Distance Sampling of Dungs as an Alternative Complementary Method To Monitor Tamaraw Abundance in Mts. Iglit-Baco Natural Park

Technical report on the pilot test conducted in February 2020.

Activity done in the frame of the Mangyan -Tamaraw Driven Landscape Program

Fernando García Gil (Tamaraw Conservation Research Officer) D´ABOVILLE Foundation and Demo Farm, Inc,
Emmanuel Schütz (Program Manager), D´ABOVILLE Foundation and Demo Farm, Inc,
Chistophe Bonenfant - Laboratoire de Biométrie et Biologie Évolutive, Université Claude Bernard Lyon1 & CNRS France.

April 2020

This document gives first insights of the data recorded during the 2020 Final Pilot Study for the Distance Sampling of Dungs of Tamaraw. This project is part of the collaboration between DAF, Laboratoire de Biométrie et Biologie Évolutive in France (LBBE) and the Department of Environment and Environment Resources (DENR), represented by the Tamaraw Conservation Program (TCP) and the Protected Area Management Office (PAMO) for Mt. Iglit-Baco Natural Park (MIBNP). This document aims to give an overview of the fieldwork, a first glimpse of the results, and the main biological and practical implications of our results.

1. Introduction

Mts. Iglit-Baco Natural Park (MIBNP), the largest Protected Area of Mindoro Island in the Philippines, hosts the majority of the tamaraw population (*Bubalus mindorensis*) (Ishihara et al., 2014, Long et al., 2018). The bulk of it is restricted to an area of around 2,500 ha, inside the so-called "**Core Zone of Monitoring**" (CZM) (Department of Environment and Natural Resources, 2019a; Department of Environment and Natural Resources, 2019b). This particular situation makes this area crucial for the long term survival of the species, currently classified as Critically Endangered by the IUCN (2020), and for the development of conservation measures to be undertaken. Since the year 2000, local authorities have been conducting an annual population count operation each April using a simultaneous multi-points count method, in order to assess population abundance (Ishihara et al., 2014, Long et al., 2018). Eighteen (18) vantage points are distributed throughout the CMZ area for this purpose. A downside of the counts is the necessity to increase the detectability of animals and to fix them on new palatable growing vegetation, purposely achieved by annual grassland burning in the weeks prior to the operation.

Three decades after its creation, and thanks to the collaboration between local stakeholders and local and international partners, MIBNP was eventually granted with a **Protected Area Management Plan** (PAMP) in 2019, providing a 10 years guideline to manage and develop the Park. In accordance to the Program.1 of the PAMP: "Conservation of species, habitats and ecosystems"; Subprogram 1.6. "Tamaraw conservation"; Action 1.6.1. and Action 1.6.2, burning should be progressively stopped in order to restore natural vegetation. Nevertheless, stopping annual burning will likely result in a reduction of the detectability of the animals due to the persistence of the older and taller vegetation and, consequently to increasing difficulty for wildlife managers to monitor tamaraw abundance if the same census protocol is to be maintained. These expected changes in the habitat management and, in turn, in the condition of observation, compels to explore new techniques to monitor the population abundance of the species.

In the last decades, worldwide, different methodologies have been used to estimate the density of animal populations while accounting for the fact that a proportion of individuals are missed during the counts and observations. One of them is the **double observer distance sampling of dungs** to assess the relative abundance of the species (Jenkins & Manly, 2008). This choice was motivated by the fact that it relies on indirect observations, the dungs of tamaraw, which are still detectable even in dense, thick vegetation when tamaraw become almost undetectable. This technique sounds hence appropriate to monitor the population of tamaraw in MIBNP in a context of a progressive shift in habitat management by the Park's authorities. This method allows us to monitor as well, with little additional efforts, the two other main species of ungulates of Mindoro found in the Park: the Philippine brown deer (*Rusa Marianna*) and the Mindoro warty pig (*Sus oliveri*), both on the Red List of Endangered species of the IUCN.

Nevertheless, and for the sake of comparison, establishing this new method requests to test and adjust it while other point count methods are still carried out and before drastic changes in vegetation's structure takes place. Therefore, the results of this study will be combined with the data from the point count methods (both traditional annual point count operation as well as with the double observer point count that will be tested in parallel). The outputs of this technique will be an independent and different estimator of the density of the animal. From this field experiment, we will attempt to extract a conversion index to link the density of animals with the density of dungs. Finally, computing the two types of abundance estimator, we aim to have a more robust assessment of the population abundance in the core zone of MIBNP.

We present here the preliminary results of this unique experiment at MIBNP, and what are the guidelines for the future of the tamaraw ecological monitoring.

2. Combining double observer and distance sampling of dungs into one framework

This study combines two methods to estimate the density of animals, double observer and distance sampling, in a single design, as already proposed by Buckland and Turnock (1992). The rationale of this approach is trying to minimize the bias produced by one of the critical assumptions of the distance sampling methodology: "Animals on the transect line are seen with probability 1" (Buckland & Turnock, 1992). Even though we worked with dungs instead of animals, this assumption is probably unmet and could be influenced by several factors like terrain, species biology, climate, time of the survey and observer efficiency (Thompson, 2004). Double observer helps to moderate this strong assumption, as it does not rely on the perfect detection on the transect. It estimates the proportion of dungs that are detected at each distance, starting from a distance equal 0 (Smyser et al., 2016), and use it to estimate the detection probability and associated density of dungs (Marques et al., 2001; Ellis et al., 2005). Although it has been proposed several decades ago, this method is underused in the field. We will take advantage of this design to assess the effect of combining the standard distance sampling estimator with and without the double observer layer on the estimated dung density.

Below, we explain the two components separately for a better understanding of this integrated method.

2.1. Distance sampling of faeces.

Distance sampling is a well-known methodology to estimate the density of ungulates (Ellis et al., 2005; Jathanna et al., 2003 Kumar et al., 2017; Marques et al., 2001; Valente et al., 2014). This methodology consists of an observer recording the number of animals through a predetermined transect of fixed length (Buckland et al., 1993). Over the time, different studies tried to apply it with different animal signs of presence, like dungs (Ellis et al., 2005; Marques et al., 2001; Valente et al., 2014). Here we also used an indirect sign of presence of animals for this study, the dung piles and so will estimate a density of dungs to assess large herbivore abundance at MIBNP. As we are recording only dungs, the observers will record every faeces they detect from the transect, taking notes of the number of dungs, species to which it belongs, distance to the transect, habitat and an estimation of the age of it.

2.2. Double observer

Even though distance sampling is a popular methodology to estimate the density of ungulates within a delimited area, if the assumption of a perfect detection on the transect is not met, the density is underestimated to an unknown extent. This lower than 1 detection probability on the transect is likely to happen in our study site given the dung size and the grass density and height. The double observer design tries to address this observational bias (Jenkins & Manly, 2008) by comparing the observations made by two or more observers (Nichols et al. 2000). In the end, the output of this method is a detectability rate to reduce the described bias.

There are two different approaches to this method: independent and dependent double observer. The independent double observer design consists in two different observers, or group of observers, with no contact during the fieldwork hence avoiding the influence that the activity of one observer could have on the other one (i.e. sightings of observer 1 are unknown to observer 2, driving them as independent observations). The dependent allows for the non-independent observations, with both observers aware of the sightings of each other but one of them only record the observations missed by the first one that he could detect.

For both approaches, we split the teams into two sub-teams, referred to as Sub-team 1 and Sub-team 2. We implemented the independent and the dependent data recording, which translated in the fieldwork as follows:

- Independent: Both sub-teams will do the same transect with a time delay long enough to avoid contact between them, and each of the sub-teams will record all the dungs they have seen.

- Dependent: Both sub-teams go together in the same group, sub-team 1 in front and sub-team 2 in the back, and sub-team 2 will only record the dungs missed by subteam 1.

3. Preparation of the study

3.1. Study area context

In 2016, the DENR (PAMO / TCP) and the Tau-Buid tribe reached a mutual agreement stating that all type of traditional hunting would not be allowed in a delineated area within the CZM, thereafter referred to as the "IP No Hunting Zone Agreement". It covers around 1,600 ha and currently shelters the bulk of the tamaraw population. Lately, some communities have been claiming part of the agreement area leading the PAMO and TCP to enter into another process of discussion and consultation. One specific claim is expressed by a prominent member of the upland communities, targeting the Tarzan / Lanas area on the N-E side of the CZM along the Iglit river. The reason the Tau-Buids alleges for this lies in the fact that is this area is a "Sagrado", which mean sacred. The concept behind this term is quite broad and remain not fully understood yet. Because of that, there are other initiatives from PAMO in collaboration with DAF to understand the environmental world of the IPs and properly define these concepts and their implications. In practice, this cultural aspect of IP's life means we cannot enter those Sagrado areas, which means we need to account for this spatial constraint in our field operations and when designing our data sampling. For this specific reason, those areas were excluded from the design.

3.2. Setting transect number, length and location

In the preceding months to the operation, TCP and DAF carried out three missions in MIBNP with the collaboration of PAMO. Our motivation was to choose the better sampling design for the double observer distance sampling for our estimation of tamaraw dung density.

The first mission was carried out between the 21st and 26th of October, 2019. DAF field team and part of the TCP rangers were involved. We selected two transects of 1 km length in the Magawang area. This first mission aimed to test the independent double observer method as protocol design. It consisted of two teams of four members walking the same transect 20 minutes apart. We recorded, with the help of GPS and data sheets, dungs, tracks, wallowing areas and resting places from Tamaraw, Philippine deer (*Rusa marianna*) and Oliver´s warty pig *(Sus oliveri*).

We carried out a second mission between 16th and 20th of November, 2019 to continue the training and define the final teams. This time, apart from TCP rangers and DAF field team, PAMO rangers were involved. After the results of this training, two aspects were changed from the original sampling design. The length of the transect was shortened from 1 km to 0.5 Km. This decision was based on two premises: the toughness of the terrain and a better reflection of the actual size of the study area. The other decision was to dismiss the independent methodology definitely in favor of the dependent sampling. The second mission indeed confirmed the difficulty to follow the same transect for the second team through tall grassland (main vegetation in the area) and bamboo forest, where often crawl and climb through the bamboo is needed. Besides, it generates additional costs due to the increase in the number of field workers. We would need the addition of, at least, four people per team (2 people in the front of the second team following the signals that the precedent team left and cleaning the path; and another 2 people responsible of the GPS and data collection). Therefore, the additional rangers added to the team could affect other activities of the offices, and the costs of field supplies would be increased.

The last mission before the Final Pilot Study was carried out between the 22nd and 25th of January, 2020. The aim was to conduct the last training with the definitive teams and selected methodology, in this case the dependent double observer method. We selected two transects between Magawang and Loibfo areas, but due to different circumstances, we changed them to Anaplahan forest and Kiling forest area. The training could not be properly conducted due to the absence of most of the proposed team. Only five people of the definitive team were present (including the three members of the DAF team). However, the testing of the dependent protocol corroborated our previous experience and conclusions, demonstrating itself as the most suitable option for avoiding the practical problems we described above.

The final sampling design hence consisted of a dependent methodology with 500 meters length transects. The study area was based on the maximum distribution of tamaraw compiled in the previous year using ranger’s reports, annual count results and DAF data. The number of transects was decided to balance between the costs and feasibility of the fieldwork, and also the need to cover the whole CZM in the best representative manner as possible, and to gather enough data to have reliable statistical results. Thirty transects were considered sufficient to properly represent the area and be logistically feasible in the proposed time frame.

After several attempts to build the sampling design to cover the whole CMZ with different approaches, we decided to use the R package “MBHdesign” (https://cran.r-project.org/package=MBHdesign). This package allows us to randomly chose the position and orientation of the transects, integrating the different types of constraints we can encounter within the CZM while maintaining the representativeness of the study areas in terms of habitat types (grassland vs Forest) and tamaraw abundance (permanent vs discontinuous presence). Importantly, we could account for the difficulties of the terrain, and the special context with the indigenous people (IPs) that have their settlements around the area; as well as the distribution pattern of tamaraw, with a very patchy density within the count zone. With this package, we generated five different but statistically equivalent designs and chose the one we considered was the most feasible in term of field implementation (see Map 1).

3.3. Teams and fieldwork methodology.

We divided the study area into two blocks encompassing 15 transects each: Team North covered transects located north of Magawang station while Team South those transects located south of Magawang station. The teams were composed of 11 members each. Consequently, the composition of both teams was as follow:

- Two members to open the path.
- Two members in Sub-team 1 going in front, tracking for dungs.
- Two members with the GPS and the data sheets collecting the data from the sub-teams.
- Two members in Sub-team 2 going in the back, tracking the dungs missed by Sub-team 1.
- One representative of IP communities per team: Fufuama (meaning "grandfather" in Tau-Buid language) Welly Ton, Mangyan elder from Sitio Tagurdes and DAF IP mediator; and Allan Lumawig, chair of the Park Area Management Board (PamB) of MIBNP as Tau-Buid IP representative and DAF Community mediator/documenter. Their presence helped us to mitigate concerns from residing communities. Additionally, both teams had IP rangers with them.
- Two members to help with the field camps and transporting equipment and supplies. They didn´t participate in the transects.

The information recorded from each of the faeces found was:

- The sub-team who spotted it (Sub-team 1/Sub-team 2).
- The animal which the faeces belongs to: tamaraw, Philippine deer or Oliver´s warty pig.
- The distance from the transect (the perpendicular line from the transect line) based in team appreciation and ranked in meters.
- Age of it (two subjective categories (old/new) based on the moisture aspect).
- Habitat type divided into two subcategories: grassland and forest.

The equipment per team was 1 GPS (Garmin eTrex 10 for Team North; GPSmap 60CSx for Team South); 1 set of spare rechargeable batteries Panasonic Eneloop; 1 battery charger Panasonic Eneloop; compass; data sheets; notebook; pens. Also, to establishing temporary camps, apart from personal working items from the rangers, two camp lamps, two tarps and food supplies for the whole expedition were provided by DAF.

Eighteen (18) days were originally planned to complete the study, ensuring that the rangers involved would be fully available for the whole operation during the period requested to PAMO and TCP offices. DAF also suggested three to four days off after and before the survey to the rangers involved due to the toughness of the activity. We take consideration of 2 transects per day (13 days), with two days of rest, two days of travelling around the surveyed area, and one extra day. We made the first plan before going on-site, establishing where to set up two temporary camps per team to facilitate the access to further transects from the Stations.

4. Survey

We carried out the Final Pilot Distance Sampling for Tamaraw Abundance in MIBNP between February 3rd and 10th 2020. Both teams assisted in the technical and supply preparation phase during the 3rd and 4th of February. Some transects did not follow the exact original design, as it can be seen in Map 1.

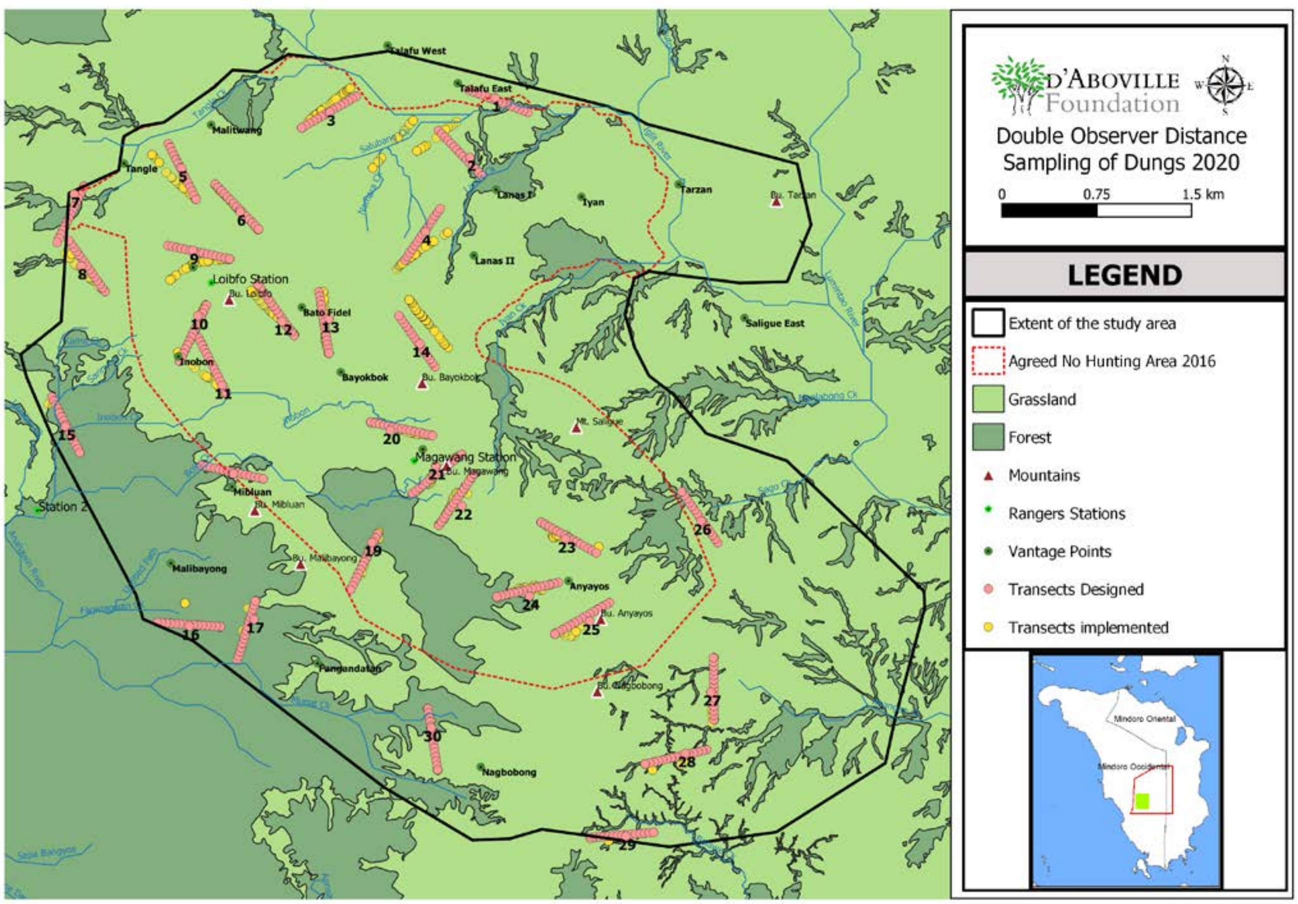
- <u>Team North</u>:

The entire 15 transects were completed. Under the request of the IP representative, two transects' itinerary (T1 and T2) were modified to the request of nearby communities.

Some transects suffered deviation of itinerary either because of GPS problems or topography (T8), while the terrain imposed moving another transect (T14) 70 meters away from its original location.

- <u>Team South</u>:

The team was able to complete 14 transects due to the impossibility to conduct T26 because of the topography. In addition, several transects had their itinerary moved of few meters to fit the terrain.



Map.1: Designed (pink) and implemented (yellow) transects from the Double Observer Distance Sampling of dungs study of 2020 in the Core Zone of Monitoring of Mt. Iglit-Baco Natural Park. Some transects has been moved or modified during the field work.

5. Preliminary results

5.1. Field work

Summing travelling distances and transects, both teams covered a total of 83,704 meters (14,607 meters if only transects), with a total elevation gain of 6,336 meters (1600 meters if only transects). Overall they recorded 850 dungs of tamaraw, 122 faeces of Philippine deer and 55 faeces of Oliver´s warty pig.

- Team North:
    - In total, the team covered a distance along the transect of 7,615 meters, with a total elevation gain of 682 meters, reaching most areas of the north part of the CZM.
    - They completed the 15 assigned transects.
    - The team recorded 396 dungs of tamaraw, with an average of 26.4 dungs per transect and a maximum of 53 in Transect 12; 86 dungs of Philippine deer, with an average of 5.73 dungs per transect and a maximum of 26 in transect 14; and 38 dungs of Oliver´s Warty Pig, with an average of 2.53 dungs per transect and a maximum of 7 in transects 3 and 4.
    - They observed agricultural plantation inside the "IP No Hunting Zone Agreement" as well as three spear traps near Inobon Vantage Point (VP) made by the Bayanan community (one of them caught last monsoon season an unknown animal (IP representative communication)), 1 spear trap near Inobon creek made by Sitio Tagurades (Fufuama Welly Ton communication). All these traps were already disabled when found.
    - Team North also found one excrement belonging to one of the two known species of civet present in Mindoro in the transect 5.

- Team South:
    - In total, the team covered a distance along the transect of 6,992 meters with a total elevation gain of 918 meters, reaching most location comprised between Magawang Station, Fangandatan, south of Nagbobong and Anyayos areas.
    - In total, they completed 14 transects due to the impossibility to do transect 26, near Sago creek because of the dangerous terrain.
    - The team recorded 453 dungs of tamaraw, with an average of 32.35 dungs per transect and a maximum of 133 in Transect 22; 36 dungs of Philippine deer, with an average of 2.57 dungs per transect and a maximum of 14 in transect 23; and 17 dungs of Oliver´s Warty Pig, with an average of 1.21 dungs per transect and a maximum of 4 in transects 20 and 29.
    - They found one spear trap and two traps for monkey (one with nylon material) near Fangandatan; one tamaraw nylon snare trap near Nagbobong summit;one old camp from outsiders in the south of Nagbobong (believed to belong to New People Army rebels); one bottle of Ginebra and one part of a tamaraw jaw in some rock formation in the south of Nagbobong.

5.2. Distance sampling

For distance sampling methodology, it is usually recommended to build a detection curve from >70 recorded distances, all data pooled and hence assuming no or little variation in the detection process among transects. With a total number of 850 tamaraw dungs, we are confident that an appropriate detection curve can be derived from our data. Consequently, our pilot study strongly suggests that the sample sizes we can expect annually from our sampling design for the future tamaraw monitoring will be sufficient to estimate dung density from the distance sampling estimator of dung density. This holds for tamaraw and possibly Philippine deer, but sample sizes appeared, however, too limited for Oliver's warty pig for which more transects or repetitions of the transects would be needed to achieve similar results as for the other two species.

In Figure 1, we display the number and proportion of dungs recorded for classes of increasing perpendicular distances to the transect. It shows a heavily skewed data to the right. We can read this as a decrease in the detection probability of dungs with the distance from the transect. We do not have any transect avoidance effect either; something which could possibly happen if the study is repeated regularly.. In addition, the assumption of a monotonously decreasing function of detection with distance is met. Regarding the data of the tamaraw, we have 4 data that are outliers of the general pattern we report. Two dungs were found at 12 meters distance, and two more at 20 meters distance. If we look at the location of these data, the two dungs at 12 meters and one of the dungs at 20 meters belong to transect 9. This transect was situated in an open landscape, allowing the observers to detect dungs from a longer distance. The other sighting of tamaraw dung at 20 meters distance was from T14. In this transect we also can find the largest distance from the transect of a faeces of deer, guiding us to a similar assumption. These large distances are therefore exceptions to an otherwise consistent and rather homogeneous detection pattern among transects. Being limited in numbers, these extreme observations will be treated in the analyses either with a covariate or by assigning the outlying observations to the last distance bin of the distribution.

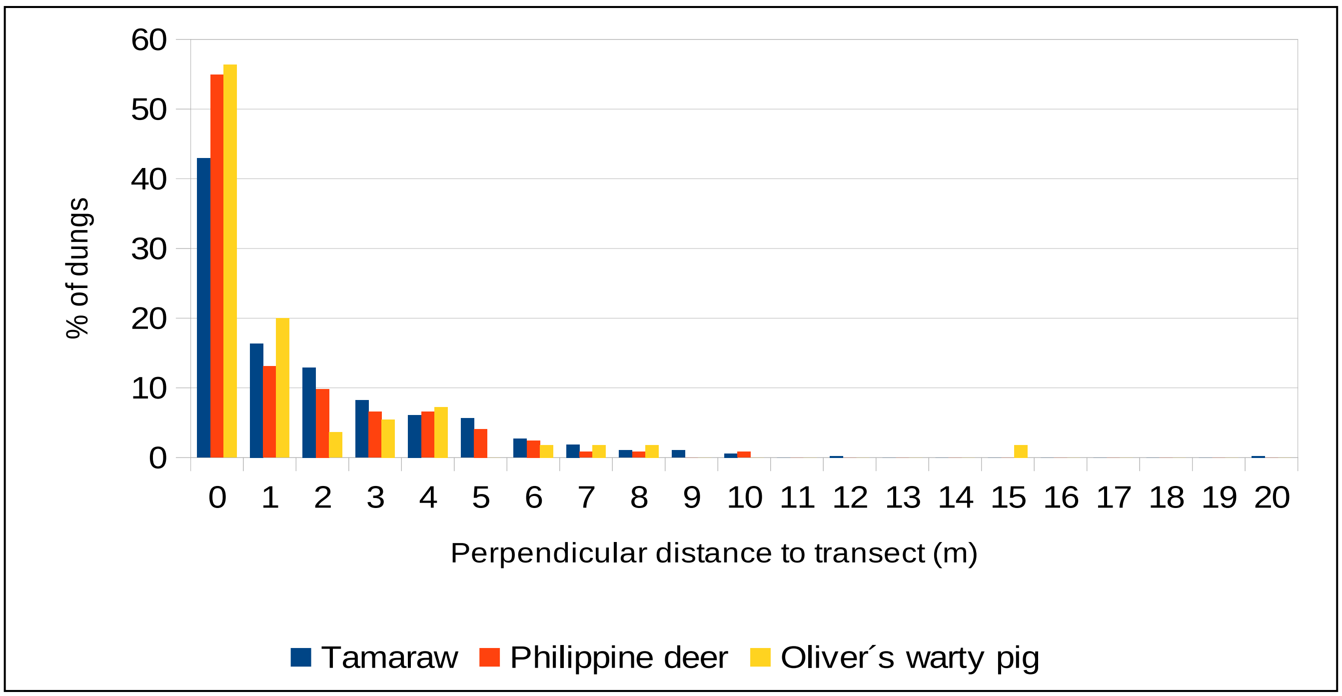


Figure.1: Distribution of the proportion of dungs for classes of perpendicular distances from the transects of the three surveyed species at Mount Iglit Baco Natural Park, during a pilot study carried out in February 2020.

Oliver´s warty pig has a more atypical distribution if we compare its values with deer of tamaraw. Its decreasing curve is not continuous; sometimes increasing the values with the distance (see Fig. 1 & Table 2, values between 2 and 4 meters). We can find a sighting of the dung of this animal at 15 meters in T6, further than the furthest sighting of deer dung (10 meters), but closer to the transect than the tamaraw (20 meters). This could be explained by the size of the faeces. Tamaraw has the biggest and more conspicuous dung from the three animal, while if we compare deer and pig faeces, generally the latter is bulkier, making it more visible. This assumption fit with the situation of Figure 1 and Table 2, where we can appreciate that the proportion of dungs decrease more rapidly with the distance than the other two.

5.3. Spatial heterogeneity in the number of detected dungs and data distribution

As it can be seen in Figure 2 and Table 3, and despite one transect less, the number of tamaraw dungs recorded by Team South was higher than the other team. Yet the number of transects without any finding was also higher in comparison with the team north (4 to 1).

We observe a substantial difference between the number of faeces of Philippine deer found in the north part of the survey area and the south part, with the same amount of transect with no presence of dungs of the animal (4) (Fig. 2, Tab. 2). Team North found more than twice the number of faeces than Team South.

The situation with Oliver´s warty pig is similar to the situation with Philippine deer. Team North found more than twice the number of faeces than team South, but with a marked difference between the number of transects with no dungs (4 Team North – 8 Team South) (Fig. 2, Tab. 2). The amount of data is probably too small for further analyses.

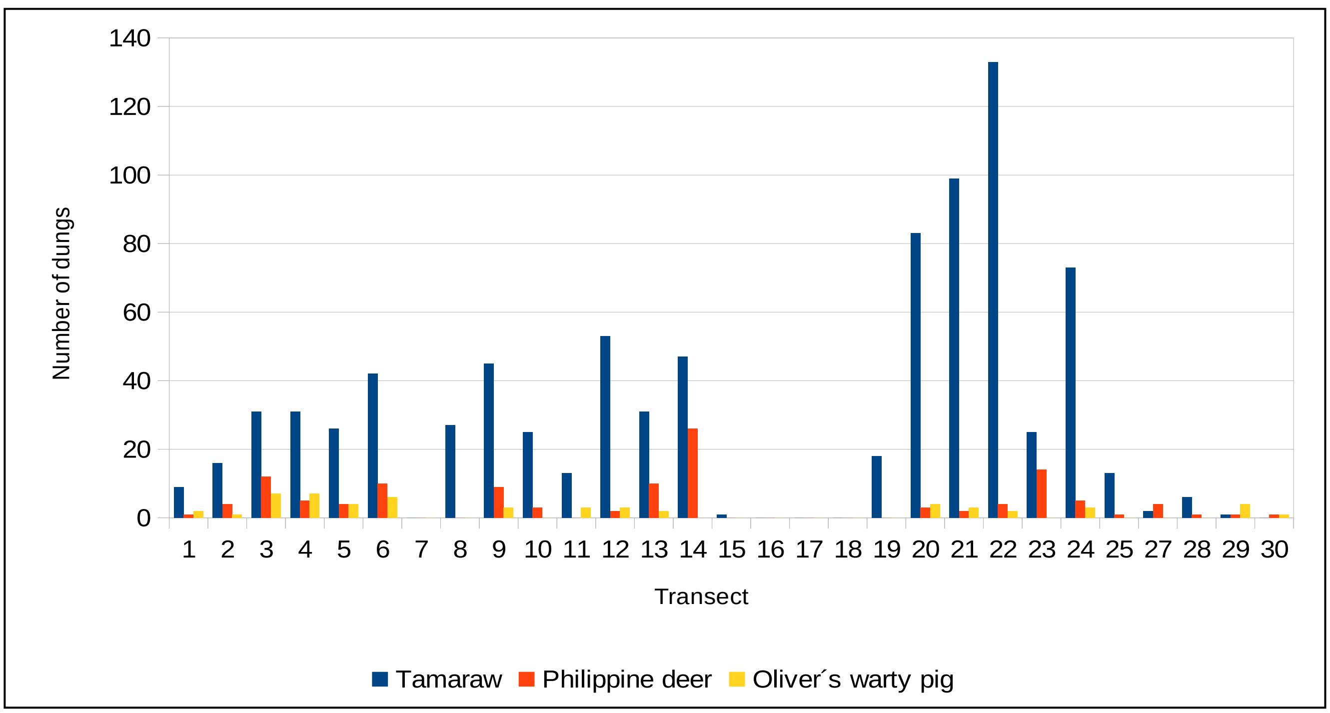


Figure.2: Number of dungs per transect (with transect 26 removed from the list) at MIBNP. We can observe big differences between the number of dungs of each animal per transect, and also between animals in each transect.

Dispersion in the number of collected data is very high and especially apparent in the tamaraw, ranging from zero to 133 with a median of 25 and a mean equal to 29.31 tamaraw dungs (Table 1).

Species	Minimum	Maximum	Total	Average	Median	Standard deviation	Coefficient of Variation
Tamaraw	0	133	850	29.31	25	32.83	1.1
Philippine deer	0	26	122	4.21	2	5.76	1.35
Warty pig	0	7	55	1.89	1	2.21	1.14

Table 1: Summary statistics of the number of feaces per transect carried out at Mount Iglit-Baco Natural Park in February 2020. We recorder dung presence of the three large herbivore species roaming in the restricted counting zone area.

The median becomes a more relevant measure in case of skewed distribution, pointing out the general tendency towards most frequent results. Not surprisingly, this is the case in the distribution of the data in the three species which are not following a Gaussian distribution at all. When we plot the data distributions (Figure 3), we can see that nearly 30% of all transects (10 cases) display less than 9 signs of presence of tamaraw, while very few transects have more than 50 recorded signs of presence. Transect 22 harbors 133 recorded dungs which can be explained by its specific location within the study area, and the important heterogeneity in the distribution of faeces in general in our study site.

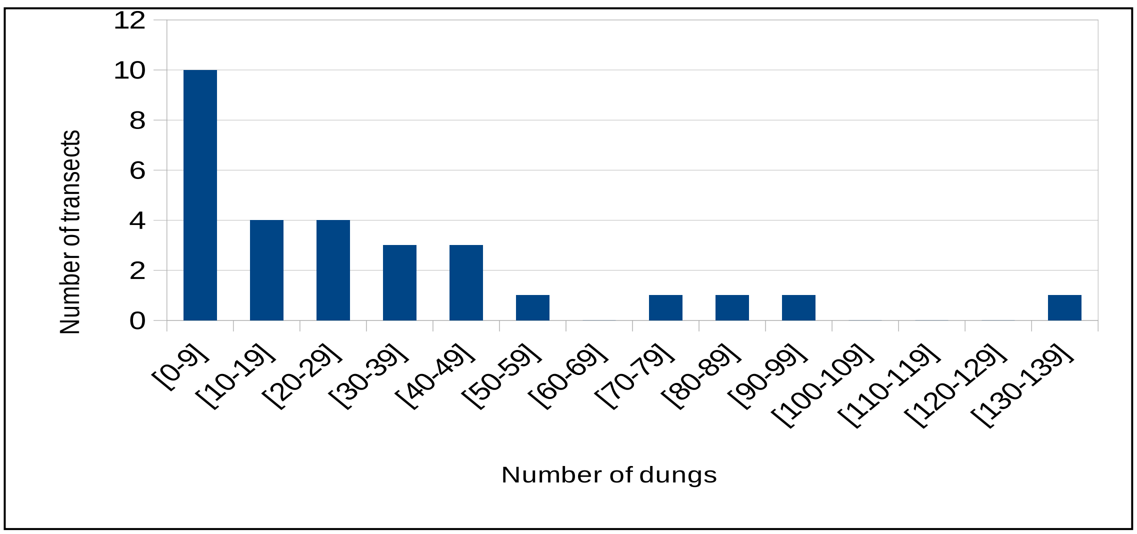


Figure.3: Number of transects that lies within the different ranks of dungs from tamaraw. We can observe a heavily skewed distribution to the right, meaning that we recorded a low number of dungs on many transects (*e.g.* 10 transects had between 0 and 9 detected dungs), and conversely made most of the observations of a few transects with a very high number of dungs. This histogram evidence a marked spatial heterogeneity in the relative abundance of tamaraw dung at CZM of Mount Iglit Baco Natural Park.

The results are similar for the other two species of large herbivores (Figure 4). Again, the distribution of the number of faeces is close to a Poisson distribution, with a long flat tail for higher numbers of signs. We can see this aspect from summary statistics presented in Table 1, where the standard deviation and the coefficient of variation are very high for the three species compared to the mean, hence corroborating the heterogeneous spatial distribution of feces among transects for the three species. Indeed, a much larger variance than the mean is indicative of aggregated patterns (Pielou, 1969), meaning that most transects were almost empty of dungs while a minority show a very high number of dungs.

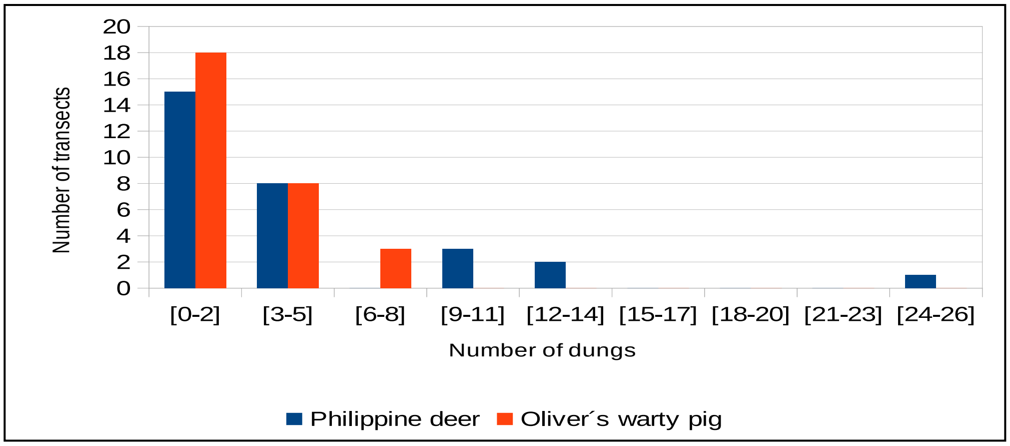


Figure.4: Number of transects that lies within the different ranks of dungs from Philippine deer and Oliver´s warty pig. We can observe a heavily skewed distribution to the right, meaning that we recorded a low number of dungs on many transects (*e.g.* 10 transects had between 0 and 9 detected dungs), and conversely made most of the observations of a few transects with a very high number of dungs. This histogram evidence a marked spatial heterogeneity in the relative abundance of tamaraw dung at Mount Iglit Baco Natural Park.

5.4. Elevational distribution pattern

We observe interesting pattern while investigating the elevation factor. We ranked the altitude into 100 meters ranks and define the total effort per elevation rank (available elevations classes in the landscape A_i) as the proportion of the total area covered by the transects or part of the transects locaed at those elevation intervals (i.e. the percentage of distance travelled by the field teams within the transect at each elevation rank). When we extract the percentage of dungs find at each interval (used elevation classes by the animals U_i) and compare and plot both values, we can see a similar distribution of this data (Figure 5) and a correlation between the A_i and the U_i of the three animals (Table 4).

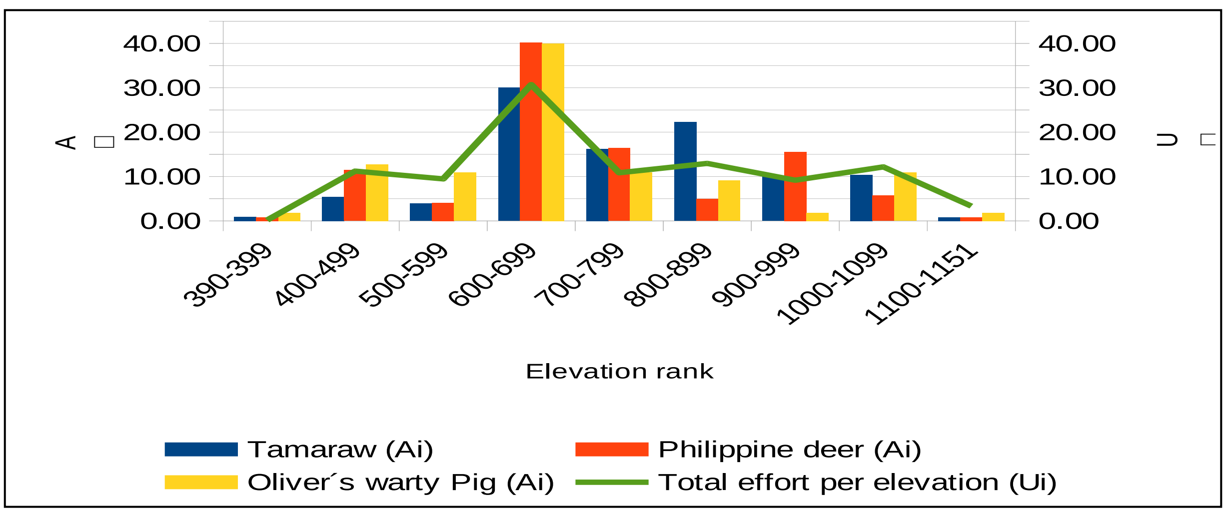


Figure.5: Comparison of the percentage of faeces of the tamaraw, Philippine deer and Oliver´s warty pig found at different elevation's intervals of 100 meter (bars) and the total effort per elevation (line), defined as the total % of the transects situated at different elevation´s ranges (i.e. % of the distance travelled by the teams during the transect for each elevation range).

We then assess the habitat selection of the three species according to the elevation by computing selection ratios (Manly, 2007). The selection ratio SR_i is the ratio of used on available habitats, which in our case is the ratio of the percentage of seen dungs in each elevation classes on the percentage of available elevation categories, following the equation: $SR_i = U_i / A_i$

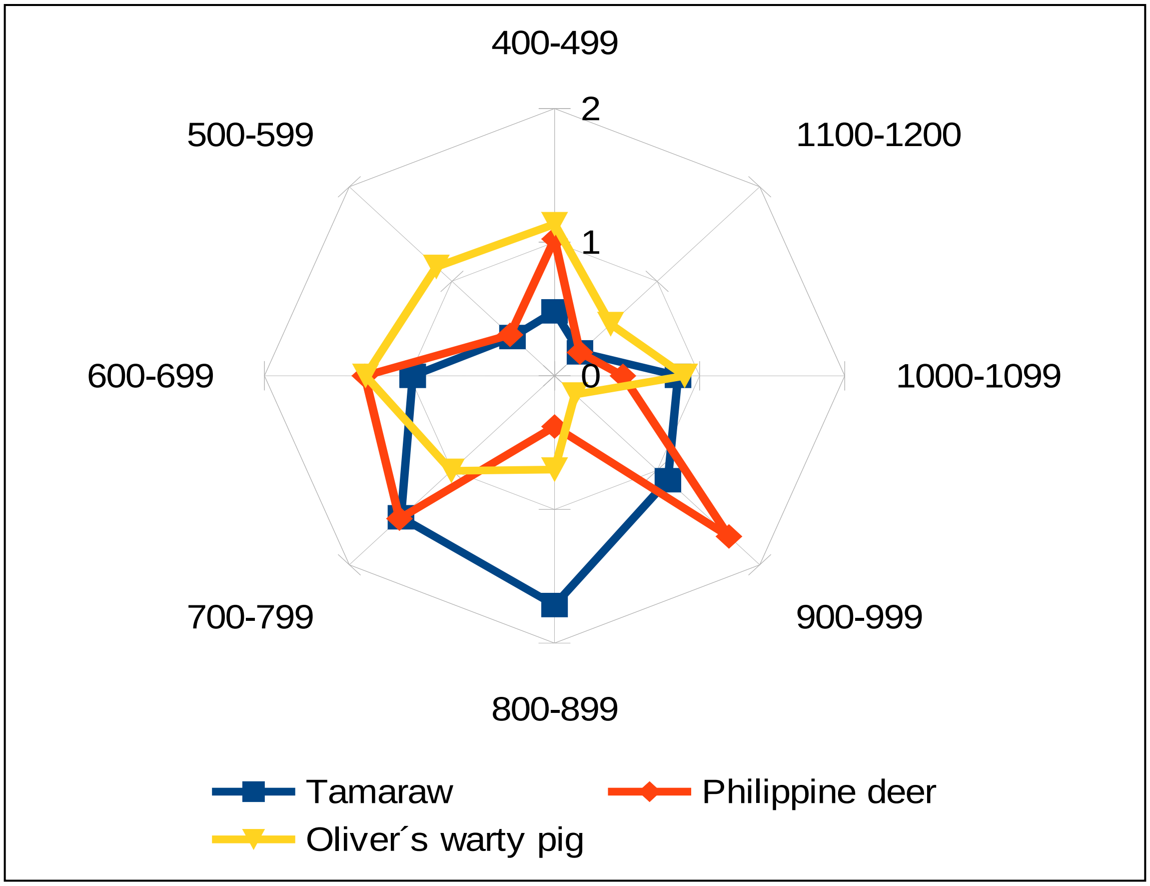


Figure.6: Selection ratio from the different elevations of tamaraw, Philippine deer and Oliver´s warty pig. A selection ratio hence takes values >1 if animals "prefer" one class of elevation (used it more that its availability), and conversely takes values <1 if they "avoid" a given elevation category (used it less that its availability).

Looking at Table 4, we can visualize the variability of the data of A_i, ranging from 30.71 (600-699 meters) to 0.17 (300-399 meters). This lowest value produces the highest SR rate for the three animals, far from the rest. However, the A_i from this elevation range is so small that probably is not representative of the actual situation of this elevation of the area (only 27 meters surveyed at this elevation rank). Besides, this small portion of the surveyed area is located near Salubang creek, corresponding probably to an optimal micro-habitat for the species, with water and the shelter of the riverine forest. If we exclude this value (Fig. 6), we can observe that the tamaraw distribution favors elevations between 700 to 999 meters with a higher concentration between 700 to 899 meters within the CZM. Meanwhile, deer favors elevations between 600 to 999, with a radical decline between 700 and 899 meters. Pig, with the cautiousness needed due to the low number of data collected, has a preference for lower elevations (400 to 699 meters).

5.5. Relationship between the results of the 2019 Point Count and Double Observer Distance Sampling of dungs of 2020.

The data obtained in the present study sustains the 2019 Annual Point Count, as highlighted in comparing Map 2 and Map 5 (see appendix). Considering that the point count covers a larger area and by comparing the coincident cells with data, we can see a decrease in the number of data from the core of the CZM to the west. One plausible explanation lies in the increasing proximity to human disturbance (IP communities, crop fields, visitors…). For both abundance proxies, we can observe a concentration of data around Loibfo, Inobon and Magawang areas, which are located along the more regular patrolling routes and base camps as well as Salubang and Namara creeks. That the highest abundance is found where patrolling is the most intensive suggests a positive influence of ranger's presence fostering a higher tamaraw density in the safest areas.

On the other hand, we observed a higher number of data collected around Anyayos during this study than in the point count. One of the reasons could be that this area is a "blind spot" for such method. This suggestion is reinforced by the fact that some of the cells are located inside Arow Bulo forest, decreasing drastically the visibility from vantage points. This aspect highlights the relevance of carrying out protocols for indirect signs of presence that enable to survey all types of habitats, especially forest, which are out of reach from vantage points.

5.6. Double observer:

In the preliminary results of the double observer, and as we can see in Figure 7, and Table 5 and 6, the Sub-team2 (at the back of the group during the transect) from both Team North and South, collected a relevant percentage of the data.

For most transects where at least one tamaraw dung was found, the Sub-team 2 has recorded one or more dungs that were not detected by the Sub-team 1 (Table 5 & Figure 7). In terms of relative effects, the proportion of additional observations made by the Sub-team 2 ranged between 0% (T15 and T19), to up to 46% at T25. On average, the Sub-team 2 recorded an additional 19.9% of tamaraw dungs compared to the Sub-team 1. Regarding Philippine deer and Oliver´s warty pig, this effect was much larger, with around 43% of the dungs found by the Sub-team 2 and not by the Sub-team 1. This result supports the relevance of the double observer method to highlight the observer bias in terms of dung detectability in difficult observation conditions such as faced here at MIBNP.

Besides, we can observe a difference in the percentage of faeces found by each of the sub-teams from both teams (Table 5 & 6 & Figure 7). In the Team North, Sub-team 1 recorded 67.75% of the total number of dungs from the three animals, while the same sub-team in Team South, recorded 84.78% of it. This suggests a significant influence of the composition of the teams for the accuracy of the data collection. The double observer will be used to correct this bias by calculating a detection rate specific to each team and allowing us to account for missed observations of dungs during the fieldwork.

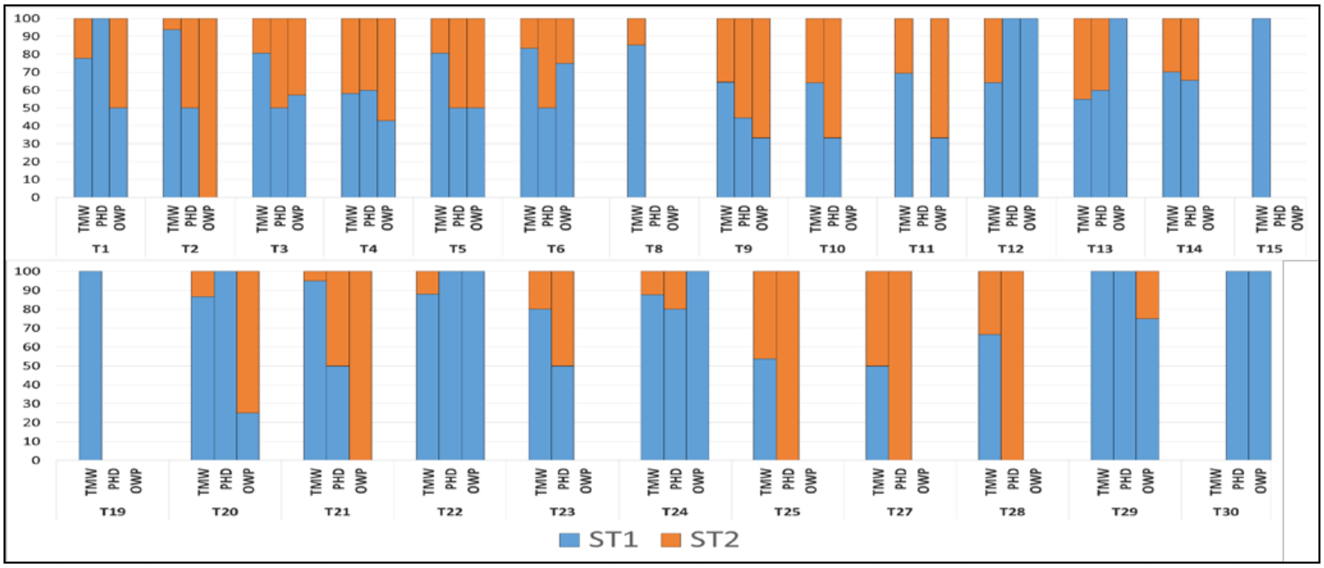


Figure.7: Percentage of observations by Sub-team 1 and Sub-team 2 in every transect with at least 1 dung of any of the three species. The first line of the graph is reflecting the transects carried out by Team North, while the second line the Team South. (TMW = Tamaraw; PHD = Philippine deer; OWP = Oliver´s warty pig; ST1 = Sub-team 1; ST2 = Sub-team 2).

6. Discussion

This final pilot study for Double Observer Distance Sampling of dungs enables us to record some very relevant biological information. It gives us some new information about tamaraw distribution, as well as a stronger overview of the situation of Philippine deer and Oliver´s warty pig within the CZM of MIBNP. The amount of data collected, aiming at monitoring the abundance of the large herbivore of the Park, is large enough to provide a robust basis for relevant statistical analyses. This study comforts the relevance of the double observer method to improve the accuracy of census designs. It is likely that it would prove also valuable when applied to the point count method, as attested by the initial test conducted during the annual count in 2019. Our pilot study not only provides relevant information on the three species of ungulates in MIBNP but demonstrates the importance of the combined Double Observer methodology and distance sampling to produce more reliable results. It can solve the problematic assumptions of the traditional distance sampling, avoiding bias like observer accuracy and allowing us to collect a larger data set.

The fact that we observe several clusters of high detection of tamaraw dungs indicates a clear spatial structure in the distribution of dungs, and hence possibly of tamaraws. This is most noticeable on the southern part of the study area where three adjacent transects (T20, 21, 22) cumulates nearly 40% of the total number of recorded dungs. As the results from past counts and regular ranger's patrol reports would predict, the biggest number of dungs were found in the area between Loibfo, Magawang and near Anyayos areas, extending to the eastern border in Tangle creek and Mibluan area, and Lanas and Mt. Saligue in the west. The drop in the number of dungs in the rest of the transects is substantial. Our data corroborate results of the last annual point count as both grid maps show similar patterns; the area of Magawang (south part) concentrates most of the observation, while it is somehow less skewed on the northern part but still aggregated on few locations. Additional studies would be needed to assess if this pattern is seasonal, or due to variation in terms of habitats availability and suitability (micro-habitats effect), or if it is mostly related to anthropogenic factors.

The coming analyses will first test and exclude a potential confounding effect of detectability bias, in combination or not with ecological variables. Most certainly, several factors are driving how tamaraws occupy their range over the year. In any case, this study reinforces what was already highlighted by previous work showing that the overall contraction of the species towards the center of the CZM is prominent and still ongoing.

Each species presents skewed distribution towards a few locations suggesting they experience similar constraints in their way to occupy the study area, driving them off their optimal ecological behavior. The three of them present an avoidance behavior to the western part of the CZM (T15, T16, T17 and T18 with only one dung of tamaraw in total), where the human presence is frequent (IP communities in the adjacent areas; main entrance for visitors to MIBNP).

Philippine deer follow a similar pattern with the highest density of dungs following the quasi straight line between Loibfo and Anyayos area (T3, T6, T13, T14 and T23 with the presence of ten or more faeces). However the apparent absence of faeces along transects displaying the highest records of tamaraws (T12, T20, T21, T22 and T24) suggests a negative impact of high tamaraw density outweighing the positive impact of ranger's presence in these areas.. In addition, the quasi absence of deer where tamaraw is the most abundant, between 800 and 899 meters (including Magawang area and Arow Bulo forest), reinforces the suspicion of adverse interaction at high density, with tamaraw preventing other species to occupy suitable areas. Additional studies with specific protocols would be needed to validate this assumption.

The very low number of signs of presence of Oliver's warty pig on the overall study area is striking. They represent only 5% of all data recorded. Yet it corroborates results of previous research work conducted by DAF former TRO in 2018–19 highlighting a low abundance of the species in the overall study area. This might be partly due to a lower detectability of their signs of presence compared to tamaraw. However, the higher proportion of signs of presence of the Philippine deer (12% of all observations), poses the question of the general status of the Mindoro warty pig in the region and the more acute hunting pressure it might suffer. Its distribution of dungs shows the highest density around Lanas, Salubang and Namara creeks and Iglit river (T3, T4 and T6 with six or more faeces). If we include the transects with four dungs (T5, T20 and T29), we observe that they are also around water sources (Iglit river, Inobon creek and Balawe creek), which are also places located at the lower elevation rank within the study area.

The general low frequency of deer and warty pig is worrying while posing biological concerns on the overall density of tamaraw in this restricted area and its environmental sustainability, and how this could be affecting other species. Especially, it raises concerns on the availability of resources and carrying capacity of this limited space to accommodate a viable population of the three species. This is even more concerning in the frame of the planned shift of habitat management and phase-out of the fire regime. Therefore it stresses the need to continue ecological study on the ecology of the three species and the dynamic of the vegetation in the area in response to habitat management.

7. Practical considerations

Although the field teams did their best to collect the data as close as possible to the theoretical sampling design, the pilot study suggests further improvements and modifications before its generalization and routine use.

There is a substantial topographic difference between the north and the south part of the study area. The south is more mountainous with more uneven terrain than the north. These different characteristics must be taken into account in the future and final design of transects. The overall landscape is mountainous and physically challenging for the teams, with cliffs, steep slopes, deep creeks, thick and tall grassland and thick bamboo forests. These features must be integrated into future designs of the transect location, a point that we underappreciated this year.

The rangers covered most of the area where they usually do patrols. Thus they were able to collect valuable additional information (crops, traps, camps, etc.) while walking along and between the transects and collecting dung data. Therefore, and in order to make the best use of such intensive fieldwork operation while balancing the toughness it requires, it seems relevant to mobilize all the tamaraw rangers assigned in MIBNP, as well as to request the assistance of the PAMO rangers as best as possible; should the operation be repeated in the future.

For better results and easier data collection for the field teams, we clearly need to improve the quality of the maps, adding more landmarks, physical constraints and revising the correct position of the ones that are already set.

This type of operation, which requires deploying most of both offices staff on the entire CZM in a short period of time, needs better communication with the local IP communities to avoid issues. It seems necessary to present the final design to them prior to the activity and to involve more prominent members of the communities in the survey. This could lead to a better understanding of the goals of the operation by all the concerned communities and possibly to grant us access to all areas of interest from an ecological point of view.

The actual duration of the operation should be closer to what was originally planned. Indeed, even so, it was proven possible to conduct it in only seven days through higher physical demand, shortening the fieldwork might result in (a) higher risk of accident and (b) lower accuracy of the data collected. More time shall be allocated for such operation if it was to be repeated in the future

Conclusion and next steps.

This study highlights several major outcomes that can be summarized as follow:

- The importance of a methodology such as the Double Observer Distance Sampling enabling to collect data from areas that are impossible to monitor from Vantage Points during the Point Count. Such operation allows to have a better representation of the overall study area.

- Capacity to study variability in the occupancy pattern between seasons by repeating the operation both at dry and rainy season, thus highlighting variability in seasonal behavior among the three species.

- The double observer method helps decrease some bias such as the variability in observer accuracy and appears relevant both for distance sampling and point counts.

In addition, the findings of this study comforts observations and results from other works. Especially it highlights the strong spatial heterogeneity in the general distribution of the animals throughout the CZM which was already palpable through the point counts results and report of the former TCRO (Gonzalez- Monge & Schütz, 2019), and geneal valuation among the rangers. The three species avoid the part of the study area presenting higher anthropogenic influence (western part), and the distribution of deer and tamaraw concentrates where the rangers do their patrolling.

Finally and more surprisingly, we can observe a net avoidance of the Philippine deer to areas with high tamaraw presence (Magawang and Anyayos area). This behavior is so far associated with extreme density values of tamaraw, suggesting interspecific competition in such conditions. Nevertheless, more studies are needed to determine if competition between animals happens when tamaraw exceed the carrying capacity of the area, implying a negative impact on habitat and a phenomenon of over density, resulting in a suboptimal habitat for Philippine deer, or if other behavioral factors are involved.

Following this initial study, all data collected will move to the next step, with a more thorough and detailed data analyses. The data from this survey will be used to (a) estimate dung density, (b), extract an index of abundance of the tamaraw and (c) a detectability rate for correction of the index, while projecting the results into a Bayesian integrated population model (IPM) with the traditional point count method and the double observer point count method.

Results of the dung distance sampling operation, combined with the point count results, will provide a more robust and unbiased estimate of the abundance of the tamaraw population in the CZM. It will require repeating such operation several times to build a stronger conclusion and finalize the more appropriate design.

Nevertheless, the decision belongs to the DENR to develop and continue such census method in the long term. This will require addressing the following points:

- A better understanding of the needs, motivation and outputs of such census methods to match the expectation of the DENR.
- Better communication between the DENR and the IP communities to avoid conflict, by better explaining the purposes of the activity as well as identifying their concerns and restriction, thus for the DENR to better capture their relationship with their environment and the way they perceive DENR intervention.
- Increase the quality of the maps, with the addition of a Digital Elevation Map (DEM), to better design the location of the transects wit regards to steepness, cliffs and the Sagrado areas.

Acknowledgments:

This work would have not been possible without the dedicated support of the **Wildlife Reserves Singapore / Singapore Zoo**, through its **Conservation Funding and Research Collaboration**.

We also want to thanks MIBNP PAMO and TCP offices and highlight the great effort and engagement of all the rangers involved. They always tried to do the best job they could, even in the worst conditions and the hardest terrain. They should be acknowledged for this work.

Appendix.

Table.2: Number and percentage of dungs of the three surveyed animals found at different distance from the transect in CZM of MIBNP. They show an important decreasing of the collected dungs with the distance

Distance	Tamaraw (number)	Philippine deer (number)	Oliver´s warty pig (number)	Tamaraw (%)	Philippine deer (%)	Oliver´s warty pig (%)
0	365	67	31	42.94	54.92	56.36
1	139	16	11	16.35	13.11	20
2	110	12	2	12.94	9.84	3.64
3	70	8	3	8.24	6.56	5.45
4	52	8	4	6.12	6.56	7.27
5	48	5	0	5.65	4.1	0
6	23	3	1	2.71	2.46	1.82
7	16	1	1	1.88	0.82	1.82
8	9	1	1	1.06	0.82	1.82
9	9	0	0	1.06	0	0
10	5	1	0	0.59	0.82	0
11	0	0	0	0	0	0
12	2	0	0	0.24	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	1	0	0	1.82
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	2	0	0	0.24	0	0

Table.3: Number of dungs per transect (with transect 26 removed from the list) during the Final Pilot Study of Double Observer Distance Samping of Dungs in MIBNP in February 2020.

Transect	Tamaraw	Philippine deer	Oliver´s warty pig
1	9	1	2
2	16	4	1
3	31	12	7
4	31	5	7
5	26	4	4
6	42	10	6
7	0	0	0
8	27	0	0
9	45	9	3
10	25	3	0
11	13	0	3
12	53	2	3
13	31	10	2
14	47	26	0
15	1	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	18	0	0
20	83	3	4
21	99	2	3
22	133	4	2
23	25	14	0
24	73	5	3
25	13	1	0
27	2	4	0
28	6	1	0
29	1	1	4
30	0	1	1

Table.4: Ai (available elevations classes in the landscape); U_i (used elevation classes by the animals); and Selection Ratio (SR) for every 100 meters elevation rank from the suveyed are in MIBNP. A selection ratio hence takes values >1 if animals “prefer” one class of elevation (used it more that its availability), and conversely takes values <1 if they “avoid” a given elevation category (used it less that its availability).

Elevation	Ai	Tamaraw		Philippine deer		Oliver´s warty pig	
		U_i	SR	U_i	SR	U_i	SR
300-399	0.17	0.94	5.49	4.78	0.82	1.82	10.61
400-499	11.21	5.41	0.48	1.02	11.48	12.73	1.13
500-599	9.46	3.88	0.41	0.43	4.1	10.91	1.15
600-699	30.71	30	0.98	1.31	40.16	40	1.3
700-799	10.84	16.24	1.5	1.51	16.39	10.91	1.01
800-899	12.96	22.24	1.72	0.38	4.92	9.09	0.7
900-999	9.16	10.12	1.1	1.7	15.57	1.82	0.2
1000-1099	12.16	10.35	0.85	0.47	5.74	10.91	0.9
1100-1200	3.32	0.82	0.25	0.25	0.82	1.82	0.55

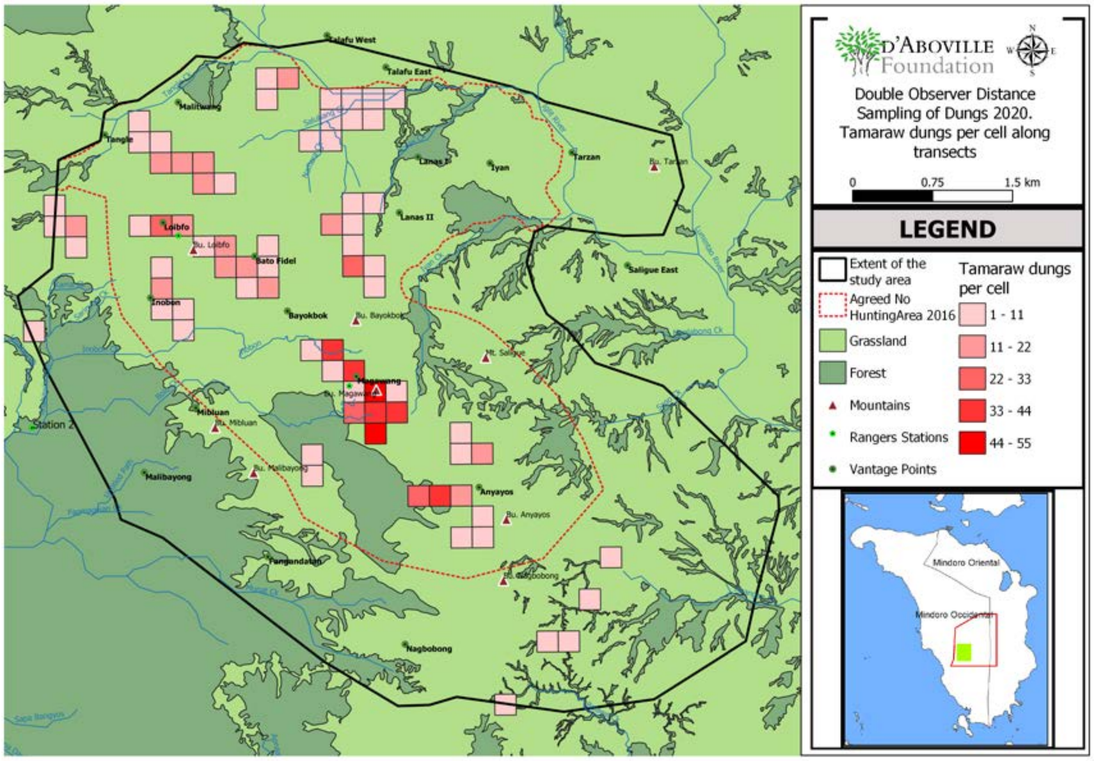
Table.5: Total number (when positive) and proportion of tamaraw dungs found by sub-team 1 and additional ones found only by sub-team 2 and difference between team North and South.

Transect	**Sub-team 1**	**Sub team 2**	**% Sub-team 1**	**% Sub-team 2**
T1	7	2	77.78	22.22
T2	15	1	93.75	6.25
T3	25	6	80.65	19.35
T4	18	13	58.06	41.94
T5	21	5	80.77	19.23
T6	35	7	83.33	16.67
T8	23	4	85.19	14.81
T9	29	16	64.44	35.56
T10	16	9	64	36
T11	9	4	69.23	30.77
T12	34	19	64.15	35.85
T13	17	14	54.84	45.16
T14	33	14	70.21	29.79
T15	1	0	100	0
Total Team North	283	114	71.28	28.72
T19	18	0	100	0
T20	72	11	86.75	13.25
T21	94	5	94.95	5.05
T22	117	16	87.97	12.03
T23	20	5	80	20
T24	64	9	87.67	12.33
T25	7	6	53.85	46.15
T27	1	1	50	50
T28	4	2	66.67	33.33
T29	1	0	100	0
Total Team South	398	55	87.86	12.14

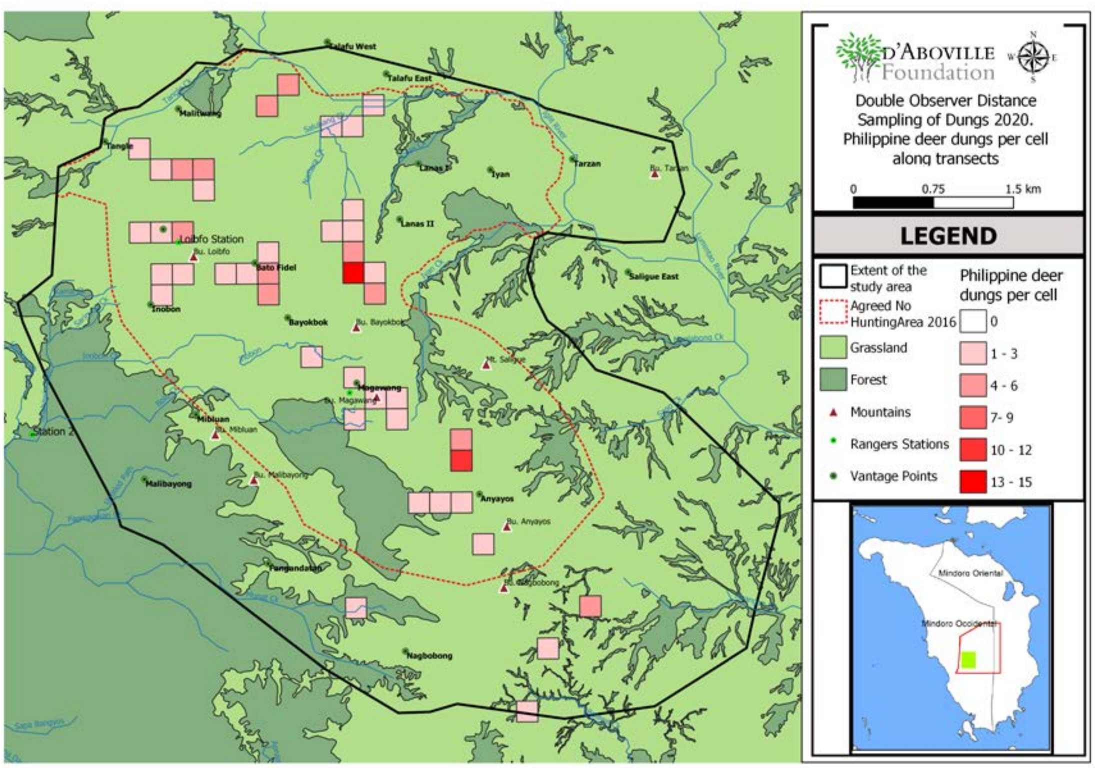
Table.6: Total number (when positive) and proportion of Philippine deer and Oliver´s warty pig dungs found by sub-team 1 and additional ones found only by sub-team 2 and difference between team North and South.

Transect	Philippine deer				Oliver´s warty pig			
	Sub-team 1	Sub-team 2	Sub- Team 1 (%)	Sub- Team 2 (%)	Sub-team 1	Sub-team 2	Sub- Team 1 (%)	Sub- Team 2 (%)
T1	1	0	100	0	1	1	50	50
T2	2	2	50	50	0	1	0	100
T3	6	6	50	50	4	3	57.14	42.86
T4	3	2	60	40	3	4	42.86	57.14
T5	2	2	50	50	3	1	75	25
T6	5	5	50	50	3	3	50	50
T9	4	5	44.44	55.56	1	2	33.33	66.67
T10	1	2	33.33	66.67	0	0	0	0
T11	0	0	0	0	1	2	33.33	66.67
T12	2	0	100	0	3	0	100	0
T13	6	4	60	40	2	0	100	0
T14	17	9	65.38	34.62	0	0	0	0
Total Team North	49	37	0	0	21	17	56.98	43.02
T20	3	0	100	0	1	3	25	75
T21	1	1	50	50	0	3	0	100
T22	4	0	100	0	2	0	100	0
T23	7	7	50	50	0	0	0	0
T24	4	1	80	20	3	0	100	0
T25	0	1	0	100	0	0	0	0
T27	0	4	0	100	0	0	0	0
T28	0	1	0	100	0	0	0	0
T29	1	0	100	0	3	1	75	25
T30	1	0	100	0	1	0	100	0
Total Team South	21	15			10	7	58.33	41.67

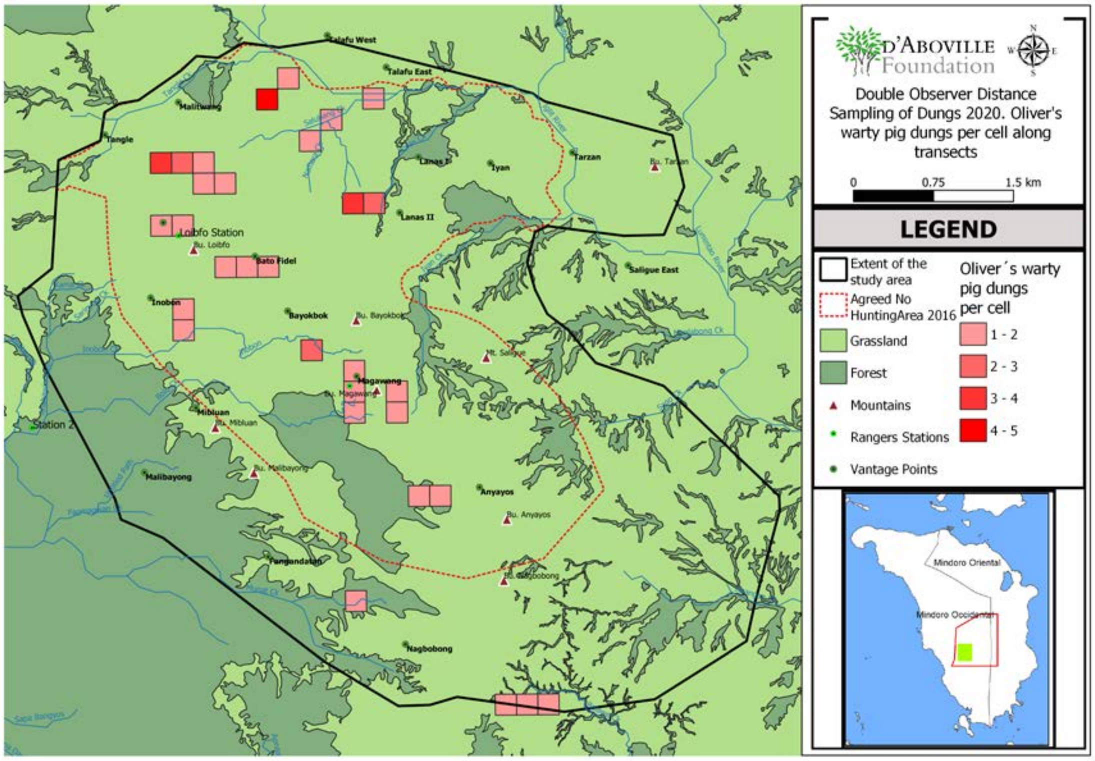
Map.2: Number of tamaraw dungs found along the transects projected on the grid map of the CZM of MIBNP, showing the relative density of them and spatial distribution pattern



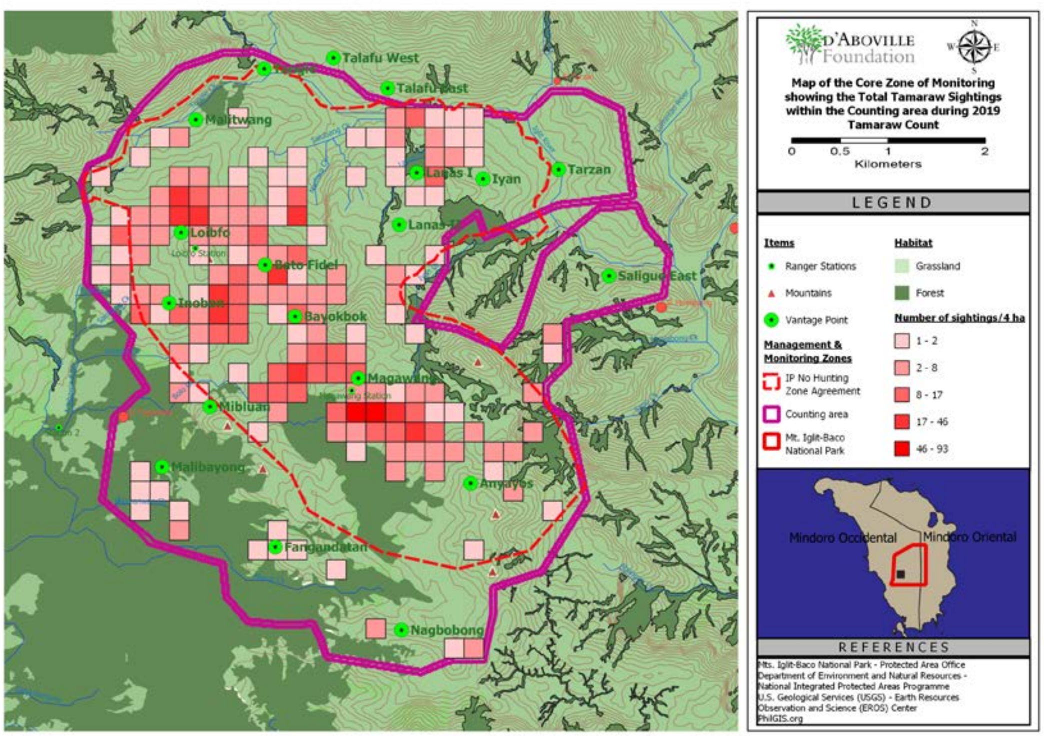
Map.3: Number of Philippine deer dungs found along the transects projected on the grid map of the CZM of MIBNP, showing the relative density of them and spatial distribution pattern.



Map.4: Number of Oliver´s warty pig dungs found along the transects projected on the grid map of the CZM of MIBNP, showing the relative density of them and spatial distribution pattern.



Map.5: Map of the Core Zone of Monitoring of MIBNP with the results of the Annual Point Count of tamaraw. We can see represented the density of sightings of the animals per cell. The pattern displayed in the map is similar to the map displaying the results from Double Observer Distance Sampling of Dungs 2020.



Bibliography

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L. (1993). Distance Sampling: Estimating Abundance of Biological Populations.

Buckland, S. T., Turnock, B. J. (1992). A robust line transect method. *Biometrics*, 901-909.

DENR. (2019a). Mounts Iglit-Baco Natural Park Management Plan. Department of Environment and Natural Resources, Philippines.

DENR. (2019b).Tamaraw Conservation and Management Action Plan 2019 –2028.Department of Environment and Natural Resources, Philippines.

Ellis, M., Bernard, R. (2005). Estimating the density of kudu (*Tragelaphus strepsiceros*) in subtropical thicket using line transect surveys of dung and DISTANCE software. African Journal of Ecology, 43, 362-368

Foster, S.D., Hosack, G.R., Lawrence, E., Przeslawski, R., Hedge, P., Caley, M.J., Barrett, N.S., Li, J., Lynch, T. Dambacher, J.M., Sweatman, H.P.A., Hayes, K.R. (2017) Flexible Spatially-Balanced Designs that Incorprorate Legacy Sites. Methods in Ecology and Evolution, 8, 1433-1442.

Gonzalez-Monge, A., Schütz, E. (2019). Technical report on habitat assessment and tamaraw distribution in Mts Iglit-Baco Natural Park relevant to tamaraw conservation and management. d´Aboville Foundation

Henry, E. H., Anderson, C. T. (2016). Abundance estimates to inform butterfly management: double-observer versus distance sampling. *Journal of insect conservation*, *20*(3), 505-514.

IUCN 2020. The IUCN Red List of Threatened Species. Version 2020-1. https://www.iucnredlist.org. Downloaded on 19 March 2020.

Ishihara, S., Boyles, R. M., Matsubayashi, H., del Barrio, A. N., Cebrian, M. R., Ishida, A., Lapitan, R.M., Atabay, E. P., Cruz, L. C., Kanai, Y. (2015). Long-term community-based monitoring of tamaraw Bubalus mindorensis on Mindoro Island, Philippines. *Oryx* 49 (2), 352-359.

Long, B., Schütz, E., Burton, J. A.,Appleton, M., Boyles, R., de Leon, J., Diamante, G., Gonzalez, A., Holland, J., Lees, C.,Marandolas, E., Natural, Jr, V. C., Pineda-David Jr, M. T., Salao, C., Slade, J., Tabaranzas, D. G., Tans, E. H. P., Tiongson, L., Young, S. (2018). Review of tamaraw (*Bubalus mindorensis*) status and conservation actions. BULLetin. Newsletter of the IUCN/SSC Asian Wild Cattle Specialist Group, 1, 18-34

Jathanna, D., Karanth, K. U., Johnsingh, A. J. T. (2003). Estimation of large herbivore densities in the tropical forests of southern India using distance sampling. *Journal of Zoology*, *261*(3), 285-290.

Jenkins, K. J., Manly, B. F. J. (2008). A double -observer surveys of forest ungulates. *Journal of Applied Ecology*, *45*(5), 1339-1348.

Johnson, D. H. (2008). In defense of indices: the case of bird surveys. *The Journal of Wildlife Management*, *72*(4), 857-868.

Kumar, N., Harihar, A., O´Kelly, H. (2017). Field practices: Estimating abundance of prey species using line transect sampling. In Methods for monitoring tiger and prey populations, 121-136. Springer, Singapore.

Manly, B. F. L., McDonald, L., Thomas, D. L., McDonald, T. L., Erickson, W. P. (2007). *Resource selection by animals: statistical design and analysis for field studies*. Springer Science & Business Media.

Marques, F., Buckland, S., Geofin, D., Dixon, C., Borchers, D., Mayle, B., Peace, A. (2001). Estimating deer abundance from line transect surveys of dung: sike deer in southern Scotland. Journal of Applied Ecology, 38, 349-363.

Nichols, J. D., Hines, J. E., Sauer, J. R., Fallon, F. W., Fallon, J. E., Heglund, P. J. (2000). A double-observer approach for estimating detection probability and abundance from point counts. *The Auk*, *117*(2), 393-408.

Pielou, E. C. (1969). An introduction to mathematical ecology. *An introduction to mathematical ecology.*

Smyser, T. J., Guenzel, R. J., Jacques, C. N., Garton, E. O. (2016). Double-observer evaluation of pronghorn aerial line-transect surveys. *Wildlife Research*, *43*(6), 474-481.

Thompson, W. L. (2004). Estimating abundance of rare or elusive species. *Sampling rare or elusive species: concepts, designs, and techniques for estimating population parameters*, *389*.

Valente, A. M., Fonseca, C., Marques, T. A., Santos, J. P., Rodrigues, R., Torres, R. T. (2014). Living on the edge: roe deer (Capreolus capreolus) density in the margins of its geographical range. *PloS one*, *9*(2).