tamaraw occurrence in the full region.

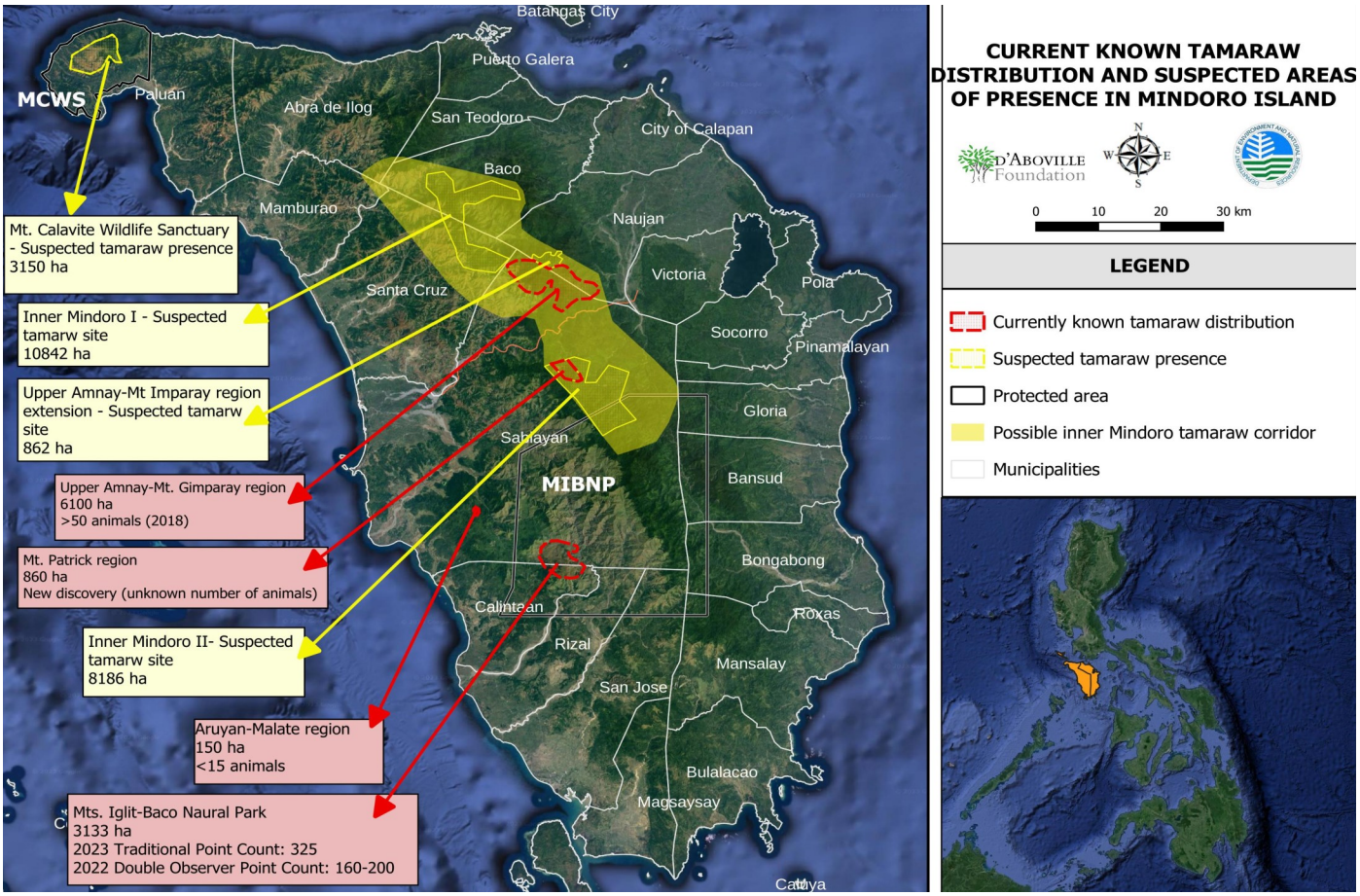

Figure 5: Map of Mindoro showing the known tamaraw sites, actual suspected areas of presence and potential area of occurrence of the species

Conclusion

Four years after the formulation of the Tamaraw Conservation and Management Action Plan, we have a better picture of the conservation status of the species across Mindoro. Unfortunately, new information has painted a bleaker picture of tamaraw status than in 2018. Recent camera-trapping evidence suggests that the two small and isolated sub-populations of Aruyan-Malati and MCWS have little chance of survival without translocation actions for population reinforcement. However and given the substantial challenges around such active conservation measures, this option may not be realistic in the short-term.

Moreover, because the revised population estimate has put the MIBNP population at approximately 200 individuals – half the size of the number used in the PHVA modelling – the assumption that the tamaraw population of MIBNP could be a safe source of animals for a translocation or *ex situ* activities may need to be reconsidered. Furthermore, the MIBNP population is also undergoing a problem with density-dependence, which translates into a decrease of the growth rate and means that the population will likely continue to contract unless the species is given more space to disperse and reproduce safely beyond its current limits.

New records of tamaraw along the inner Mindoro spine provide hopeful news amid this overall quite pessimistic picture. In fact, with the revised population estimate for MIBNP, it is possible that the central Mindoro population or sub-populations may represent the best hope for the

long-term survival of the tamaraw, even if densities in upland forest habitat are lower than in the grassland dominating landscape of the core area at MIBNP.

To save the tamaraw from extinction it is critical to implement the conservation strategies outlined in the TCMAP. Within that context, the TCP, with the support of local and international partners, is planning to launch an island-wide work-plan of activities to improve protection efficiency in all sites while exploring the feasibility of conducting *ex situ* interventions. In addition, the authorities of MIBNP have engaged in a consultation process with residing IPs communities to expand the 1600ha. No Hunting Zone agreement that was agreed in 2016, building a larger "wildlife safe reproduction zone" using the customary laws of the Taobuid.

If successful, these conservation actions will be able to reverse the trend and avoid the need for emergency *ex situ* program.

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

Species	Location	Body mass (kg)	Density (/km²)	Reference
Okapia johnstoni (Okapi)	Afro-tropical region	250	0-4	Fa & Purvis (1997)
Tragelaphus spekeii	Afro-tropical region	100	55	Fa & Purvis (1997)
Sincerus caffer nanus (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 caffe*r (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
Tragelaphus strepsiceros (Greater Kudu)	Southern Rhodesia (Zimbabwe)	250	1,3	Dasmann & Mossman (Cited by Bourlière 1962)
Bos gaurus (Gaur)	Kuiburi National Park	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)