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Proposal for new tamaraw population monitoring methods at Mts Iglit-Baco Natural Park, Mindoro, Philippines

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Structure of the document

1. Background and rational

1.1. Situational analysis at Mts. Iglit-Baco Natural Park

The tamaraw (*Bubalus mindorensis*) only occurs in four isolated areas across the Mindoro Island in the Philippines. Knowledge of the range and abundance of these sub-populations remains at the core of conservation objectives. Mts Iglit-Baco Natural Park (MIBNP) hosts the largest population of this endemic and Critically Endangered species. As such, the annual tamaraw population count has been the cornerstone activity of local authorities to assess population status of the species, and in turn, the effectiveness of conservation activities. This historical field operation aims at estimating the number of tamaraws still present in the protected area, and involves the simultaneous multi-vantage points count method. Nevertheless, our past experiences with the historical method uncovered several constraints and limitations to this approach:

- The sampling area is limited to 2000ha “count area”, inside the core area of patrolling of the rangers ; according to results from patrols and sporadic observation, the total area of tamaraw presence is slightly larger.
- The annual count has been overestimating the real number of tamaraws assumed to be present in the count area for a decade or more due to several biases inherent to the method;
- The recent experiment with the double observer estimator conducted in April 2022 confirms the overestimation issue and rather suggests a population closer to 200 animals, thus half of what is estimated from annual counts;
- The method requires seeing animals (direct observation). Because of this, large tracks of grassland are burned annually at the peak of the dry season prior to the count to increase visibility of animals attracted by regrowth of young grasses.

We treated all above points in the report: ***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the simultaneous multi-vantage points count method and the double observer point count estimator*** (DAF, October 2022 unpublished); we suggest that the reader refer to this document for more detailed overview of these points.

The burning of grassland prior to counts is critical to the counting method as it has been implemented, and has led to criticisms of this approach due to its negative impact on the habitat and local fauna. This intrusive habitat management practice, undertaken for the sole purpose of the tamaraw count, was discussed during the ***Tamaraw Population and Habitat Viability Assessment Workshop*** in 2018. The need to engage in a process of transition by phasing-out burning and promoting the restoration of natural vegetation was subsequently recommended as a priority objective in both the ***Tamaraw Conservation and Management Action Plan (TCMAP 2021-2030***) and the ***Protected Area Management Plan for Mts Iglit-Baco Natural Park (PAMP MIBNP)***.

Such shift of habitat management makes *de facto* the current method obsolete, as it will drastically decrease the chance of spotting animals when the vegetation becomes denser. Therefore, the TCMAP and the PAMP also recommended the implementation of an **alternative monitoring method of tamaraw abundance** that does not require intrusive habitat intervention.

This document aims at proposing a comprehensive, though non-exhaustive, set of options in order to enable the Department of Environment and Natural Resources (DENR) to decide, select, and implement the most appropriate option for the future monitoring of tamaraw population at MIBNP. It is based on the intensive research work conducted by the D'ABOVILLE Foundation and Demo Farm Inc. together with the Tamaraw Conservation program and Protected Area Management Office and its international partners between 2020 and 2023.

We based our rational on three assumptions:

- The phase-out of grassland burning within the count zone will be effective in the coming years.
- Consequently, authorities will likely stop the simultaneous multi-vantage point count method in the near future.
- Authorities will take over responsibility of the new methods that will be selected in the long run, though they could seek technical assistance from the D'ABOVILLE Foundation and Demo Farm Inc. and its partners during the transition phase (establishment of the method in the field and training of local staff if needed).

1.2. Developing and selecting new monitoring methods

The results and findings described in the above-mentioned report corroborate the long-term consideration from the scientific literature pertaining to estimation of wildlife population abundance:

It is practically impossible to measure the exact number of individuals of a certain species and a certain population in the wild without a probabilistic estimator of abundance accounting for detection probability of animals (see below). The annual counts of tamaraws do not, and have never, given an actual number of tamaraw and should be considered as an index of abundance. **An index of abundance reflects relative changes in number of animals (relative abundance) only, and can be far from the true population siz**e. Thus, the aim to obtain a number of tamaraws present inside MIBNP, from a practical standpoint, must be reconsidered.

In this respect, it is important to formulate new options for monitoring the tamaraw population within the CZM that integrate this reality and the context on site:

- The main method should be based on indirect signs of presence to account for the fact that, in the absence of burning, animals will be more difficult to detect.
- The operation should be feasible, repeatable, and the results reliable and comparable in time and space.

In this matter, local authorities and decision makers should define the clear objectives they seek from such an operation and the results they expect from it. They should select the method or methods according to:

- The existing capacities of the office in charge of conducting this task (staff skills, technical expertise, materials available).
- The financial resources they are able to invest.
- Their capacity to conduct it in the long term and use the results for management and protection purposes.

2. Shifting from a number of animals to an Indicator of Ecological Change (IEC)

For almost two decades, tamaraws have been counted annually by authorities at MIBNP for management and conservation purposes – and such data have given helpful insights into the population (for example, see Bonenfant et al. 2022). The desire to obtain a population size comes as no surprise because monitoring and managing wildlife from population counts is likely one of the most deep-rooted habits for wildlife managers. The underlying idea is to consider wild populations of large herbivores like a herd of domesticated animals, for example, similar to cattle. Such a pragmatic approach bears two major pitfalls that should incline wildlife managers to use more integrative and informative data on their target population.

First, estimating animal abundance is not a simple task, and often riddled with large uncertainty and unknown accuracy. In most cases, the uncertainty of annual abundance estimation is about 30% (Caughley 1977), meaning that an actual increase or decrease of abundance cannot be formally detected. From one year to another very few populations of large herbivores see their abundance changing by more than 30%. The tamaraw abundance, for instance, grew by only 5% on average over 20 years (see Bonenfant & al. 2023). The second reason for why the knowledge of population abundance is limiting for wildlife conservation and management relates to the functioning of a population. A given population abundance does not inform its ability to grow or to reach the natural limits of the habitat where the population occurs. In a favourable environmental context, a density of 10 animals per square km^2 could be acceptable, while in harshest conditions the population of the same species could already have reached the ecological carrying capacity at the same population density.

Teasing apart those two different situations is important from a conservation point of view, but this move requires to take a rather different approach and to put less emphasis on the actual number of animals and more on the population response to food resources.

To solve the challenges of managing wildlife with population size only, the last two decades have seen the development of alternative tools for the management of large herbivores in Europe and North America (Morellet et al. 2007, Collier et al. 2013). Although initially developed on roe deer, its generality and applicability to other large herbivore species such as the tamaraw is straightforward because of their relatively similar biology. These new tools are a set of **indices** collected in the field and called **indicators of ecological changes (IEC,** *sensu* Morellet et al. 2007**)**. IEC inform on the relative abundance of a population of large herbivores, the performance of individuals, and the impact of herbivory on the plants they feed on. Recorded annually, those indicators are cheaper to collect and together give a more comprehensive picture of the population dynamics. We briefly describe below how IEC works and quickly move to how this approach could apply to the conservation of the tamaraw at MIBNP.

2.1. Managing wildlife with the indicators of ecological changes.

Indicators of ecological changes are a set of three complementary measures, two on the animals and one on the plants, from which one can tease apart different scenarios of population dynamics (Morellet et al. 2007). The **three types of indices making IEC are (1) abundance index, (2) animal performance index** and (3) the **index of impact on the vegetation**. IEC is rather flexible because one can use a combination of different indices adapted to local manpower and expertise or to the species in question. For the roe deer (*Capreolus capreolus*), for instance, the suggested set of indices are the number of animals seen per km to capture the relative variation in abundance overt time, the average body mass of fawns to measure roe deer performance, and the consumption of young shoots of woody species to inform on their impact on plants. Different indices are possible or better adapted to other species. Pregnancy rates of young female red deer (*Cervus elaphus*) have been proposed as a good index of animal performance because of its rapid change with population density (Bonenfant et al. 2009). Best results are obtained with the three indices interpreted together but the two on the animal population are already very informative, and the impact on plants is often secondary if management goals do not include wood production and forest regeneration.

A population may be stable, increasing, or decreasing in size. Changes in abundance may not have meaningful consequence on demographic rates if the population is far away from the **ecological carrying capacity** of the area it occupies. Conversely, it may require some conservation actions when approaching this natural limit. **The ICE allows one to understand these dynamics and if the monitored population is close to the carrying capacity**

depending on the temporal co-variation of the three indices (see Fig. 1 for a description of biologically realistic situations).

For example, let us consider a population of tamaraws for which relative abundance, individual performance, and impact on plants has been monitored for 5 years, and let us put aside what measure has been used for the sake of illustration (see below for suggestions). Let us consider the observed patterns: the relative abundance is increasing in time, individual performance is decreasing, and at the same time the herbivores have an increasing impact on vegetation. The conclusion would be that the tamaraw population is increasing in density and approaching the carrying capacity of the habitat. This is because at high density (notably above half of the carrying capacity), large herbivores suffer from reduced performance, expressed through a reduction of the average body mass or lower reproductive rate and success of females (see Eberhardt 2002; Bonenfant et al. 2009).

Of course, different patterns of temporal co-variation between three indices would lead to different conclusions and actions to be taken. A similar increase of the abundance index but no change in body mass over 3 or 4 consecutive years would indicate an increase in population size without detectable density-dependence, meaning the population is far from the carrying capacity of the environment. In terms of conservation, this could translate into two situations: (a) the population is close to what the environment can support, and conservation measures shall seek avoiding carrying capacity to hamper its long-term viability, by increasing its potential range for instance, or (b) the population is at low density and below the carrying capacity, enabling conservation decision to seek for increasing the population abundance in the current range (see Fig.1).

Note that at no point is the absolute knowledge of population size required to use ICEs and to conclude on the population dynamics; the most important information is in the temporal trend of the three indices. We are not interested in how many animals there are, but in how these indices change over time.

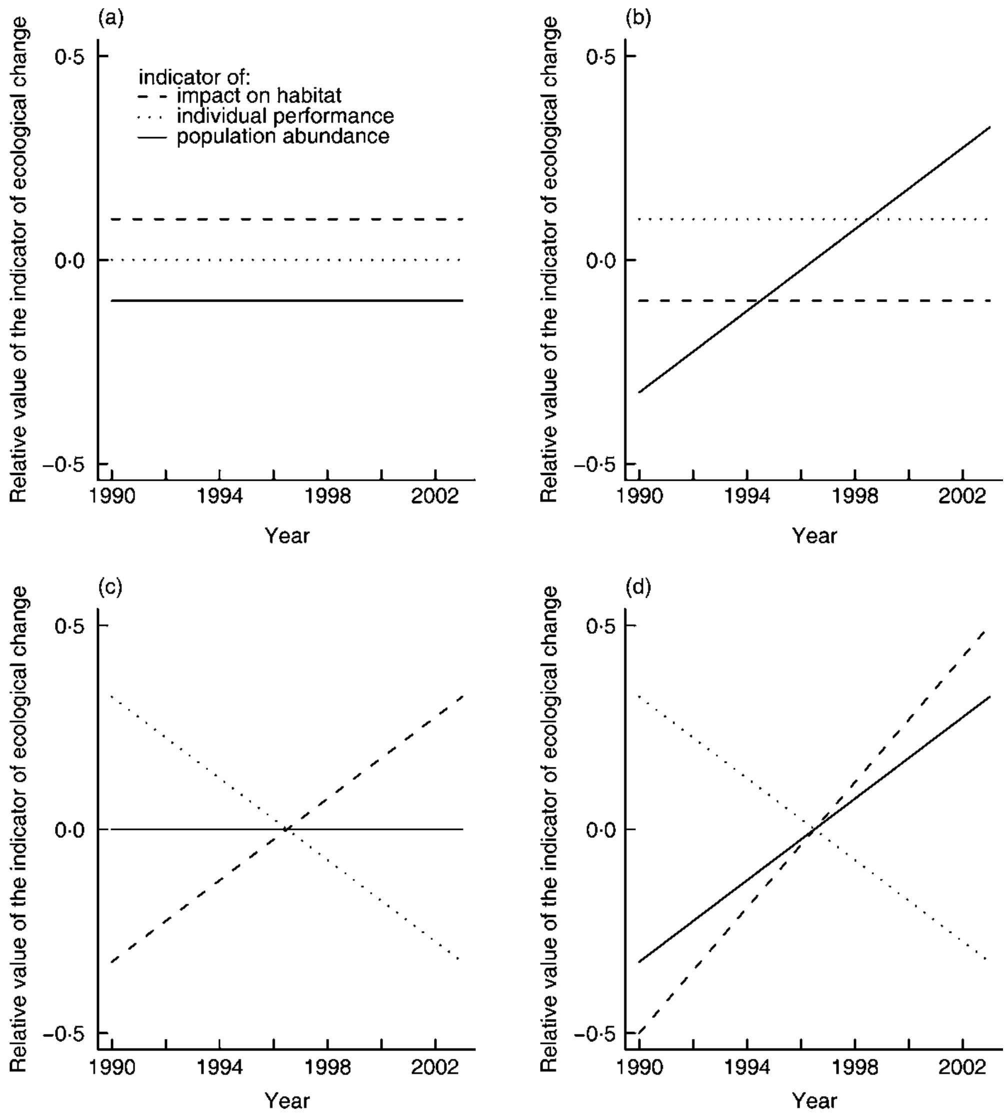

Fig. 1. *Theoretical temporal changes of a set of indicators describing population abundance, individual performance and habitat impact in a population–habitat system. To simplify the representation of the four (of an infinite number of possible) different scenarios, we have assumed linear relationships over time and an arbitrary scale for the variation of the indicator centred around zero, with marked temporal patterns: (a) a stable situation without any variation of the population–habitat system; (b) a colonizing population; (c) a situation of declining habitat resources; and (d) a classic case of density-dependence with impact on both compartments of the population–habitat system.*

2.2. Applying the indicators of ecological changes to the tamaraw at MIBNP

The monitoring of the tamaraw population at MIBNP needs to be adjusted to the future changing conditions of observation in the field. The discontinuation of grass burning will likely lead to a dramatic reduction in visibility of animals within the tamaraw range. Such decrease in the detection rate of tamaraws in a close future will make managers and authorities blind with regards to the tamaraw population dynamics. As an alternative way of monitoring the tamaraws, we propose to use the IEC approach framed to the tamaraw biology and habitat constraints (rough terrain, different type of biotopes, and change in habitat following cease of fire regime…). Though we suggest to implement the three indices, the partial redundancy of the three indices making IECs is interesting if, for some reasons, one of the measures becomes difficult to carry out in the field. The priority is to implement, on a yearly basis, the animal abundance and performance indices because the impact on plants is of limited interest for the conservation of the species and the management of the MIBNP ecosystem so far.

3. Developing IEC at MIBNP – methods and options

3.1. Index of population abundance

Several options can be envisioned for capturing temporal changes in tamaraw abundance. The key idea here is to find the appropriate trade-off between the accuracy of the abundance estimation and the effort needed in the field to collect the appropriate data.

Four methods can be considered

- Distance sampling of dung transect
- Camera trap
- Drones
- Non-invasive (genetic) approaches

3.1.1. Distance sampling of dung transect

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 in an observer recording the number of animals through a predetermined transect of fixed length to which is applied a statistical estimator of population density (Buckland et al., 1993). Over the time, different studies tried to apply it with different animal signs of presence, like dung (Ellis et al., 2005; Marques et al., 2001; Valente et al., 2014). Distance sampling of dung transects was tested at MIBNP between 2020 and 2022. This index of abundance does not count animals and instead returns a density of tamaraw dung, not a density of animals.

The proposed method is therefore an **indirect estimation of relative abundance of tamaraw**. Working with dung density instead of population counts therefore assumes a relationship, positive and linear, between the number of tamaraws present in the area, and the density of dungs that is measured.

For the operation conducted at MIBNP observers recorded every faeces they detected from the transect, taking notes of the number of dungs, species to which it belongs (tamaraw, deer and warty pig), perpendicular distance to the transect, habitat, and an estimation of the dung's age. In addition, we implemented the dependant double observer estimator to measure the probability of detection of dungs. (see Garcia et al. 2020 for details and results of the experiment).

A first difficulty arising from the use of the distance sampling methods is that it requires specific statistical skills to extract the density of tamaraw dungs. Although the analyses of distance sampling data are routine in many ecological programs, the underlying statistical analyses are rather advanced (see Buckland et al. 2003) and need to be taught to the analyst to perform it correctly.

A second difficulty lies in the fact that the assumption of a constant detection probability of tamaraw dungs is not supported by our experiment at MIBNP. The use of the dependant double observer method combined with distance sampling showed how detection probabilities of dung could vary from one season to another (see Garcia & all, 2020). However, measuring the variation in dung density using the double observer method requires additional manpower (i.e. there needs to be a front team and a back team) and makes for more tedious post-experiment processing of the data.

The combination of distance sampling and double observer methods where both dung density and probability of detection are measured (Burt et al. 2014) is an attractive approach for the long-term comparison of dung density, as a proxy for the relative tamaraw abundance. This is the most complete and complex approach of distance sampling but simpler protocols can be considered to monitor population abundance according to the amount of time, skills, and resources that the implementers can invest. These three aspects are keys in guiding the decision making prior to choosing the final protocol and design. Four different options to monitor tamaraw abundance in the future are presented here, all deriving from the distance sampling method using dung transects.

- <u>Distance sampling combined with dependent double observer</u>

Expected information: dung density + probability of detection with distance to transect + probability of detection by observer

This is the option that was implemented at MIBNP previously. Results and design are detailed in the BULLetin article (Garcia et al. 2020) and described in figure.2. As mentioned above, this option is the most sophisticated approach, returning the most accurate results, though a front team and back team are needed to apply both protocols.

Data processing and analyses require advanced statistical skills to extract both density of dungs and the associated probabilities of detection. To our knowledge, the only accessible way to painlessly run such analyses is by using the DISTANCE software (https://distancesampling.org/) or the *mrds* package for R (https://github.com/DistanceDevelopment/mrds). DISTANCE uses a graphical interface, while R does not, and would require some coding.

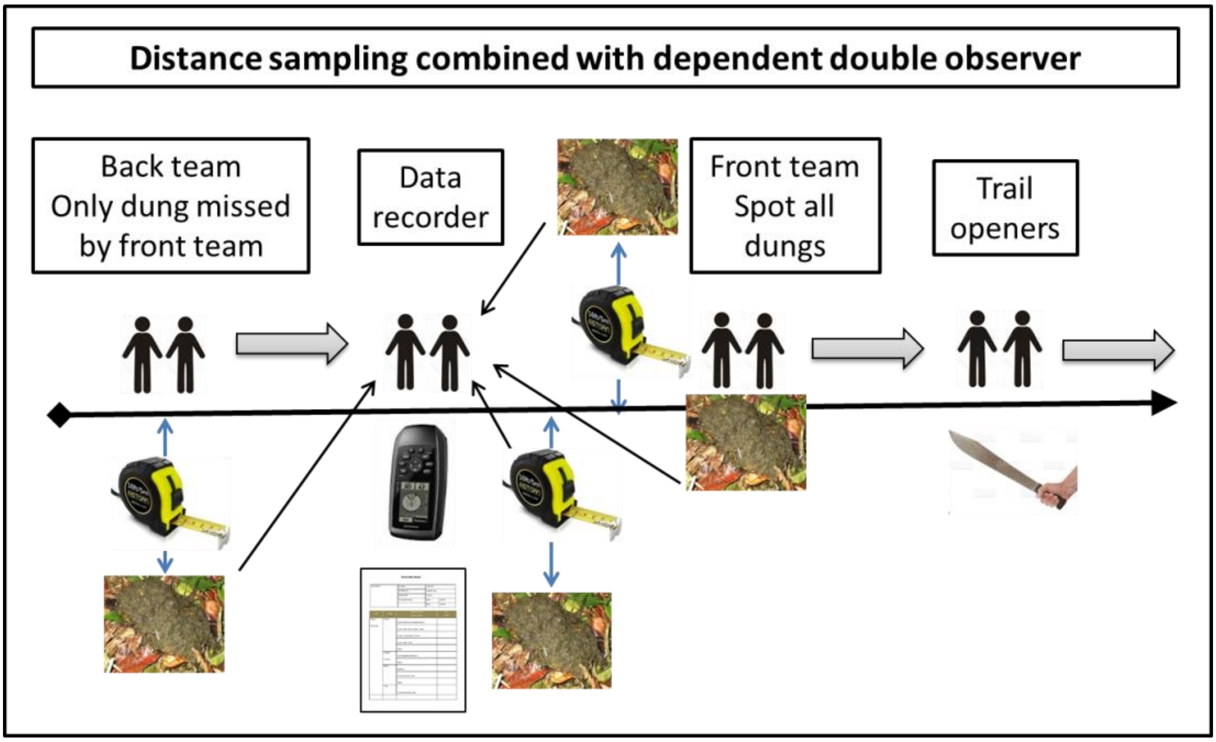

Fig.2. Diagram explaining the concept of distance sampling of dung transect combined with double observer. This option requires a front team and a back team as well as data recorder. Distance to the transect are measured for each dung spotted. GPS locations are taken for each dung.

- <u>Standard distance sampling</u>

Expected information: dung density + probability of detection with distance to transect

This option is less tedious and time consuming to implement in the field as it would require only one team of observers, while the measurement of the perpendicular distance to transect is conserved to estimate the decrease in detection as the dung is located further away from the observer walking along the transect line. The absence of the double observer estimator in the protocol implies the assumption that no dungs are missed by the observers, which we know is untrue from our earlier work in MIBNP (i.e. the back team capturing nearly 20% of dungs missed by the front team). This simpler method would return less accurate results than the first option, underestimating dung density by a factor of 10 according to our previous results. Figure.3 describe the contept.

Data processing and analysis involve statistical skills to extract dung density. Stand-alone DISTANCE software (https://distancesampling.org/) and specific packages are currently available to conduct standard distance sampling analyses of R (i.e. *unmarked*, *Rdistance*)

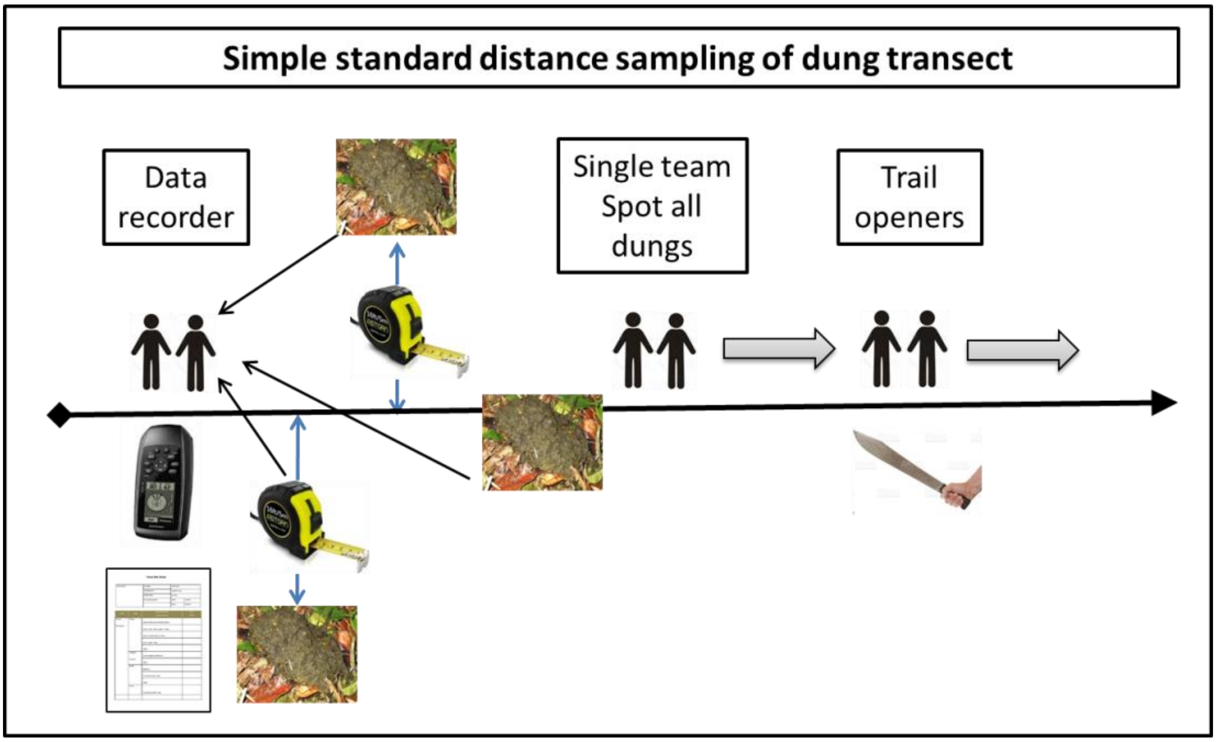

Fig.3. Diagram explaining the concept of standard distance sampling of dung transects. This option requires only one team to spot dungs. Data recorder can be the spotters as well. Distance to transect is measured for each dung spotted. GPS locations are taken for each dung.

- <u>Dependent double observer only</u>

Expected information: dung density + probability of detection

This option requires to build two teams (a front team and a back team) but is no longer associated to distance sampling as we omit the measurement of the perpendicular distance of the dung to the transect. Thus, it is much faster to conduct in the field.

The rationale behind this option relies on the fact that our experiment at MIBNP shows that the detection of dung falls rapidly with the distance to the transect. In fact, more than 95% of the dungs are detected within a sighting range of 50 cm on each side of the transect line (see Fig. 4). Therefore, with an effective width of the transect of 80cm (on each side), the number of missed dungs located >50-80 cm from the transect is small (<5%). Moreover, the detection probability is quite homogeneous for dungs located within a 50 cm distance from the transect, meaning that not accounting for the perpendicular distance of the dungs located between 0 and 50 cm to the transect does not have huge consequences on the estimated detection probability. On the other hand, our experiment highlights that the detection probabilities we estimated from the double observer show relative stability probabilities (around 0.10, 0.08 and 0.12 for the three first operations).

Therefore, removing the measurement of dung to transect from the protocol would still be expected to capture a substantial part of the variation of dung detection probability from one year to another. At the same time, with this simpler method we move away the real number of dungs and accept to work with a relative index of tamaraw abundance.

This option further removes the burden of sophisticated post data analysis except for the probability of detection, which can be extracted from simple formulas in a spread sheet. Formulas may be found in the original paper describing the double observer estimator of abundance (Nichols et al. 2000).

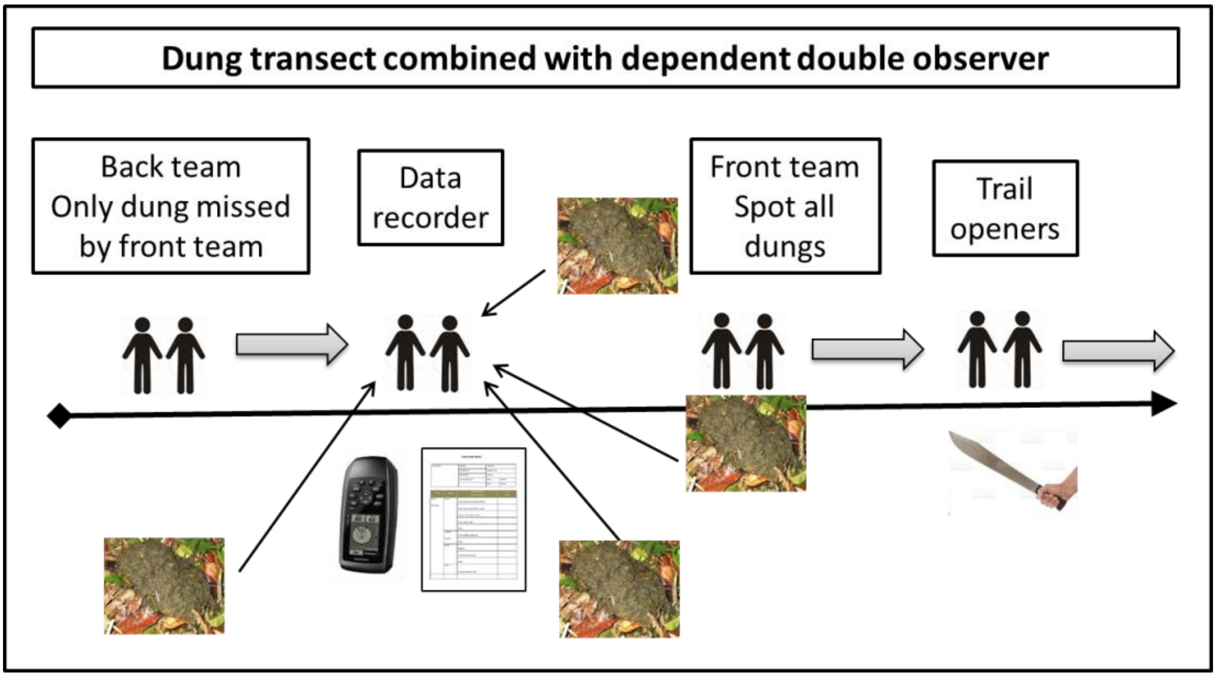

Fig.4 Diagram explaining the concept of simple dung transects using the double observer method. This option requires a front team and a back team as well as data recorder, but distance to transect is disregarded. GPS location is optional but not required in the associated data processing.

- <u>Raw data</u> / simple dung transect

Expected information: number of dungs per distance unit

Of the four options, this one is the simplest index of abundance, as no correction for detection probability is applied whatsoever. It means that dung abundance is severely biased low, and that comparison of abundance values with other tamaraw sites like Aruyan-Malati is not possible.

In addition, it will be hard to ascertain accuracy of comparison of the results over time, as we expect the capacity to detect dungs to change in the future following the phase-out of the grassland burning, while this will not be estimated.

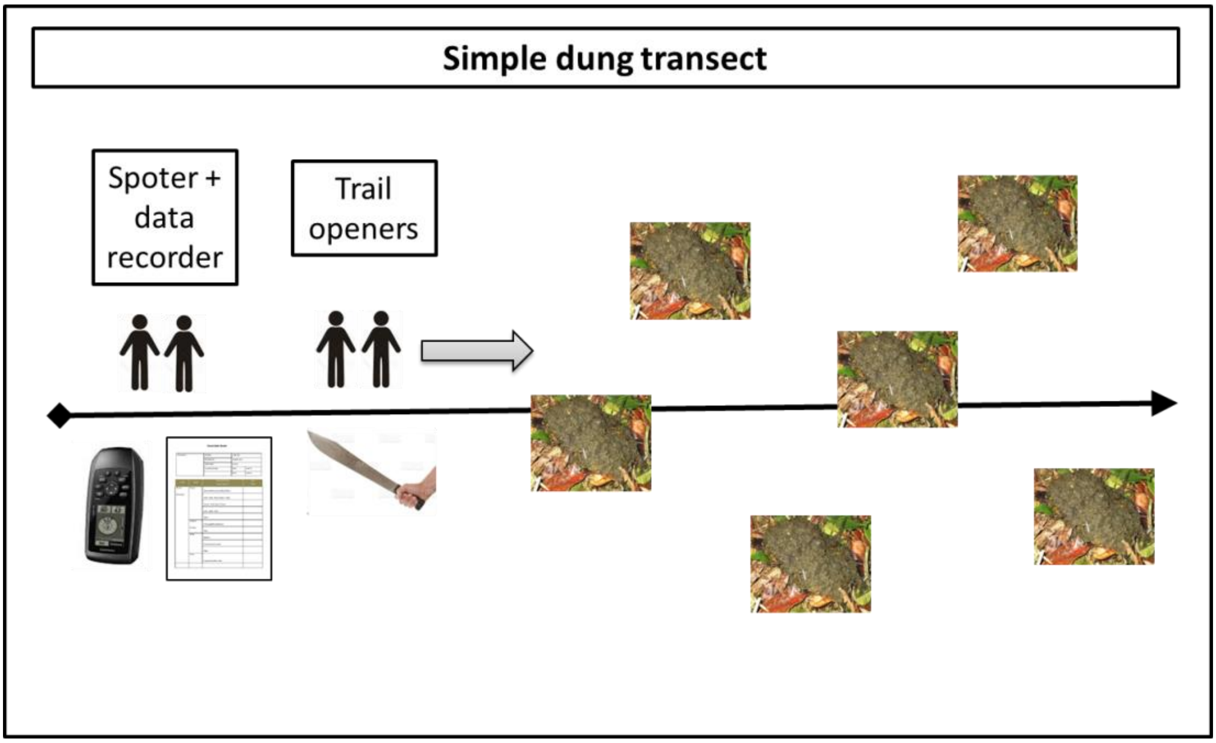

Fig.5. Diagram explaining the concept of simple dung transects. This option only requires a single team of spotter and data recorder. Distance to transect is disregarded. GPS location is optional but nor required for data processing. Only the number of dung spotted is recorded on simple data sheet.

This simple index of tamaraw abundance is the easiest option to implement, requiring less skills, manpower and time in the field. On the other hands, it may lead to difficult interpretation of the ICE if, for instance, we face contradictory patterns in abundance, performance, and herbivory indices. The data processing and analysis is simple but prone to errors in case of substantial variability in the conditions of observations of dungs. Concluding on a significant increase or decrease of abundance in time will be more challenging than with the distance sampling approaches.

Conclusion:

Among the four options we reviewed, the third one (dung transect with dependent double observer) is likely the one offering the best compromise between accuracy, data processing and resources involved. In this case, we account for the main sources of detection uncertainty from one year to another. A comparison of dung abundance over the years is relatively reliable and straightforward.

3.1.2 Camera trap as a method to monitor tamaraw abundance

Since the development of this technology, camera traps have been widely used for studying wildlife (*Rovero et al. 2016*) but been more effective in species where individual identification is possible, such as tigers *(Panthera tigris*) *(Karanth et al. 1995)*, jaguars *(Panthera onca*) *(Silver et al. 2004)*, and clouded leopard (*Wilting et al. 2012)*. Three types of research approaches for population dynamic derive from this property: unmarked population (i.e., animals cannot be identified individually), partially marked population (i.e., a certain proportion of the population can be individually identified), and marked population (i.e., all animals of the population can be individually identified from the camera trap pictures).

In the case of the tamaraw, few camera-trap studies have been carried-out in the past few years in different sites across Mindoro. Identifying animals has been tested but has shown to be inconclusive, making the species fall under the category of unmarked population. In practical terms, this means that, from camera-trap images, it is not possible to identify specific animals. Because of this limitation, we cannot use camera trapping to estimate abundances or densities from the data collected using capture-recaptures methods. Consequently, camera-traps are a less reliable option for getting a population abundance index for tamaraw. Nonetheless, there are alternative monitoring metrics. Here we present one of them.

- Occupancy modelling:

The most appropriate alternative metric to consider is occupancy modelling. Simply put, occupancy assesses the probability of presence of a species across a given area. One major advantage to this method is that it explicitly accounts for imperfect detection probability; i.e. the model can tease apart situations in which an animal was present at a site but not detected verses not detected and not present (Mackenzie et al, 2022) The final output is a probability that an animal - *i.e.* tamaraw – is present in different spatial units across a landscape.

How does occupancy relate to abundance? There is no straightforward answer. Various studies have tried to draw connections between occupancy and increases in population size (i.e. abundance). In practice, the link between abundance and occupancy remains highly context-specific. In most cases, occupancy should be considered as a metric that measures *distribution* for a species, with the understanding that changes in abundance (i.e. an expanding population) will also result, in most cases, in a change in distribution.

There are advantages and disadvantages to using occupancy as a monitoring state variable. One advantage is that occupancy is a well-established approach for the monitoring of large vertebrate populations (for example publications, see Gray et al 2014; Johnson et al, 2020; Tilker et al, 2020). Both the field methodology and analytical procedures are clear.

One disadvantage is that, because occupancy is a proxy for population size, it may fail to capture moderate changes in population size. This is especially true for situations in which population size changes without a corresponding change to distribution (referred to as the "area of occupancy").

There are four main considerations for occupancy designs:

(1) Studies must be sufficiently short to approximate the closure assumption (i.e. no local extinction or colonisation at sampling sites).

(2) Camera spacing must be sufficiently large to ensure individuals cannot be photographed at several sites.

(3) Occupancy models are very sensitive towards false positives, which can severely bias model estimates. Thus, reliable species identification is important.

(4) During field surveys, all habitat parameters thought to influence detection probability of the target species must be collected at adequate spatial scales and simultaneously with the camera-trapping study.

These four considerations mean that any camera-trap study in MIBNP would need to:

1. Last no more than 2-3 months for sampling. Since camera traps can be left for months in the field, this should not be a problem.
2. Ideally have no more than one camera within the home range of each tamaraw. This may be problematic, as we have an incomplete understanding of tamaraw home range / movement patterns.
3. Tamaraw are not mistaken for other species in the camera-trap images. This should not be a problem, as there are no confirmed domestic buffalo in the CZM.
4. Collect detailed information on any habitat parameters that might influence the likelihood of tamaraw being detected, or not, at a site. This may be challenging, especially since multiple unknown factors may be relevant to tamaraw detection.

<u>Field implementation</u>:

The area of sampling – which would, presumably be centred on the current count zone, plus peripheral areas where tamaraw might expand to in the future – would be divided up into grid cells. The grid cells would ideally be the approximate size of a tamaraw home range. Then, one camera would be placed in each grid cell for 2-3 months' time. The exact placement of the camera trap should correspond to areas that maximize the detection of tamaraw (ridges, trails, wallowing sites); there is no need for camera placement to be completely random.

The most obvious difficulty with an occupancy-based approach MINBP is the fact that, when burning stops inside the Strict Protection Zone, the grassland vegetation will become denser. From a practical standpoint, this will make any camera-trapping difficult, since the camera will need a moderate field of view to capture animals. Possible alternatives would be to select microhabitats where the grass is not unusually high or to choose water sources / mud wallows that provide an open space. However, the feasibility of these options should be explored by people familiar with the site.

Data processing:

The first step in processing the data would be to identify all images from the camera-traps. The most important information would be to note tamaraw presence at each of the camera-trap stations across the study period. Then, tamaraw detection / non-detections for each station for a given time period (usually 5-10 days) will be coded into a simple matrix that shows when tamaraw were detected across the study site for each camera trap. In addition to this detection / non-detection matrix, it will also be needed to code covariate information into a matrix; this would be a quantified version of any factor that might influence tamaraw presence or detection probability at a camera trap station. The actual occupancy modelling is fairly straightforward, thanks in part to a number of new software tools that have come out in recent years. With a small amount of coding experience, users can use the R package *camtrapR* (Niedballa et al 2016) to run basic occupancy models. For people without any coding experience, simple occupancy models can also be run in the program PRESENCE (https://www.mbr-pwrc.usgs.gov/software/presence.html), which has a point-and-click graphical user interface.

Conclusion:

The use of camera trap appears as a possible alternative to monitor tamaraw presence, but provides limited options in the context of MIBNP with results that might not be worth the cost of such operation (purchase and maintenance of equipment) in comparison with other methods. In addition, the use of camera trap for that tamaraw population will face the problem of consent from residing Taobuid communities, which might see this as an intrusive operation in their living landscape.

3.1.3. Drone technology/Unmanned Aerial Vehicle (UAV).

Note: Most information mentioned below is summarized in the unpublished paper produced by DAF in 2021 entitled:" On The Use Of Drone Technology To Monitor Tamaraw Populations And Its Habitat In Mindoro".

Most wildlife monitoring projects using unmanned aerial vehicles (UAV) are still centred on testing methodologies, their accuracy, and their benefits and constraints (Wang et al., 2019).

No experiment using UAV has proven conclusive so far to monitor wildlife population abundance in the field in comparison to other methods. Therefore, and at this stage, there is no existing simple solution or customized protocol that could be implemented for tamaraw population monitoring. In other words, evaluating the use of drone technology for tamaraw at MIBNP would be an exploratory process with ultimately no certainty on its effectiveness.

In this context, we highlight several concerns on the benefits of experimenting drone at MIBNP. First, several researchers that have been recently experimenting this technology for medium to large mammals concluded that using drones in thick habitats (forest, tall grasslands) or uneven terrain is not an ideal approach, because detection probability of animals, even using a thermal camera, tends to be low. The terrain and types of habitats that can be found where tamaraw are present raise serious questions about whether this approach would be feasible in the context of the tamaraw at MIBNP

Another concern of using drones lies in the acceptability of this technology by IP communities residing at the periphery of the count zone. People would likely consider this technology as intrusive because the drone must fly over their settlements or crops to sample the tamaraw population range exhaustively. Deploying drones at MIBNP would therefore take time to come to an agreement with IPs, and to train a team to fly the aircraft. In terms of manpower and time allocation, drones record many images that require careful and somewhat time-consuming post-processing to extract relevant data. In our case, one would have to search for tamaraws in the aerial photographs. Given the amount of data collected during each campaign, the annual processing of photographs would require either a tedious and elaborated post-analysis by human eye, or to build an artificial intelligence model to automate the process.

Finally, the use of a drone technology to sample the population would not remove the challenges faced by any other method to estimate animal abundance, that is, the problem of detection and multiple counts. Population abundance estimators would still be needed, as they are with the capture-recapture and distance sampling estimators. Compared to the estimation of dung density, the benefits of using drones are weak at best.

In conclusion, we do not recommend drones to monitor tamaraw abundance at this stage as this would require undertaking a tedious process of testing and evaluation (including to find and hire the people with proper expertise and equipment), with a huge uncertainty in terms of results in comparison to other methods that are more straightforward to implement.

3.1.4. Genetics, using DNA of dung sample

Population size estimates can also be obtained through DNA analysis of dung samples (so called non-invasive sampling of wildlife populations: Schwarz et al. 1998). With fresh dung samples, modern genetic analysis techniques are able to establish the identity of individual animals. With individual information from multiple animals from a population, it is then possible to use capture-mark-recapture analyses to estimate population size. The methodological and analytical steps for dung-based population estimates are well-established (Petit and Valière 2006, Knapp et al. 2009), and it is now a common method for population monitoring of many large mammal species, including elephants (see Eggert et al 2003 and Hedges et al 2013). An added benefit of using a dung sampling approach is that additional information on population structure (i.e. age and sex) can also be obtained.

Data collection:

Data collection for dung-based monitoring is straightforward: dung samples, preferably from fresh dung, are collected and stored in a buffer solution that preserves the DNA. Ideally, samples would be collected from a wide area to enhance the probability of identifying multiple different individuals. How many samples are needed? There is no right or wrong answer, as an increase in samples will necessarily increase the probability that there are multiple individuals identified and, therefore, the chances of producing more reliable population estimates. However, as a rule, most studies on large mammals use hundreds of dung samples to produce enough data for reliable population estimates. Theoretically, at least seven "recaptures" of the same individuals is needed to yield correct results.

DNA extraction:

Data analysis is more complicated (see Valière et al. 2007). Samples need to be processed in a DNA-laboratory with a moderate degree of expertise in modern genotyping. This includes "clean" extraction facilities (i.e. areas where precautions are taken against outside contamination), appropriate equipment for PCR amplification, and the expertise needed for bioinformatics (to assess individual identify among the samples).

Data analyses:

The estimation of non-invasive data to estimate population size falls primarily into the category of capture-mark-recapture estimators (Otis et al. 1978), with the additional difficulty that genotyping errors must be accounted for. Specific software maybe found such as GENECAP (Wilberg and Dreher 2004) although standard capture-mark-recapture software are also suitable (MARK). We strongly advise not to use the saturation curve methods to estimate population size from non-invasive data (see Petit and Valière 2006 for a description) as the results proves to be very sensitive to heterogeneity in detection probability among individuals (Bonenfant et al. 2023).

Considerations and limitations:

While genetic approaches offer a promising approach to estimating tamaraw abundance, there are three considerations that make this method potentially problematic:

- First, any dung collection and removal would need to be approved by the Taubuid communities living in and around the core zone of monitoring and undergo FPIC process.
- Second, these biological materials would need to be sent outside Mindoro to a reliable DNA laboratory for samples processing. If such a facility does not exist in the Philippines, then this would require samples to be sent abroad, which would possibly incur a considerable amount of paperwork for CITES and Nagoya protocols.
- Third, the method can be costly. Exact costs are impossible to estimate, given the range of variables involved, but based on previous studies it is likely that laboratory costs alone can run to USD 20,000 or more.

3.2. Monitoring tamaraw phenotypic performance

The phenotypic performance is a biological measure capturing the ability of animals to survive and reproduce. In large mammals, body mass is a good measure of phenotypic performance because large individuals generally enjoy higher reproductive rate and success compared to lighter individuals (Ronget et al. 2018). Similarly, reproductive rate of females from a sample of harvested animals by sport hunters is also a relevant measure of phenotypic performance (Gaillard et al. 2016). A general observation is that phenotypic performance of large mammals declines with shortage of food resource, and particularly so with increasing population density (Bonenfant et al. 2009). This is the manifestation of the classical density-dependent demographic phenomenon, which is the decrease in population growth rate with rising population density, at the individual level (Hassell 1975, Fowler 1987). The relationship between phenotypic performance and population density lies at the heart of the IECs based wildlife management and conservation and as such is of paramount importance (Morellet et al. 2007).

Here, we tentatively propose two indices of phenotypic performance that could be used to monitor the tamaraw dynamics at MIBNP: the proportion of females with calves and the pregnancy rate. Although we could not carry our preliminary experiments on these two indices, we are confident that they apply to the tamaraw because of the almost universality of density-dependent responses of phenotypic performance.

3.2.1. Calf-to-cow ratio, approaching reproductive success

The calf-to-cow ratio has been widely used in the past century in population dynamics studies of large herbivores (Creel et al. 1991; Hebblewhite and Merrill 2011; Eacker et al. 2017; Bonardi et al. 2017).

The observed percentage of females with a calf at heel after weaning is often taken as an approximation of female reproductive success. In addition, calf-to-cow ratio is the product of pregnancy probability and of juvenile survival probability, which both respond differently to population density and environmental changes (see Bonenfant et al. 2009; Gaillard et al. 2000). Although the calf-to-cow ratio may not capture reproductive success accurately enough for scientific purposes (Bonenfant et al. 1999), a well framed sampling design combined to records of group composition in the field make this variable an appealing measure of phenotypic performance of large herbivores in the context of ICEs.

Implementing the calf-to-cow ratio at MIBNP will require some knowledge of the reproductive biology and timing of tamaraws beforehand. So far, little is known about when exactly females give birth in a year. If seasonality of birth is a common pattern in large herbivores (see Thel 2021 for an overview) some species living in tropical ecosystems see births taking place all year round (Bronson 1989). The best timing for estimating calf-to-cow ratio is around 6 months after birth peak. Rangers consider that most births occur during the rainy season between the months of June and November though a proper field operation may be needed to precise the peak period. Recording the calf-to-cow ratio, for instance, once a week for one year would shed light on the seasonality of reproduction of this species. In addition to bringing important biological knowledge about the tamaraw, we could set the best timing for conducting the field estimation of the calf-to-cow ratio more accurately.

Once the best timing for field observation of females with a calf at heel is set, the annual estimation of the calf-to-cow ratio may be implemented on an annual basis. Here we are proposing two options to measure the calf to cow ratio: a first option using direct visual sighting and a second option using camera trap technology.

3.2.1.1. Sampling with direct visual sightings

We propose here to build the sampling design based on the multiple-vantage points used for the annual tamaraw population count. We know from long-term counts at MIBNP and rangers' reports that fewer females with calf are seen in the most peripheral and distant vantage points. Thus, the estimation of calf-to-cow ratio of the tamaraw population could focus on the most central vantage points. We identified between 7 and 10 suitable vantage points (see Fig. 7 to sample the group composition or tamaraws). The order of visited vantage points should be selected at random except if the number of people involved enables to do all of them simultaneously. We suggest one-hour long observation sessions at dawn and dusk. Observations should last until a total of 50 tamaraw groups, with or without calf, have been detected for the sample size to be meaningful. Recorded data consist in the time of observation, location and group composition split into calves, yearlings, adult females, adult males and unknown.

3.2.1.2. Sampling with camera traps

An alternative to direct observations of animals by humans consists in using camera traps to record observations of group composition of tamaraws. The most important when using camera traps is the sampling design for the data to be unbiased and relevant. A network of camera traps should be set based on a grid superimposed on the core area of presence of the species. The best would be a systematic location of camera traps at the centre of each grid cell depending on the number of available devices, but regular spacing is advised with a limited number of cameras at hands. Between 20 and 30 cameras would be suitable but without any prior experiment to assess the method, there is no warranty of collecting sufficient data once in place. The expected number of detected tamaraw groups is unknown, as well as the ability to record a sufficient number of photographs or videos suitable to describe the group composition in terms of males, females and calves. Like with the previous sampling design, a minimum of 50 described groups should be a reasonable goal.

Note that the costs-to-benefits ratio of this sampling method is unclear, so it is not necessarily better than having rangers making direct observations.

3.2.1.3. Computing the calf-to-cow ratio from field data

From field data, the calf-to-cow ratio, noted R_{cc}, is computed as follows:

$$R_{cc} = \frac{1}{k}\sum_{i=1}^{k} \frac{Nc}{Nf}$$

where N_{c} is the total number of calves in group k, and N_f the number of reproductive females in group k, hence sub-adult and adult female tamaraws. The index R_{cc} is the mean of group specific calf-to-cow ratio. We therefore assume that no calf is seen alone (division by zero) without at least one female. Note that adult males are not part of the calculus. Animal counts being not corrected for detection probability, R_{cc} is consequently not a robust measure of the reproductive success of tamaraw females, nor it is an absolute measure of population recruitment. **R_{cc} is an index of reproductive performance in the framework of ICEs** and as such, only its temporal variations (increase, decrease, stability), do make sense. A value of R_{cc} reading 0.5 does not mean that 50% of females do reproduce in the population, because the number of reproductive females is not known. The number of females in a group is a mixture of individuals with different reproductive status, some being barren because of a previous reproduction, too young to reproduce or simply not seen with a calf. Note that **if no calve is ever seen, then R_{cc} may be an empirical clue for a lack of reproduction in the population**. The correct interpretation is, however, **if R_{cc} shows a steady decline over 3 or 4 years, this should be interpreted as a warning sign that condition of tamaraws is decreasing**, for instance consecutive to food restriction because of high population density.

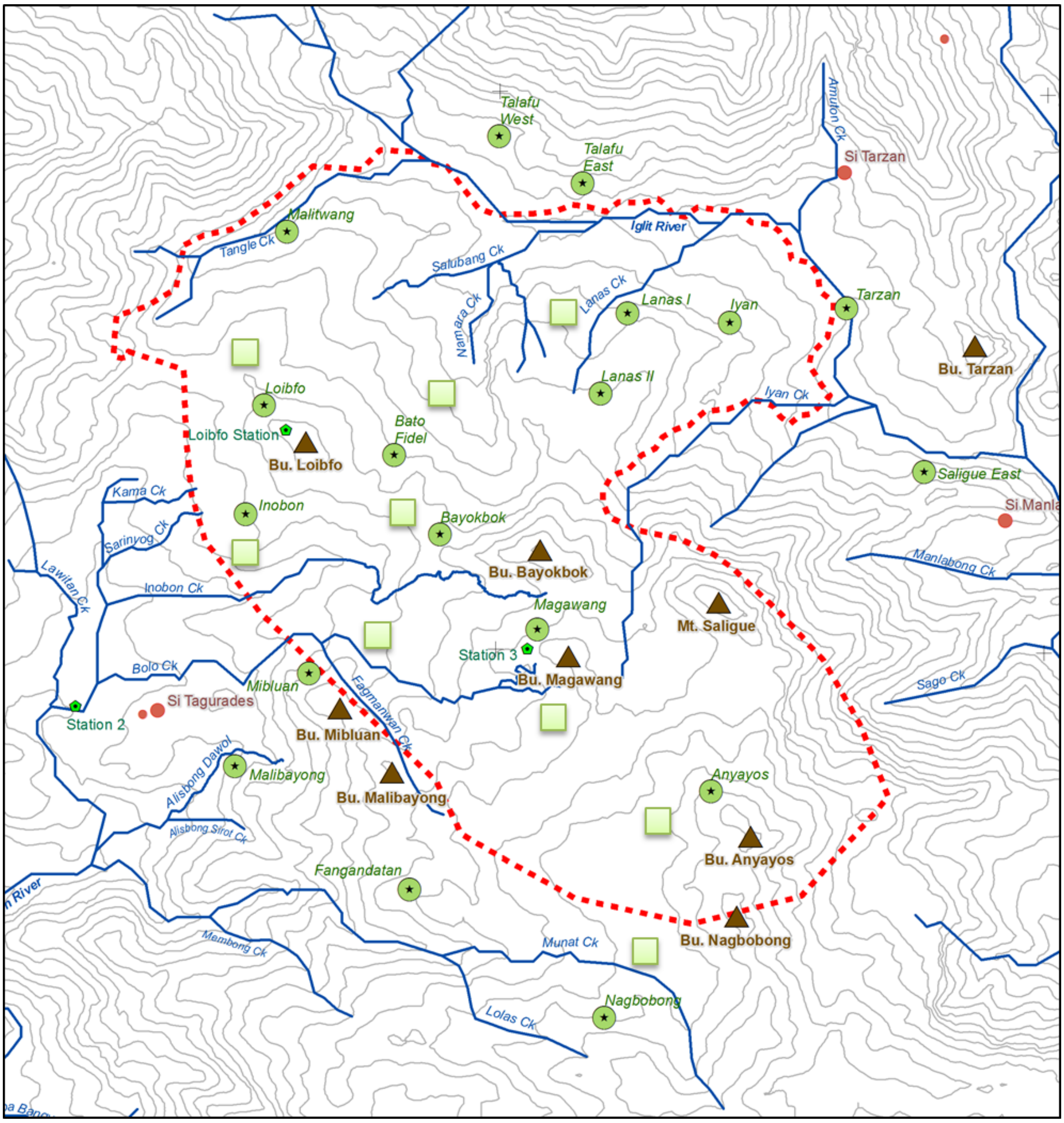

Fig.6. Map of the counting area with location of the parcels (burned of manually cut) for the direct visual observation option. In this case, 9 vantage points have been selected. For convenience, parcels are all located inside the Strict Protection Zone, in rather flat areas outside existing forests and not overlapping rivers and creeks.

3.2.1.4. Maintenance of habitat openness to carry the sampling designs

In the same way than the historical annual tamaraw counts, the use of the calf-to-cow ratio is conditional on the visibility of the tamaraws in the field and therefore shares the same practical limitations. When plant height and density are blocking the detection of animals by rangers or the camera trap, it will be no longer possible to properly estimate the calf-to-cow ratio. In the context of a progressive phase-out of the grassland burning, this concern becomes detrimental. Two options are envisioned to overcome this problem of visibility and improve the detection probability of tamaraws.

- <u>Controlled fire to maintain a network of open grassland parcels</u>

The two decades of annual tamaraw population count have provided experience in using fire inside the count area. Thus, it could be envisioned to use controlled fire, on limited scale, to maintain, yearlong, a network of areas across the count zone that would remain grassland habitat. As proposed, 7 to 10 locations from selected VPs could be used on that purpose. We consider that the size of the areas to be maintained open shall range between 1ha and 5ha; the most important being avoiding large heterogeneity of sizes between parcels.

These selected sites could be burned annually, between February and March, so as to enable the design proposed above. Fire breaks could be used in critical sites to prevent uncontrolled expansion of the burning, for instance by cutting grass around the targeted parcel on five meters width.

- <u>Manual cutting to maintain a network of open grassland parcels</u>

The same aim as above could be achieved by using manual cutting instead of fire. This option, though being more manpower demanding, reduces the risk linked to uncontrolled fire expansion. The experience of grassland cutting conducted at the landing area in the frame of the habitat restoration experiment using permaculture approach shows that this task is feasible and much faster than one would expect.

<u>Considerations and limitations</u>:

In both cases, we assume that maintaining open areas artificially and promoting regrowth of young grass, creates a behaviour bias to tamaraws. Unlike the annual count where most of the count zone is burned, creating only few of these areas could trigger competition to access these attractive spots of young grass shoot, especially if the operation is conducted at the peak of the dry season. For instance, we could expect an over representation of males or dominant adults. This phenomenon will not be integrated in the analysis but for one interested in temporal trends this index could be relevant still.

It is to be noted that in both cases, this regime of artificial intervention could be integrated into the "habitat restoration plan for the Strict Protection Zone and Tamaraw Safe Expansion Area" currently being elaborated. Furthermore, maintaining open areas could be part of a strategy to mitigate the expected decrease of carrying capacity in a context of expansion of forested habitats inside the Strict Protection Zone of the park, and the risk of detrimental effects such as vagrancy or further decrease of reproduction rate.

3.2.2. Pregnancy rate using biological samples on faeces

If the maintenance of habitat openness is not possible, an indirect way of obtaining the reproductive performance of female tamaraws can be achieved with a measure of pregnancy rate from faeces**. The pregnancy rate is highly relevant because it is an absolute measure of reproductive rate**. When reproductive rate is close to 0, it means recruitment will be low in anyway. On the contrary, if reproductive rate is high, close to 60% for large cattle species, females are in good enough body condition to engage into reproduction, the per capita food rate is good, and the population is more likely to grow (Bonenfant et al. 2009; Burthe et al. 2011). As of now, the capture of tamaraw to collect blood samples or for ultrasonography diagnostic of pregnancy (see roe deer at Chizé, France: Sempéré et al. 1989) or to measure body mass of yearling tamaraws, is no option. Once again, we are left with indirect sampling of animals in which case faeces have proven to be very useful (see Putman 1999 for a review).

The **immunoassay of Pregnancy Specific Protein B (PSPB)** or of progesterone is a reliable and easy way to test for pregnancy of cattle from biological samples (blood, Northtrop et al. 2019). Luckily, both hormones can be found in female faeces and its quantity estimated by immunoassay to assess the pregnancy status of females (Pereira et al. 2006, Cain et al. 2012, Burgess et al. 2012). Any modern biology lab can run PSPB immunoassays from commercial kits for cows and quickly return a pregnancy diagnosis. Quantitative measure of progesterone metabolites with ELISA kits maybe purchased to specialized companies like Arbo Assay (https://www.arborassays.com/product/progesterone-metabolites-eia-kit/), which offer online tutorials about how to proceed with the kits (https://www.youtube.com/watch?v=awkdPFs38m0). The minimum laboratory material needed to perform ELISA-based pregnancy tests is:

- a dryer
- pipes 5-10 ml
- precision scale (mg)
- centrifugal machine
- bench-top agitator
- eyedropper
- Spectrophotometer illuminating at 450 nm

A sample is declared to belong to a pregnant female if the estimated quantity of the hormone concentration falls above a given threshold. This threshold is known for domestic cattle, African buffalos, and a couple of deer species but is obviously unknown for the tamaraw. We can advise a threshold value of 150ng/g to establish pregnancy from a sample, which is the value found for pregnant female of swamp buffalo (*Bubalus bubalis*) (Lin et al. 1993). Yet, this value will need to be refined refine in the eventuality that some tamaraw could be captured to start a breeding centre in the frame of an *ex situ* conservation program.

A major advantage of the pregnancy rate as an index of performance is that data sampling and collection is less sensitive to observations conditions than the calf-cow-ratio. In the likely event of a burning phase out, sampling faeces is affected by visibility to a much lesser extent than the calf-cow-ratio method because it does not require seeing the tamaraws directly. For the same reason we suggest relying on the estimation of dung density to monitor tamaraw relative abundance, the implementation of a pregnancy rate index can be envisioned on the long run to monitor tamaraw phenotypic performance. The advice is to collect tamaraw faeces at the same time while dung transect are being conducted for the index of abundance. The number of collected dungs from MIBNP will depend on the financial investment of authorities into the tamaraw monitoring, but we advise to run immunoassays on ~100 samples to get meaningful results.

Computing the pregnancy rate from field data:

In practice, pregnancy rate P_r is obtained as follows:

$$P_r = N_+ / N_{tot} \times 100,$$

Where N_+ is the number of collected dungs with a positive pregnancy diagnostic, and N_{tot} the total number of dungs collected in the field. The statistical analyses of the temporal variation in pregnancy rates should ideally be performed with binomial regression that any statistical software will do (R, SPSS, SAS). A logit transformation of P_r ($logit(P_r) = ln(P_r / (100 \times (1 - P_r)))$) analysed with a regular regression in Excel could also do the job (Zuur et al 2007).

Consideration and limitations:

If, for the future of tamaraw monitoring, pregnancy rate appears as a good choice for an IEC of animal performance, we can already point out at a few limitations for this index. The main problem with the estimation of pregnancy rates from faeces is the mixture of male and female dungs during sampling. It seems very difficult to identify a dropping of female from a male tamaraw in the field without additional information (*e.g.,* direct observation). Obviously, we should expect rather low pregnancy rates from faeces samples unless we can assign the sex of the animal that produced the dung from DNA. DNA "sexing "of tamaraw dungs is very possible, but not without increasing running cost substantially. In the absence of sex assignment, it is no longer possible to interpret the pregnancy rate as an accurate measure of a demographic rate, but rather as a proxy of it. We could interpret this IEC as relative variations of female reproduction only but could not use it to guess the exact recruitment in the population. Indeed, juvenile survival is omitted despite it is the most variable demographic parameters of all (Gaillard et al. 2000). It means there are some risks of overlooking situations where females do give birth but fail to raise their offspring because of food limitation or disease for instance.

3.3. Index of impact on vegetation

The design of an appropriate index of tamaraw impact on vegetation would need some basic knowledge about its diet that is currently missing (but see Talbot and Talbot 1966). The following hence assumes that both deer and warty pigs have non-overlapping diet niches or that their respective densities are too low in comparison with tamaraws to interfere with tamaraws impacts on vegetation. The general idea is to compare similar areas with and without tamaraw grazing. The larger the difference, the stronger is the impact of tamaraws on the vegetation. All methods will hence involve some fencing of small areas inside the tamaraw range at MIBNP.

Field implementation:

If manual cutting of grass is implemented in the future for tamaraw observations, a simple protocol could be set at the same time. Squared boxes (1x1 m or more) made of iron mesh could serve as protection of re-growing plants against tamaraw consumption of grass (see Fig.7 for an illustration). Randomly placed right after cutting and thoroughly fixed into the ground, one can compare the average height of grass in time inside and outside of the protected areas. It is expected that grass growing inside the boxes will grow faster and taller than grass growing outside of the fences.

Protected and unprotected areas should be paired. Height measurement of grass for the unprotected area should be performed in a virtual square on the ground, attending the protective box and be of the same size. Height measurement is repeated 5 times per station for each of the protected and unprotected areas to estimate the mean growth. The operator should then calculate the difference in grass eight between inside and outside of the box for each station called $d_{i,t}$ (whereby *t* stands for year and *i* for the identifier of the station).

Fig. 7. Example of simple cattle exclosure to prevent grazing

Data processing:

The yearly index for the plant component is the average of the *n* station differences:

$$\overline{d}_t = \frac{1}{n}\sum_{i=1}^{n} d_{i,t}$$

The statistical analysis of *d* is a simple regression (to detect temporal trends) or *t*-test (to compare two years) and hence, does not require advanced statistical knowledge. Any statistical package or Excel can handle such analyses.

Obviously, as more tamaraws will feed on the attractive growing grass after cutting the difference between fenced and unfenced areas will become larger. An increase of the difference in grass growth between these should therefore be interpreted as a higher impact of tamaraws on the vegetation. Two possible interpretations of such an observation would be an increase of abundance or decrease in food resources.

4. Interpretation of the IEC

Taken one by one, IECs are not as informative as when interpreted all together – this approach should be taken as a package. IECs should be seen and used like a dashboard of a car, whereby each index informs on the key processes of the population dynamics, like the different levels are for the engine functioning. IECs only make sense in time; on one single year, there is not much to say about the status of a population. Although IECs were originally developed for the management of game species to set hunting quotas (Morellet et al. 2007), the concept makes perfect sense when applied to conservation. An abundance index can help assess the effectiveness of conservation policies, while the performance index can give insights on animal body condition and per capita food rate.

IECs should be used as a tool for adaptive management of a species (Holling 1978; Nichols et al. 2015). For example, if one future decision of MIBNP authorities is to stop burning grass with the consequences for tamaraws of a reduction in the carrying capacity of the environment, one should expect a decrease of the phenotypic performance index in the following years. If this prediction is supported by the IECs, it should trigger a rapid reaction from managing authorities to either allow tamaraws to disperse into other distant and safe areas, or to increase the carrying capacity by clearing openings in a less invasive ways than with fire. Generally speaking, if an action is taken, this should be reflected in the IECs. If the expected ecological responses are not observed, managers should try to understand why, or to set new actions until they reach their expected goals.

Figure 8 explains the principle of the IEC applied in the context of tamaraw at MIBNP.

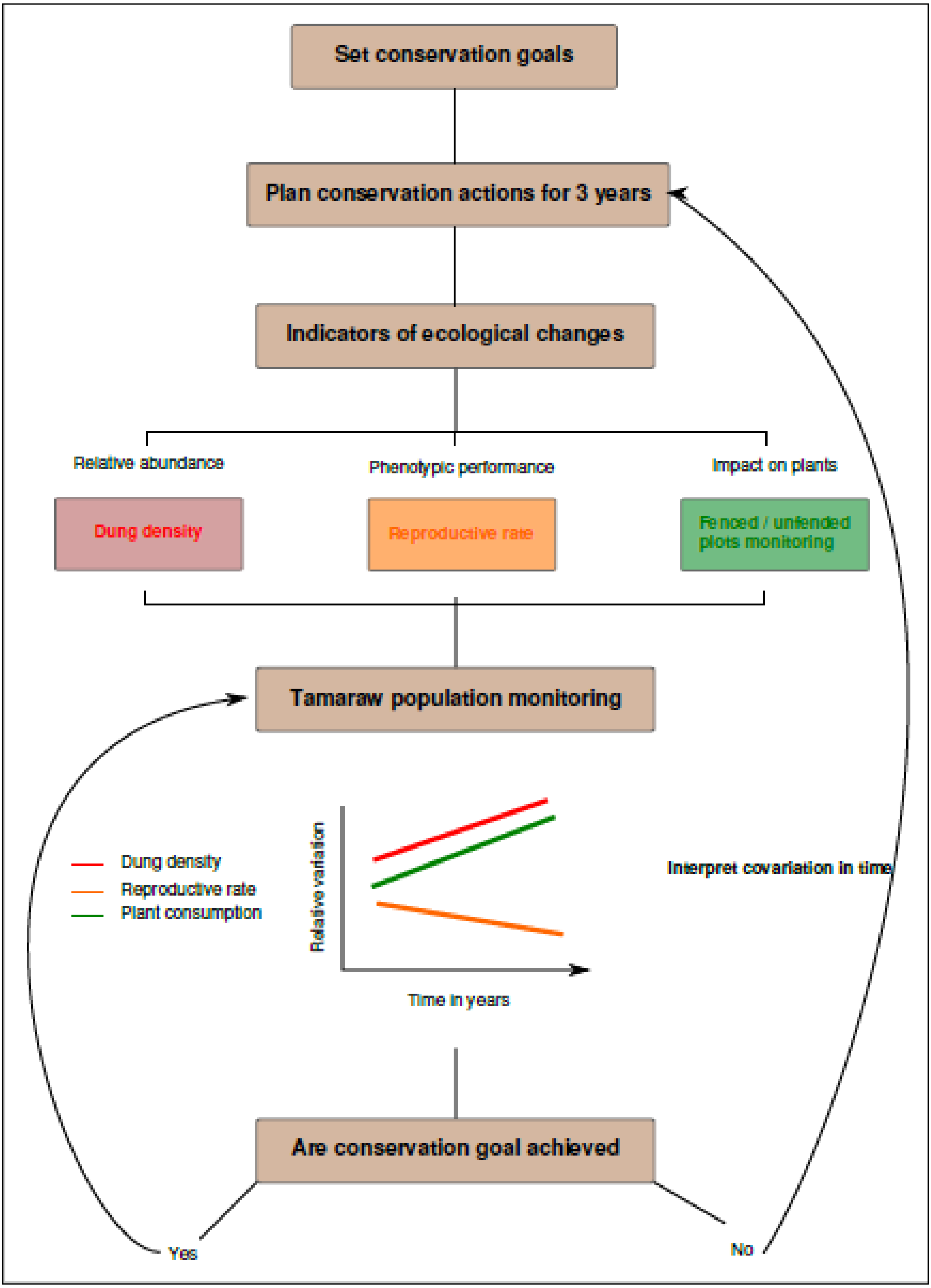

Fig.8. Application of the IEC concept to tamaraw at Mts Iglit-Baco Natural Park

5. Consideration on the selection of the IEC methods

Here we propose the IEC as a consistent and more modern way to monitor tamaraw population at MIBNP compared to census methods that do not provide a reliable number of animals. Nevertheless, and as mentioned earlier, selecting a population monitoring method is a difficult task and subject to several considerations, which falls under the decision of the authorities that will use and act according to the information collected.

5.1. Capabilities of the office in charge to mobilize manpower?

The first consideration lies in the capacity of the office in charge to carry out the method in the field. Several questions and parameters must be addressed before a method is selected:

- Will the staff implement the field work or will it be contracted to a different entity?
- In the first case, what are the skills of the staff in place and are they able to conduct the protocol? Do they need additional training on that purpose?
- Are there enough people available to conduct the selected method; otherwise is it possible to mobilize additional manpower?

5.2. Capabilities of local authorities /offices to conduct data post-processing

The second consideration and possibly the most crucial one refers to the data processing and associated statistical analyses to extract the final results after the field operations. The office in charge must evaluate if:

- It has the proper skills among its staff to run this phase of the operation?
- If not, is the office able to recruit an officer with the proper academic background to conduct the data post-processing?
- Otherwise, is the office able and eager to build a partnership with an academic institution or another entity to do this task, though, this must be a long-term commitment?

5.3. Cost of operation

Finally, the question of the financial costs of the operation shall be properly evaluated even more with the aim to conduct the selected methods on a regular basis. The office in charge shall be allocated and allocating the adequate budget on that purpose.

Appendix 1 summarizes, for each proposed method, all the parameters to be taken into consideration.

6. Conclusion - Recommendations

This document is not an exhaustive compilation of all the wildlife population monitoring methods available in the bibliography. The aim is to highlight and describe a few methods that we either consider relevant and feasible for tamaraw, that have been already experimented in the field, or that have been considered but not tested yet in MIBNP.

The main message is that any tamaraw population monitoring system in MIBNP should not be based on the concept of census that attempts to estimate the exact number of animals – this is, in practice, not attainable, and not needed for adaptive management. In this sense, the most important parameter to be considered is that the new approach is reliable and repeatable to enable managers to obtain trends over time in tamaraw abundance and population dynamic. This trend will then inform on the health status of the population and subsequently on the best manner to react.

For these reasons, we are proposing here the Index of Ecological Changes (IECs) as a suitable and sustainable tool to monitor and manage the tamaraw population at MIBNP. It will inform managers not only on the abundance of the species over time, but will also provide insight on how to interpret this information within the contest of other considerations. IECs will enable managers to build adaptive response and management solutions which are in lines with the objective set in the TCMAP.

Next steps:

We propose here few steps that could be undertaken following the submission of this document to the Philippine authorities:

(a) Presentation and selection phase:

- o Face to face meetings of DAF and its partners with the concerned authorities and other stakeholders to present the different options in a summarized and more visual/friendly manner;
- o Open forum or remote exchanges to respond to questions and concerns;
- o One or several workshops with the concerned authorities and the offices in charge of implementing the tamaraw monitoring to discuss the pro and cons of each option, validate the selection of one IEC package and explore the steps required for future implementation

(b) Preparation and implementation:

If the selected IEC package requires further technical support, DAF and its partners could be contracted to assist in this phase. This could include:

- o Build and finalize field protocols
- o Training of staff and/or students in the different protocols

- Mentoring of technical staff or partner academe to the post data processing and analysis
- Conduct field test of methods if those were not yet employed at MIBNP
- Coaching offices in analysing results of the IEC

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APPENDIX

The table below summarizes all the options, details of implementation and pro and cons.

Index	Method	Option and protocol	Information expected	man-power (per team)*	Equipment	Field implementation	Duration of field work	Data processing	Data accuracy	Costs	Limitations	Ranking choice (0-5)
Index of population abundance	**Distance sampling and derivatives**	Distance sampling of dungs with double observer on transects	Density of dungs and probability of detection from transect and observers	5 to 8 people	GPS, data sheet, measuring tape	Once or twice a year	6 to 12 days	Advanced statistical skills	Very good	Field costs only (+ cost of data processing if contracted)	Need advance modelling and statistical skills to extract and interpret all data	4
		Standard distance sampling (single observer) of dungs on transect	Density of dungs and probability of detection from transect	4 to 6 people	GPS, data sheet, measuring tape	Once or twice a year	6 to 12 days	Advanced statistical skills	Good	Field costs only (+ cost of data processing if contracted)	Bias low the density of dungs	3
		Simple double observer of dungs on transects	Density of dungs and probability of detection of observers	4 to 7 people	Data sheet (GPS)	Once or twice a year	5 to 10 days	Moderate statistical skills	Good	Field costs only (+ cost of data processing if contracted)	Bias low the density of dungs	5
		Simple dung counts on transects	Number of dungs per distance unit	2 to 4 people	Data sheet (GPS)	Once or twice a year	4 to 8 days	Basic statistical skills (formula)	Moderat e	Field costs only	Prone to errors of interpretation and changes in habitats	2

	Camera trap	Occupancy modelling on grid cells or on microhabitats	Probability of tamaraw presence	2 to 4 people	Data sheet, GPS; number of camera trap to be defined but > 50	One per year, 3 months activity	One deployment (6-8 days) and one retrieval (3-6 days)	Advanced statistical or modelling skills; or use of software	To be tested	200-500 USD/ item + ID cards + batteries + chargers + field costs	Tamaraw not identifiable individually from pictures limiting performance of this method	1
	Drone	To be tested	relative density of tamaraws without probability of animal detection	to be evaluate d	Drone + sensor (camera)	To be tested	to be tested	Advanced statistical skills; need of AI model	To be tested	Costs of testing phase with expert then cost of device (USD1500 for drone + USD 1000+ for sensor + SD card + batteries) and operator+ data processing officer	Has never been tested for tamaraw and in context of MIBNP; no positive feedback from literature at the moment on such terrain and species	0
	Genetic	Non-invasive estimates of abundance (DNA) through dung samples + CRM technic	population size and probability of animal detection	2 to 3 people	Buffer solution in tubes + data sheets + GPS	During distance sampling	5-12 days + lab phase	Need lab and bio-informatics	Good	USD 20,000 for lab phase + field work + transportatio n to lab + storage	Permits needed. Costs for laboratory phase	2
Index of phenotypic performance	**Calf to cow ratio**	Direct visual sightings with controlled fire	Proportion of females with calf	1 to 3	Binoculars, data sheet	Once or twice a year	3 to 10 days + burning phase	Basic statistical skills (formula)	Good	Field work only including burning phase	Behaviour bias of the habitat intervention + risk of uncontrolled fire	2

		Direct visual sightings with manual cutting of grass	Proportion of females with calf	1 to 3	Binoculars, data sheet	Once or twice a year	3 to 10 days + cutting phase		Good	Field work only including cutting phase	Behaviour bias of the habitat intervention + additional manpower for cutting	4
		Camera trap	Proportion of females with calf	2-4 people	20-30 camera traps, data sheet, GPS	Occupancy survey design ones a year	One deployment (6-8 days) and one retrieval (3-6 days)	Basic statistical skills	Good	200-500 USD/ item + ID cards + batteries + chargers + field cost	Visibility in vegetation and/or behaviour bias if micro-habitat position selected	3
	Pregnancy rate	Immunoassay of hormones from dungs to estimate pregnancy rates	Proportion of pregnant females	1 to 3	data sheet, tubes and mini lab kit	during distance sampling	5 to 12 days	Basic statistical skills	Good	Lab kit + field work	Male and female dungs not distinguishable without additional genetic information, limited interpretation	3
Index of impact on vegetation	**Grazing vs non grazing comparison**	Network of grazing exclosures	Height of grass difference to measure tamaraw consumption of grass	2-4 people	Fencing mesh, measuring tape, data sheet, GPS	X exclsures with regular monitoring of grass height	6-8 days	Basic statistical skills (formula)	Good	Fencing mesh, field work	Diet of tamaraw not yet fully described, limiting power of the method	4