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BULLetin

Newsletter of the IUCN/SSC Asian Wild Cattle Specialist Group

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BULLetin

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Camera trapped banteng, Cambodia © Caleb Jones FFI/ACCB

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AWCSG Asian Wild Cattle Specialist Group

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Note from the Chair

James Burton

Chair, IUCN SSC Asian Wild Cattle Specialist Group

I am pleased to share with you the first edition of the new IUCN SSC Asian Wild Cattle Specialist Group's (AWCSG) newsletter; the BULLetin! The aim of this newsletter is to present novel research and share Asian wild cattle conservation activities, to inform the Asian wild cattle conservation community.

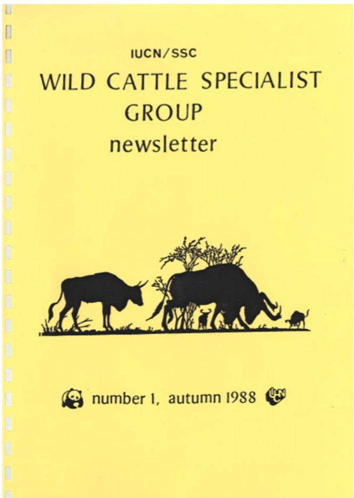
The AWCSG is a global group of conservationists dedicated to promoting the long-term conservation of Asian wild cattle species and their habitats by means of information-sharing, identification of conservation priorities and facilitation/delivery of these priority actions through collaborative conservation work. For more information about the group, please take a look at our website (www.asianwildcattle.org) and social media (Facebook: IUCN Asian Wild Cattle Specialist Group, Twitter: @IUCN_WildCattle, Instagram: @iucn_wildcattle)

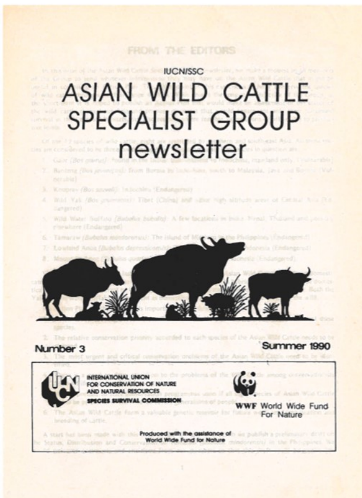
The first edition of the AWCSG newsletter was published in 1988 by Prof. Vo Quy and Dr Charles Santiapillai with the last edition coming out in December 1994. Since then the group has grown and evolved to address the growing challenges for Asian wild cattle. We plan that this and future newsletters will continue to inform and inspire those that work to preserve these species.

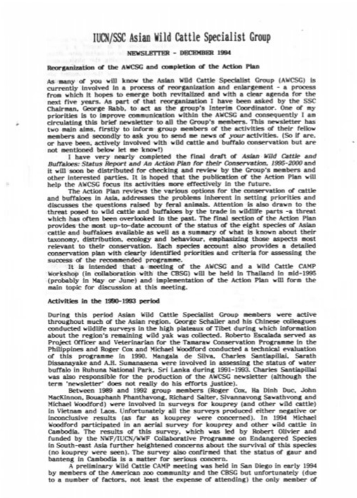
We are keen to hear from you if you would like to contribute to the newsletter, whether that is writing an article or providing a short update. Please get in touch via social media or contact the editor (Stuart Young; s.young@chesterzoo.org). We plan to produce two editions of the newsletter per year.

The AWCSG applies the One Plan Approach to conservation that integrates *in situ* conservation and conservation breeding (*ex situ,* as an insurance population) into a single programme, where appropriate. We will therefore include articles and news from both the field and zoos. In this edition we share with you a review of the *in situ* status of tamaraw in Mindoro, Philippines, as well as an article on banteng behaviour to help improve captive management.

I would like to use this opportunity to thank our major sponsors Chester Zoo, Global Wildlife Conservation, the Center for Conservation of Tropical Ungulates and San Diego Global. We would not be able to do much without their support. We also very much appreciate partnerships and activities by all supporters of the specialist group.







IUCN/SSC Asian Wild Cattle Specialist Group

NEWSLETTER - DECEMBER 1994

Reorganization of the AWCSG and completion of the Action Plan

As many of you will know the Asian Wild Cattle Specialist Group (AWCSG) is currently involved in a process of reorganization and enlargement - a process from which it hopes to emerge both revitalized and with a clear agenda for the next five years. As part of that reorganization I have been asked by the SSC Chairman, George Rabb, to act as the group's Interim Coordinator. One of my priorities is to improve communication within the AWCSG and consequently I am circulating this brief newsletter to all the Group's members. This newsletter has two main aims, firstly to inform group members of the activities of their fellow members and secondly to ask you to send me news of *your* activities. (So if are, or have been, actively involved with wild cattle and buffalo conservation but are not mentioned below let me know!)

I have very nearly completed the final draft of *Asian Wild Cattle and Buffaloes: Status Report and An Action Plan for their Conservation, 1995-2000* and it will soon be distributed for checking and review by the Group's members and other interested parties. It is hoped that the publication of the Action Plan will help the AWCSG focus its activities more effectively in the future.

The Action Plan reviews the various options for the conservation of cattle and buffaloes in Asia, addresses the problems inherent in setting priorities and discusses the questions raised by feral animals. Attention is also drawn to the threat posed to wild cattle and buffaloes by the trade in wildlife parts -a threat which has often been overlooked in the past. The final section of the Action Plan provides the most up-to-date account of the status of the eight species of Asian cattle and buffaloes available as well as a summary of what is known about their taxonomy, distribution, ecology and behaviour, emphasizing those aspects most relevant to their conservation. Each species account also provides a detailed conservation plan with clearly identified priorities and criteria for assessing the success of the recommended programme.

It is intended that a meeting of the AWCSG and a Wild Cattle CAMP Workshop (in collaboration with the CBSG) will be held in Thailand in mid-1995 (probably in May or June) and implementation of the Action Plan will form the main topic for discussion at this meeting.

Activities in the 1990-1993 period

During this period Asian Wild Cattle Specialist Group members were active throughout much of the Asian region. George Schaller and his Chinese colleagues conducted wildlife surveys in the high plateaux of Tibet during which information about the region's remaining wild yak was collected. Roberto Escalada served as Project Officer and Veterinarian for the Tamaraw Conservation Programme in the Philippines and Roger Cox and Michael Woodford conducted a technical evaluation of this programme in 1990. Mangala de Silva, Charles Santiapillai, Sarath Dissanayake and A.H. Sumanasena were involved in assessing the status of water buffalo in Ruhuna National Park, Sri Lanka during 1991-1993. Charles Santiapillai was also responsible for the production of the AWCSG newsletter (although the term 'newsletter' does not really do his efforts justice).

Between 1989 and 1992 group members (Roger Cox, Ha Dinh Duc, John MacKinnon, Bouaphanh Phanthavong, Richard Salter, Sivannavong Sawathvong and Michael Woodford) were involved in surveys for kouprey (and other wild cattle) in Vietnam and Laos. Unfortunately all the surveys produced either negative or inconclusive results (as far as kouprey were concerned). In 1994 Michael Woodford participated in an aerial survey for kouprey and other wild cattle in Cambodia. The results of this survey, which was led by Robert Olivier and funded by the NWF/IUCN/WWF Collaborative Programme on Endangered Species in South-east Asia further heightened concerns about the survival of this species (no kouprey were seen). The survey also confirmed that the status of gaur and banteng in Cambodia is a matter for serious concern.

A preliminary Wild Cattle CAMP meeting was held in San Diego in early 1994 by members of the American zoo community and the CBSG but unfortunately (due to a number of factors, not least the expense of attending) the only member of

News

Successful Banteng Transfers

Ellen Marandola

Field Programmes Intern, Chester Zoo

The Action Indonesia Global Species Management Plans (GSMPs) manage two threatened Indonesian wild cattle taxa; anoa (*Bubalus depressicornis* and *B. quarlesi)* and banteng (Bos javanicus), as well as the pig taxon babirusa (*Babyrousa sp.*). Since their founding in 2015 by the Indonesian Zoo and Aquarium Association (PKBSI), the Association of Zoos and Aquariums (AZA), the European Association of Zoos and Aquaria (EAZA), IUCN Species Survival Commission and the Wild Cattle and Wild Pig Specialist Groups, the GSMPs have created a strong network of over 50 partner organisations. By drawing on the expertise of these partners, the GSMPs have been able follow the One Plan Approach, bringing together both in situ and ex situ conservationists.

In 2017, the first breeding and transfer recommendations were made by the GSMPs using studbook analysis to match animals whose offspring would best maintain or increase genetic diversity within captive populations. These were then approved by PKBSI and the Indonesian Ministry of Environment and Forestry. Following the recommendations, three banteng bulls were moved between three Taman Safari Indonesia (TSI) zoological collections and Baluran National Park in July 2018, in journeys that included two sea crossings. Then, in August 2018, anoa were moved between TSI Bogor and Bali Safari & Marine Park. These moves were made easier by skills learned during GSMP husbandry workshops, which included training banteng bulls to enter transportation crates.

These moves represent major milestones for both the GSMPs and for Indonesian zoos, as this is the first time transfers have been undertaken for the purpose of co-operative breeding. The first breeding recommendations also resulted in the births of several calves, helping populations get closer to the GSMPs' targets of 100 banteng and anoa each in Indonesian zoos without compromising genetic diversity. It is hoped that births resulting from the transfers will help further approach the set targets. These calves, along with the continued co-operation between Indonesian zoos allowing future transfers, will help achieve the GSMPs' goals of creating and maintaining viable ex situ populations of these species.

For more information about the Action Indonesia GSMPs, please see the Action Indonesia newsletter (available at www.asianwildcattle.org), or contact us.

Photo credit: Ivan Chandra/TSI

News

Sabah Banteng Action Plan

Penny Gardner
Banteng Conservation Officer, Danau Girang Field Centre

On the 20th September 2018, the first Action Plan for Borneo banteng was soft-launched at the Hilton Hotel in Kota Kinabalu, Sabah (Malaysia), by the Sabah Tourism, Culture and Environment Minister Christina Liew. The action plan is the culmination of extensive field research on the species conducted across the Malaysian state of Sabah over the years 2011-2016 by the Danau Girang Field Centre (Cardiff University) in affiliation with the Sabah Wildlife Department and Sabah Forestry Department. This research aimed to identify accurate survey methods of banteng in order to collect robust parameters on a variety of ecological and life history measures (see box).

Using biological parameters from this research and from the literature, the first Population and Habitat Viability Assessment (PHVA) for Borneo banteng was conducted late last year and underpins the recommendations set out by the Banteng Action Plan. Four geographically-distinct management units are proposed as a method for managing the population, in addition to increased effectiveness of anti-poaching and enforcement, *in situ* captive breeding and continued monitoring over the next 10 years. The Banteng Action Plan requires a cabinet paper to be tabled to the Sabah state administration in order for it to be officially endorsed and to commence implementation of conservation measures.

Research

The research conducted aimed to help in the collection of parameters including; distribution across the landscape, population size, herd demography, sexual segregation and breeding occurrence, body condition scores, behaviours and use of the habitat in response to logging, their genetic diversity and ancestral lineage, and the suitable habitat that remains within Sabah for conservation planning.

Photo credit: Yayasan Sime Darby

News

The Saola Working Group: Embracing the One Plan Approach to conservation in the Annamite Mountains

Olivia Petre
Head of Operations, Saola Working Group

The saola (*Pseudoryx ngethinhensis*) is one of the rarest large animals on earth, found only in the Annamite Mountains of Laos and Vietnam. The Saola Working Group (SWG), which is part of the Asian Wild Cattle Specialist Group, was formed in 2006 in recognition of the need for urgent, coordinated action to save the saola from extinction. In addition to being the main driver of saola conservation in Laos and Vietnam, the SWG advocates for conservation of the globally significant Annamite Mountains as a whole. The SWG is not a standalone organization, but a collaborative partnership made up mainly of volunteers. However, given the recent growth and increased demands of the SWG, several new paid members of staff have been employed.

Photo credit: Terry Hornsey

The SWG embraces the IUCN One Plan Approach to the conservation of saola, integrating captive breeding as a guard against extinction and for future re-introduction with the conservation of animals in the wild. A Memorandum of Understanding between IUCN, on behalf of the SWG, and the Vietnam government, allowing the construction of an 'Annamites Endangered Ungulate Conservation Centre' in Bach Ma National Park, and the capture of saola and large-antlered muntjac for the centre, has just been signed. This will allow activities to move forward in Vietnam.

An MoU is also under preparation for activities in Laos, between IUCN and the Lao government, for an expanded saola conservation program in that country. In the meantime, given the importance and urgency of the situation for saola conservation, work has been moving forward in both Vietnam and Laos through the SWG's strong collaborations with conservation partners on the ground there. This has allowed the SWG to carry out surveys to detect saola, which will aid in knowing where to focus protection efforts, and where to direct eventual capture attempts.

This detection and *in situ* protection work, through SWG's in-country partners (e.g., WCS, WWF, Lao Wildlife Conservation Association Vinh University), has allowed over 400 camera traps to be placed in three key sites in Laos and one in Vietnam (126 in Pu Mat). In one site, the initial findings have been remarkable - no saola yet, but the first check of 100 camera traps showed that 69 had detected the Critically Endangered large-antlered muntjac. SWG is also supporting patrol teams giving technical oversight and training, including in the collection of dung samples for saola DNA analysis (in collaboration with Vinh University in Vietnam). SWG is also using eDNA samples as a detection tool (working with Project Anoulak in Nakai-Nam Theun). The patrol teams are removing large numbers of snares in key areas; in a recent mission, for example, more than 200 snares were removed from the site in XeKong where camera traps are located. Village interview surveys have been carried out in Bolikhamxay, with promising results in three sites, which will be followed up with detection surveys including camera traps and dung collection for DNA analysis. Three interview surveys have also been conducted around Pu Mat National Park. An additional component of the work that is being developed is research exploring the use of local hunters and hunting dogs as a potential capture method for saola.

To find out more, and read the recent annual reports, please visit the Saola Working Group website:
www.savethesaola.com

Research Article

Activity patterns and social network of banteng (*Bos javanicus*) at Chester Zoo

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Abstract

Many species of wild cattle are now listed as endangered on the IUCN red list. These species are commonly kept in zoological collections, aiding their conservation through viable *ex situ* populations and increasing the understanding of effective species management. However, wild cattle are often underrepresented in zoo animal behaviour research. The aim of this study is to add to this research area using banteng (*Bos javanicus*) as a focal species. Behavioural data was collected using focal and group instantaneous sampling of a herd of thirteen banteng at Chester Zoo. Results revealed that banteng spent the most time resting and eating, with juvenile animals spending more time conducting exploratory and locomotive behaviours than adult and sub-adult animals, which corresponds to patterns in wild populations. To fully explore how similar the patterns are further research is needed into nocturnal behaviour as wild banteng are thought to be more active during the night. A social network analysis of the positive social interactions within the herd revealed that the bull received the most positive interactions, which is typical in a wild herd. Other positive interactions were observed with mothers preferentially associating with their offspring. Very few negative interactions were observed within the herd revealing that competition for resources is low. This study adds to the limited knowledge of banteng behaviour but a greater sample using data from other collections could be used to provide a more thorough basis for their behaviours in captivity.

Introduction

Asia is the richest region in terms of wild cattle species; 9 of the 12 extant species are found on this continent, but there is little tradition of effectively managed protected areas, demanding a need for appropriate conservation and management measures (Mellitti & Burton, 2014). Increasing human populations have encroached upon wild cattle habitat and all species are threatened by human activities; hunting and urban development being two of the most common and potentially severe threats (Pedrono & Clausen, 2009). Many species of wild cattle are now listed as endangered on the IUCN red list of threatened species (IUCN, 2010). Steps can be taken to prevent the loss of these species; including increasing the effectiveness of protected-area management, and involving local people in conservation activities (Melletti & Burton, 2014). Conservation breeding of these species is also a key part of their conservation; by ensuring viable ex-situ populations and increasing the understanding of effective species management provides a framework for in-situ efforts to protect wild cattle species (McGowan *et al.,* 2017).

Role of zoos in wild cattle conservation

The conservation of wild cattle species is often a challenge due to limited knowledge as a consequence of their behaviour; being naturally wide-ranging, nocturnal, shy, solitary or occurring in low densities (Gray, 2012). There is immense potential value of zoo-derived data for helping to understand how taxon, ecological niche, breeding success, and captive environments together affect animals' responses to captivity

(Mason *et al.,* 2007). Empirical measures of animal behaviour and space use within the captive environment can provide important information about animals' requirements, preferences and internal states, which can then be implemented in ex-situ conservation projects (Ross *et al*., 2009). Ungulates are often underrepresented in zoo animal behaviour and welfare research, yet they comprise some of the most widely-kept captive species and as such, their lives within the zoo are worthy of closer investigation (Rose & Robert, 2013). The aim of this study is to add to the understudied research area of wild cattle behaviour ex-situ, using banteng (*Bos javanicus*) as a focal species.

Behaviour of cattle

Although little behavioural research exists for wild cattle species, other species of cattle, including domestic cattle have been studied more intensively (Melletti & Burton, 2014). The behaviours observed in other cattle species can potentially provide a basis for wild cattle behaviour. As ruminants, grazing occupies a large amount of time in cattle species, approximately 8-9 hours per day, and the pattern of grazing behaviour is relatively similar for each herd member (Sato, 1982). Rumination most often occurs during resting and is roughly three-quarters of the time spent grazing (5-6 hours per day) (Sato, 1982; Clauss & Hoffman, 2014). As many cattle species typically exist in large, mixed herds, social behaviours are an important aspect of their lives (Bouissou *et al.,* 2001). Social interactions can be divided into negative (such as aggressive and avoidance reactions) and positive social behaviour (including social grooming, olfactory communication and minimal social distance) (Bouissou *et al.,* 2001). Recognising the difference between normal, healthy and aggressive or stereotypic cattle behaviour and applying this knowledge to wild cattle species can be used to develop better husbandry practices and contribute to improving the standard of ex-situ conservation programmes with Asian wild cattle.

Banteng ecology and behaviour

Banteng naturally inhabit open dry deciduous, mixed deciduous or evergreen forest, preferably in low elevation zones. Optimal banteng habitat includes open grassy areas with access to water and mineral licks (AWCSG, 2015). Banteng play a key role in circulating nutrients through ecosystems, dispersing seeds and maintaining food chains as they are also a critical food source for many carnivore species, including tigers and leopards (AWCSG, 2015). It is estimated that there could be as few as 5,000 banteng left in the wild, with their numbers in decline due to reduction of habitat, hunting, hybridisation with domesticated cattle, and infections with cattle diseases (Timmins *et al.,* 2008). Attempts to conserve this species include translocation and captive breeding programmes (Bradshaw *et al.,* 2006). Despite their elevated conservation status, and an increasing global captive population, zoos do not yet have information on optimal husbandry (Rowden & Rose, 2016). Banteng are an example of a species of conservation concern without current "best practice" guidelines, as they have been the focus of little applied husbandry research (Rowden & Rose, 2016). This study, therefore aims to increase our understanding of Banteng behaviour in captivity using a heard at Chester Zoo, UK. Chester Zoo has been a leader in the conservation and breeding of endangered Asian wild cattle. The opening of the *Islands* exhibit in 2015 aimed to provide even greater capacity to achieve the highest standards in breeding and education, as well as profile the Zoo's in-situ activities with these species (Chester Zoo, 2017).

Figure 1. Female banteng (*Bos javanicus*) with two calves at Chester Zoo (image: © Chester Zoo).

In 2017, Chester Zoo was home to a herd of 13 banteng, herd sizes in captivity tend to be smaller than those observed in the wild, where they can live in groups of up to 30 (Rowden & Rose, 2016). Since arriving at the zoo in 2013, the herd at Chester Zoo has had a number of calves born, demonstrating the success of the breeding programme and helping to raise the profile of this species in captivity. Despite these successes, overall cattle species are still generally overlooked in zoo settings as they are not deemed an 'exciting' species by visitors (Hediger, 2013).

The aim of this study is to add to the body of knowledge on captive banteng behaviour, investigating the animals' activity patterns with a particular focus on social behaviour within the herd.

Materials and Methods

Data was collected over 50 hours (5 hours per individual) over a period of 14 weeks from mid-March 2017 until the end of June 2017. The observations were carried out for hour-long periods and were conducted between 10am and 5.30pm.

Study species

The group of banteng consisted of 13 individuals (fig. 1), one adult bull male (11 years), five adult female cows (ranging between 3-7 years), two sub-adults (one male, one female, both aged two), two juveniles (one male, one female both aged one) and three calves. All banteng were individually identifiable from ear tags, excluding the three youngest calves. Focal data was not collected for the three youngest calves, as they were unable to be individually identified. However, any social behaviour towards a calf initiated by another herd member was recorded.

Sampling methods

There is little published literature on banteng behaviour, particularly in captivity, so an ethogram of 30 defined behaviours was developed based on previous studies carried out on similar species e.g. Kilgour (2012) and Fell & Clarke (1993) (Table 1). A mixture of instantaneous group sampling and instantaneous focal sampling were used to gather behavioural data at both an individual and group level for the banteng. Instantaneous group samples were recorded for the banteng at 5-minute intervals whereas instantaneous focal samples were collected at a 30 second interval rate, where each individual was observed in turn following an order that was generated randomly. The observations were carried out from the same location for every session (the visitor viewing area) which provided a good view of the entire enclosure. The only area of the enclosures not visible from these viewing platforms was the indoor area so when the focal individuals were indoors at the point of observation, they were recorded as out of sight. The frequency of social behaviours was also recorded. For any social interactions that were observed, the focal individual and the recipient of the social behaviour were recorded based on the behaviours defined in the ethogram.

Data Analysis

The 'Type of Behaviour' category from the ethogram was used for descriptive analysis. Behaviours under 'Positive Social' and 'Negative Social' were combined to 'Social' as very few negative interactions were observed. No procreative behaviours were observed during the study. Instantaneous behavioural data was converted into proportion per observation session for analysis. Social network analysis was conducted using R-Studio 1.0.136 using the number of positive social interactions observed between individuals.

Table 1. Ethogram of behaviours of banteng based on Kilgour (2012) and Fell & Clarke (1993)

Type of Behaviour	Behaviour	Description of Behaviour
Exploratory	Browse	The animal forages around the enclosure, sniffing at the ground often in search of food.
Eating	Graze	The animal browses and eats food from the ground.
	Eat	The animal eats food prepared in food areas of the enclosure.
Ruminating	Ruminate	The animal is re-chewing cud, a common behaviour in cattle species.
Drinking	Drink	The animal drinks water.
Maintenance	Groom	The animal licks its own body.
	Excretion	The animal urinates or defecates.
Resting	Sleep	The animal is asleep and is not alert to environmental changes.
	Rest	The animal is standing but is not making any specific movements in any particular direction.
	Sit	The animal is sitting or lying and not making any particular movement.
Locomotive	Walk	The animal is moving in no particular direction at a slow to moderate pace.
	Run	The animal is moving in no particular direction at a moderate to quick pace.
	Orientation towards stimuli	The animal moves in a specific direction towards a stimulus, such as food.
Self Expression	Vocalise	The animal makes an auditable sound.
	Head Roll	The animal Rolls its head backwards in a circular motion.
	Paw ground with forefoot	The animal taps or rubs its hoof against the ground.
	Tail Wag	The animal flicks its tail in a deliberate manner, often to swat away insects.
	Perform flehmen	The animal curls back its upper lip exposing its front teeth, inhales with the nostrils usually closed and holds this position for several seconds.
	Startle Reflex	The animal reacts in an erratic manner to a stimulus such as a sudden noise ore another individual.
Positive Social	Sniff	The animal sniffs another individual in the heard.
	Approach	The animal moves towards another heard member or members.
	Guard	The animal stands protectively between one individual and another.
	Rub against another animal	The animal rubs its own body against another individual in the herd.
	Social grooming	The animal licks another individual or solicites licking by another animal in the herd.
	Suckling	The animal suckles or the mother stands to allow the young to suckle.
	Mount	The animal mounts another individual in the herd or allows another individual to mount them.
Negative Social	Withdraw	The animal moves away from another herd member or members.
	Agnostic Actions	The animal engages in agnostic or aggressive behaviour, such as head-butting, charging at or locking horns with another herd member.
Procreative	Inseminate	A male in the group attempts to breed with a female in the herd.
	Gives Birth	A female in the herd gives birth to a calf.

Results

The most common behaviour observed by all the banteng in the heard was resting (fig. 2), with all individuals spending approximately 60% of the time exhibiting this behaviour. The second most observed behaviour was eating, with the adult females (21%) and sub adult (23%) animals spending the most time eating, and juveniles spending the least (10%). The largest differences were observed in the more active behaviours with juvenile animals spending more time exploring (13%) and in locomotion (5%) than other heard members. Adult animals spent more time ruminating (7%-10%) than the sub-adults (2%) and juveniles (3%).

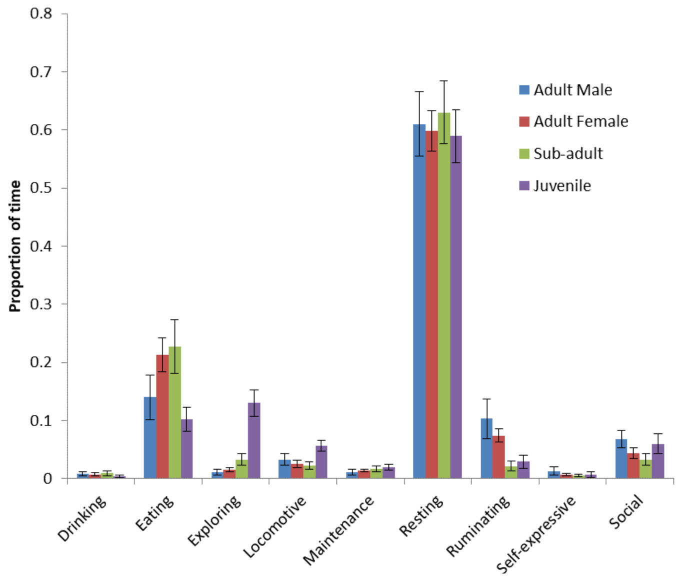

Figure 2. The mean (± standard error) proportion of time banteng (N=10) were observed exhibiting different behaviours according to age group and sex of adult animals.

Banteng spent between 4-6% of their time engaging in social behaviour. Positive interactions were seen regularly between heard members (fig. 3), many of the positive interactions were directed towards the dominant bull (adult 1 male) with his position towards the centre of the network. The dominant bull and many adult females directed positive interactions to adult female 3, suggesting she is one of the higher ranking females in the group. Adult female 5 also received positive interactions from many herd members. The mothers of the three calves (combined values were used for the calves as they were unable to be individually identified) have strong positive interactions with their offspring (adult females 2, 5 and 6). This bond appears to continue into later life with the two juveniles both having strong positive interactions with their mothers (adult female 3 and juvenile 2, and adult female 4 and juvenile 1). The two sub-adult animals and adult female 6 were the ones who received fewest positive interactions.

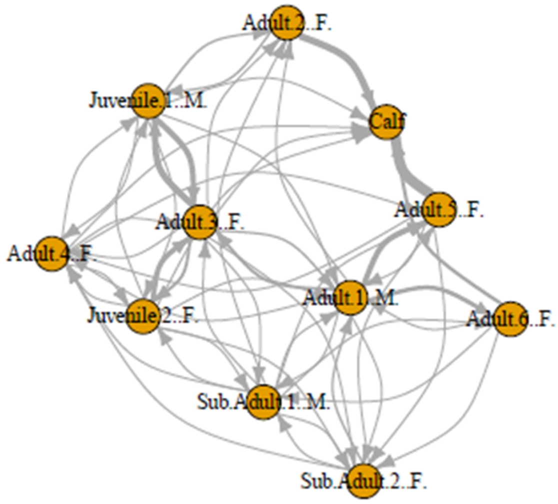

Figure 3. A social network analysis for banteng at Chester Zoo using positive social interactions

Discussion

This study investigated the activity patterns and social interactions of a herd of banteng at Chester Zoo. The most common behaviours observed in all individuals were resting and grazing. This corresponds to activity patterns in wild populations where banteng activity has been found to decrease from mid-morning until early afternoon, when they tend rest and ruminate (Melletti & Burton, 2014). When peaks in activity occur, they often forage and socialise (Gardner 2016). Juvenile animal activity patterns were most different from the adults with more time spent exploring and moving around their enclosure they often forage and socialise (Gardner 2016). Juvenile animal activity patterns were most different from the adults with more time spent exploring and moving around their enclosure and less time eating and ruminating. This is likely due to the difference in age with young animals potentially still feeding on milk, as banteng calves wean around 10 months of age

(Saari, 2004), potentially leaving more time for other activities. This study focused on the diurnal behaviour of banteng during zoo opening hours, a study of banteng in the Cambodian Eastern Plains found that 80% of camera-trap observations took place between 18:00 and 06:00 (Gray *et al.,* 2012), suggesting that banteng are active nocturnally. Future research could investigate nocturnal activity of the banteng to see if their activity in captivity also increases during this time.

Many animals preferentially associate with certain other individuals (Snijders *et al.,* 2017). This study found that females preferentially associate with their calves and older offspring. Grooming is often associated with suckling and is an important activity of cows towards their calves, grooming for long periods of time (Keeling, 2001). The amount of grooming a day remains high for more than 10 months after birth (Keeling, 2001). Banteng tend to gather in herds of two to 30 members, with each herd containing only one adult bull (Saari, 2004). There were many positive interactions, such as sniffing and social grooming displayed by the dominant bull towards the females, which is typical of a dominant male towards females in a herd (Keeling, 2001; Melletti & Burton, 2014). There appeared to be a difference in social ranking amongst females with some receiving many more positive interactions than others. This social structuring can influence how populations respond to changes to their environment, thus making network analysis a promising technique for understanding, predicting and potentially manipulating population dynamics (Snijders *et al.,* 2017).

Negative interactions between cattle usually occur when there is increased competition for food resources or water access, a better suited resting place, for defending their territory, and in bulls, fighting for the right to mate with females (Acatincăi & Gavojdian, 2010). Agnostic behaviour can be recognised by aggression and/or fighting although fights are rarely recorded, and usually their duration is short (Acatincăi & Gavojdian, 2010). Very few negative interactions were observed in the herd at Chester Zoo revealing that levels of competition for resources were low. The patterning of social relationships between individuals influences how space is utilised and how animals interact with resources provided for them (Rose & Croft, 2015). Social interactions and patterns of association are important to health, welfare and the fitness of individuals (Price & Stoinski, 2007; Silk *et al.,* 2009).

This study adds to the body of knowledge of banteng behaviour. However, this research only focusses on the behaviour of banteng in one zoological collection, a greater sample using data from other collections could be used for comparison and provide a more thorough basis for behaviours of these species in captivity. Data collected from rare, understudied and endangered species not only contributes to the understanding of sociality and behaviours but may also serve as a tool to identify environments that support an adequate activity budget for these species (Cartagena-Matos *et al.,* 2017).

In conclusion, this study has revealed that the herd of banteng at Chester Zoo exhibit similar behaviour patterns to those observed in the wild during the day. The results of the social network analysis demonstrate that animals often exhibit positive social interactions and few negative social interactions which is an indicator that the herd has low levels of competition

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Research Summary

Of dwarfed buffaloes and conservation palaeobiology

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Islands are home to extraordinary biotas and have long been recognised as laboratories for the investigation of the fundamental biogeographical processes of colonization, evolution, and extinction (e.g., Darwin, 1860; Wallace, 1880; Whittaker et al., 2017). Bovids are intriguing elements of insular faunas and encompass several species that inhabited or are still living on islands located in different regions, from the Mediterranean to Southeast Asia. While the most popular insular endemic bovid is without doubt the extinct mouse-goat (*Myotragus balearicus)* from the Balearic Islands (e.g., Bover & Alcover, 2003; Köhler & Moyà-Solà, 2009; Bover et al., 2010; Palombo et al., 2013; Rozzi & Palombo, 2014), living examples of these wonders include three miniaturised buffalo species, which are of concern to the IUCN Asian Wild Cattle Specialist Group (AWCSG): the tamaraw (*Bubalus mindorensis*), endemic to Mindoro, the Philippines, and the anoas (*B. depressicornis* and *B. quarlesi*) from Sulawesi. Well over a century of studies by evolutionary biologists, ecologists, palaeontologists, and biogeographers have identified particular traits and syndromes on which island forms repeatedly converge. The peculiar changes undergone by island bovids include body size reduction, increased molar crown height, transition towards a low-gear locomotion, and changes in brain size and morphology (e.g., Köhler & Moyà-Solà, 2004; Rozzi et al., 2013; Rozzi & Palombo, 2014; Rozzi & Lomolino, 2017; Rozzi, 2017, 2018).

Body size variation is a crucial aspect of the so-called island syndrome (sensu lato; see Lomolino et al., 2017). Large vertebrates, especially mammals, dwarf on islands in response to a combination of selective biotic and abiotic forces (e.g., characteristics of the islands and the species itself and release from ecological pressures of competition and predation; see e.g., Lomolino et al., 2012, 2013; Rozzi & Lomolino, 2017).

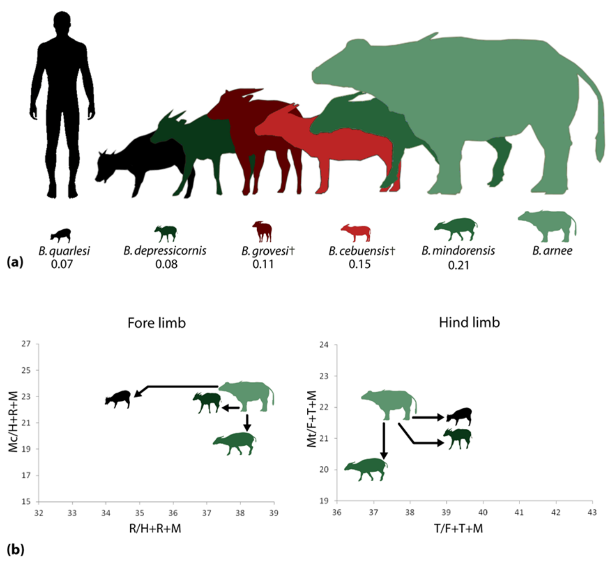

Figure 1. Body size divergence S_i values of selected living and extinct representatives of *Bubalus* (*Bubalus*) and *Bubalus* (*Anoa*). The dagger symbol (†) is used to designate extinct species. The scheme shows the focal buffaloes in proportion to a 1.8 m tall human. Modified from Rozzi, 2017 (a). Graphs comparing the ratio between metacarpal and radius length and ratio between metatarsal and tibia length, normalised with respect to the total length of the forelimb and hindlimb long bones. Black arrows highlight phyletic relationships among focal insular Bovini. Modified from Rozzi & Palombo, 2014 (b).

The island rule predicts this pattern and bovids are no exception, exhibiting body size reduction. To explore the size shift of focal species I calculated their body size divergence Si (= mean body mass of individuals from an insular population or species divided by that of individuals of the mainland or ancestral form; see Rozzi, 2017, 2018). Values obtained for living and fossil dwarfed buffaloes are shown in Fig. 1a (for a comprehensive overview of their body masses see Rozzi, 2017, 2018). The estimate rests on the assumption that fossil water buffaloes would be the ancestors of the anoas and their Late Pleistocene/Holocene relative *B. grovesi* (see Rozzi, 2017), of *B. cebuensis* - the extinct buffalo from Cebu Island, and of *B. mindorensis*, and that the body masses of those putative ancestors would not differ significantly from that of their extant relative *B. arnee* (Rozzi, 2017). The relative size of *B. grovesi* indicates an average body size reduction of about 89% (Si = 0.11) with respect to a typical water buffalo. *Bubalus depressicornis* and *B. quarlesi* exhibit even more extreme values, with a body size reduction of about 92% (Si = 0.08) and 93% (Si = 0.07), respectively (Fig. 1a).

Endemic buffaloes from the Philippines are larger than the anoas and their relative size indicates an average body size reduction of about 79% (Si = 0.21) for *B. mindorensis* and of about 85% (Si = 0.15) for *B. cebuensis* (Fig. 1a). Island dwarfing of bovids is more pronounced for species which have evolved on the focal islands for longer time periods (Rozzi, 2018). Moreover, while release from competitors appears to be the major force influencing dwarfing of other insular wonders (e.g., proboscideans), results of my research highlight the central role of predator diversity, or predatory release, in driving the body size evolution of insular bovids (Rozzi, 2018). This likely reflects differences in prey preferences. In fact, bovids and other ruminants (i.e., mesoherbivores) are among the most common prey of large carnivores both now and in the past. In contrast, large body size of megaherbivores, such as mammoths, stegodonts and elephants, renders their populations less susceptible to “top-down” limitation by predators.

A common feature in dwarfed island herbivores is a great shortening of the limbs, especially the distal limb elements. This has been explained as an adaptation for what Sondaar (1977) described as low-gear locomotion – a frequent phenomenon believed to be more adaptive, in the absence of predators, for climbing across rocky and/or uneven terrain than the ancestral (mediportal) bauplan (see e.g., Rozzi & Palombo, 2013, 2014). Limb bone shortening cannot be explained by a simple allometric downscaling of the animal, because the relative proportions of limb elements are drastically changed. Therefore, it is useful to compare the ratio of length of metacarpal/length of radius and length of metatarsal/length of tibia of extant insular species with that of their ancestors and with data available for the fossil species (Rozzi & Palombo, 2014). Results obtained for dwarfed buffaloes (Fig. 1b) indicate that all the extant species exhibit a shortening of limb length and metapodials, although each taxon shows peculiar relative proportions of limb elements. One of the most extreme cases is *B. mindorensis*, which strongly shortened the metapodials with respect to its closest mainland relative *B. arnee* (length of metapodials is less than 20% of the total length of the other limb elements) and only slightly reduced the lengths of radius and tibia (Fig. 1b). The variation of the limb shortening pattern in extant and fossil island herbivores can be explained in light of the predatory pressure that each focal species had/has to face in each insular community. For instance, bovids that evolved in a predator-free environment, such as the tamaraw, acquired morphological traits typical of low-gear locomotion (Rozzi & Palombo, 2014).

Several recent studies have illustrated how knowledge of the deep-time fossil record of ecological and evolutionary dynamics can contribute to the conservation of biodiversity (see e.g., Dietl & Flessa, 2009, 2011; Dietl et al., 2015; Dietl, 2016; Barnosky et al., 2017 and references in those papers).

***Conservation palaeobiology:** "the application of theories and analytical tools of paleontology to the solution of problems concerning the conservation of biodiversity" (Dietl & Flessa, 2009).
****Ecological naiveté:** "the tendency for long-term inhabitants of low diversity and disharmonic (unbalanced) islands to lose their capacities for detecting, avoiding or otherwise coping with competitors, predators and parasites from the mainland or otherwise more-balanced and species-rich assemblages - i.e., species at least initially absent from these islands" (Lomolino, 2016; Lomolino et al., 2017).

In particular the conservation palaeobiology* perspective (i.e., the perspective provided by geohistorical data) is essential for the development of successful conservation strategies under current global change. Insular populations of large vertebrates, such as dwarfed buffaloes, often exhibit a trend towards ecological naiveté** and heightened vulnerability to extinctions - especially those at the hands of non-native species, including humans and their commensals (e.g., Lomolino, 2016). Investigating their evolutionary history and, in particular, how these endemics often lose or wane in those traits that allowed their mainland ancestors to survive in the face of intense ecological interactions can provide valuable information for conservation planning. Both taxon-based palaeontological methods - which rely on the presence, absence, or abundances of certain taxa and their underlying diversity - and taxon-free palaeontological methods - which use variables that reflect ecosystem function rather than structure - can provide critical data and insights (see Barnosky et al., 2017). For instance, delving into the phylogenetic relationships, timing of colonisation and mode of evolution of the anoas and tamaraw and of their extinct relatives is crucial to outline the range of taxonomic and relative abundance variation that characterises their ecosystems as they fluctuate over time. On the other hand, by focusing of their functional traits (i.e., 'ecometrics') - such as locomotor attributes, dental morphology and body size – it might be possible to infer the ability of these taxa to persist under particular scenarios of rapid environmental change or introduction of invasive species. All in all, palaeontological studies have the potential to inform conservation strategies for extant miniaturised buffaloes and to produce detailed information on their uniqueness (i.e., ecological naiveté) and, thus, a better assessment of their conservation value.

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Status Review

Review of tamaraw (*Bubalus mindorensis*) status and conservation actions

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Abstract

The tamaraw (*Bubalus mindorensis*) is a Critically Endangered wild buffalo species, found on Mindoro Island, Philippines. The number of locations with confirmed tamaraw population has declined to three, and the general species range has contracted. However, the total estimated population size appears to be increasing. Therefore, there are some positive signs for this species, though the population dynamics need to be better understood before this is verified as a strong positive indicator for the species. This paper reviews the population status, threats, and opportunities for the future conservation of tamaraw. This is presented in a historical and socio-economic context, following extensive research.

In the coming months there will be a Mindoro Tamaraw Action Planning Process that will develop a ten-year plan. This will include broad stakeholder engagement and a Population and Habitat Viability Assessment workshop (PHVA). This is the second PHVA process for the tamaraw, the first being in 1996. It is hoped that this workshop will strengthen the already active partnership and also catalyse all partners to increase their efforts and focus on the priority actions that need to be achieved most urgently. This paper highlights the need to look towards a meta-population approach, of protecting and securing multiple populations of tamaraw, rather than focusing efforts on one population. This will increase the chances of conserving the species and its habitats in the long-term.

Introduction

Tamaraw

The tamaraw (*Bubalus mindorensis*) is a dwarf buffalo species, endemic to the island of Mindoro in the Philippines (Heaney et al., 1987; Custodio et al., 1996; Cebrian et.al., 2014). The tamaraw probably diverged from the related wild water buffalo (*Bubalus arnee*) into a distinct insular bovine species during the Pleistocene, 1.5 million years ago (Tanaka et al., 1996; Schrieber et al., 1999). Although the tamaraw is currently the only wild cattle species in the Philippines, some evidence suggests that wild *Bubalus* species may have had a wider distribution prehistorically in the Philippines, although this needs to be critically analysed (Beyer, 1957, Custodio et al., 1996, Croft et al., 2006).

The tamaraw is listed as Critically Endangered on the IUCN Red List of Threatened Species (Boyles et al., 2016). There are only three distinct populations known to survive today in Mindoro with a minimum estimate of 409 animals. However, 80% of individuals are presumed to be in only one subpopulation, in a restricted area of less than 3,000ha within Mounts Iglit-Baco Natural Park (MIBNP), while the total area of occupancy of the species on Mindoro Island may not exceed 10,000 hectares.

Tamaraw were historically found across Mindoro, from sea level to over 1,800 masl (Everett, 1878; Steere, 1888b, 1891). Until 1900, Mindoro maintained 70% forest cover (ESSC, 1999), and the island was sparsely populated due to the prevalence of malaria (Wernstedt and Spencer, 1967). The indigenous Mangyan population (see below) was estimated at no more than 20,000 at this time (Miller, 1912). Human influence on the tamaraw was minimal at the turn of the twentieth century and the species distribution extended throughout the island, including the lowland areas and river basin plains, with an estimated population of 10,000 (Harrisson, 1969). The species was still reported in the "North-eastern great plain" of Mindoro, in the foot hills of the Mt. Halcon Range, Calapan region in the first decades of the 20th century (Helbling and Schult, 2004).

Although residing on a forested island, tamaraw have been observed searching for transitional sites where open areas adjoined forest and sources of food and water occurred together (Talbot and Talbot, 1966), and to prefer open grasslands, forest glades, thick bamboo-jungle, marshy river valleys, and low to mid-elevation forests (Rabor 1977).

Mindoro natural landscape

The island of Mindoro is the seventh largest island in the Philippine archipelago at 10,572 km². It is characterized by its broad mountainous spine centred on Mt. Halcon (2,597 masl) and Mt. Baco (2,489 masl). Mindoro falls within the Philippines biodiversity hotspot (CEPF 2011) and is designated as an important centre for endemic species (Gonzalez *et al.* 2000) with 22 species recognized as endemic to the island (MBCFI 2018).

Historically, Mindoro was entirely forested, but its lowland plains have been cleared for permanent agriculture and upland forests have been degraded by swidden agriculture, cattle ranching, conversion for agriculture and commercial logging (Helbling and Schult, 2004). By 1988, only 30.01% of the total area of the island remained (Gonzalez *et al.* 2000; De Alban *in prep*). Mindoro suffered a further loss of over 30,000 hectares of forest cover between 1988 and 2015 (Rodriguez, 2015; De Alban *in prep*). A total logging ban was implemented in 2011 and the Department of Environment and Natural Resources (DENR) has initiated a large-scale reforestation program (National Greening Program) including several sites in Mindoro. Despite this however, forests remain threatened (Israel and Lintag, 2013).

The Mangyan Indigenous People of Mindoro

Mangyan is a generic term that encompasses the eight ethnolinguistic indigenous tribes which are considered to be the original inhabitants of Mindoro. For the last two centuries, government policies have encouraged immigration from other provinces (Schult, 1991). These inter-island immigrants settled mainly in coastal areas, often maintaining their specific cultures, traditions and dialects. This immigration pushed the Mangyans, known to have been coastal dwellers originally, further inland (Helbling and Schult, 1997). Today, many Mangyan communities are experiencing a rapid shift in their traditional land-use system (shifting cultivation and hunting-gathering), progressively adopting more modern lifestyles (permanent settlement and permanent agriculture).
Mangyans are still highly dependent on natural resources for their subsistence and cultural practices (Helbling and Schult, 2004). Since most of Mindoro's natural areas are now restricted to the interior of the island, where Mangyans are currently living, they are highly concerned by biodiversity conservation programs and natural resource management policies.

The aim of this review is to put the status of the tamaraw into its historical and socio-economic context for the first time. An extensive literature search was undertaken, data were collated from the DENR Biodiversity Management Bureau (BMB), the Tamaraw Conservation Program (TCP), and on-going efforts by conservation organizations such as the Mindoro Biodiversity Conservation Foundation, Inc. (MBCFI), World Wildlife Fund-Philippines (WWF), Haribon Foundation and D'Aboville Foundation, Inc. (DAF), including qualitative data gathered during field missions, workshop activities, and formal and informal discussions with local communities, DENR personnel and tamaraw rangers.

Estimated Tamaraw Population Decline

Tamaraw numbers decreased to an estimated 1,000 individuals by 1949, then to 244 in 1953 (Manuel, 1957), 200-250 in 1965 (Hediger, 1965), and by 1969 it was thought that only about 100 Tamaraw survived (Harrisson, 1969b; Alvarez, 1970). In 1971, it was estimated that around 150 - 200 tamaraw remained, including about 80 in the Mount Iglit Game Refuge (Kuehn, 1975, 1976, 1977; National Research Council, 1983). In 1982 the Presidential Committee for the Conservation of the Tamaraw (PCCT) estimated that a maximum of 250 tamaraw remained. Other estimates of numbers include 356 in 1987 (Petocz, 1989b), more than 500 in 1990 (Callo, no date), and 250 in 1994 (Read et al., 1994). However, all these figures are rough estimates.

Table 1 presents population estimates from the areas occupied by tamaraw over the past 30 years. Tamaraw were still found in seven sites in 1987, possibly only four in 1996, and today only three (since no sightings have been reported for several years in Mount Calavite Wildlife Sanctuary). Of these, the very small sub-population of Aruyan-Malati faces imminent threat of local extinction. In Mounts Iglit-Baco Natural Park, the tamaraw range appears to have contracted in the past 30 years towards the so called 'Core Zone of Monitoring' (primary zone of intervention by the authorities encompassing the "annual count zone", the regular rangers patrolling zone and zone of contact with residing Mangyan communities). Tamaraw are no longer seen in many adjacent areas where they used to be present (Ballagit and Mappad Valley, Kinwala plateau, Upper Anahawin Watershed, Upper Kinarawan Watershed). Tamaraw were extirpated from the upper Busuanga watershed and Mount Wood on the east side of the Park in the 1990s (Schütz, 2015). Although the number of animals was small, surveys suggest that tamaraw were still roaming the mid-elevation forest between the Core Zone of Monitoring (MIBNP) and the Aruyan-Malati area three or four decades ago, thus connecting these two sub-populations (Figure 1).

Current Population Status

Based on the annual tamaraw census conducted by the local authorities, there was an estimated minimum population of 401 animals within Mts Iglit-Baco Natural Park in 2017, which is the largest known population representing possibly 80% of the total tamaraw population on Mindoro. Sizes of the other sub-populations are estimates from non-systematic surveys (Figure 2; Table 2). However, it is possible that some sub-populations are larger than expected and that additional small sub-populations could be found outside of the listed sites.

Mounts Iglit-Baco Natural Park

MIBNP holds the largest number of tamaraw, but this sub-population is now restricted to only one location in the south-west part of the Natural Park, on the Occidental side of the Province. The area consists of a hilly plateau dominated by grasslands, interspersed with numerous wooded creeks, secondary forest fragments and steep hills. This range corresponds to the former cattle ranch of Victor Korionoff, a Russian owner who supported the establishment of the TCP and Natural Park. It was defined as the "Core Zone of Monitoring", concentrating most of the protection efforts, thus substantially lessening pressure on the species following the closure of the cattle ranch. The Natural Park encompasses large tracks of the Ancestral Lands of the Tau-buid and Buhid Mangyan tribes. Furthermore, the living space of several of the Tau-buid communities overlaps the current tamaraw range, between the Lumintao River and the Anahawin River.

Table 1. Summary of Tamaraw population estimates from 1987, 1996 and 2017.

Site	Year of population estimate		
	1987 [1]	1996 [2]	2017 [3]
Mount Calavite Wildlife Sanctuary	45	>1	0?
Mount Halcon - Eagle Pass	65	65	0?
Upper Amnay Watershed Region – Eagle Pass			5-70+
Santa Cruz – Pinagturilan	20	0	0
Mounts Iglit-Baco Natural Park (MIBNP), "Core Zone of Monitoring" (5% of PA extent)	145	175	400+
Aruyan - Malati Tamaraw Reservation	41	14-30	10-12
Oriental Mindoro (Municipalities of Victoria - Bansud – Bongabong – Mansalay)	40	0	0?

[1]Petocz (1989b); [2]de Leon (1996); [3]TCP/ Emmanuel Schütz (unpublished)

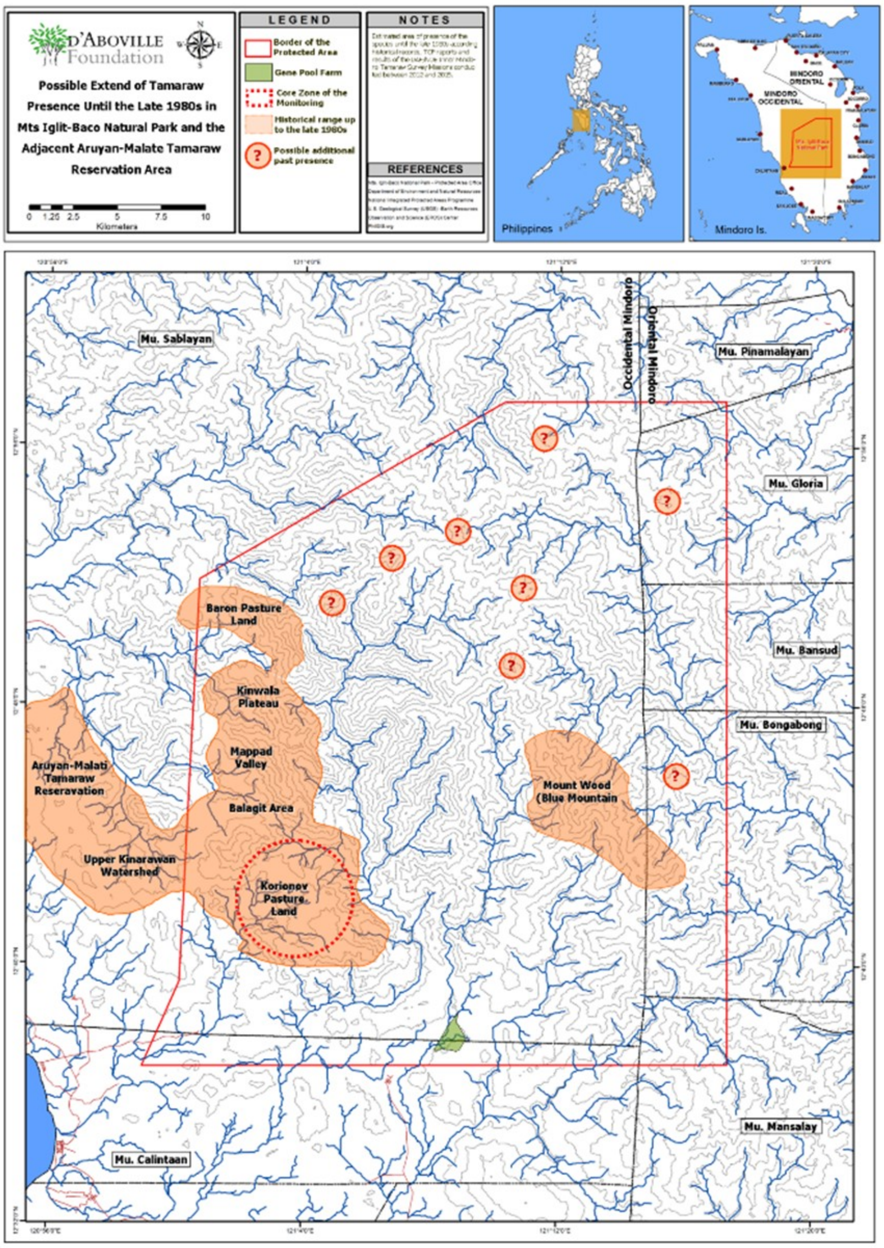

Figure 1. Possible range of the Tamaraw within and around Mts Iglit-Baco Natural Park up to the late 1980s

Table 2. Number of Tamaraw per known sub-population

Subpopulation / area	Number of animals	Year of assessment	Assessment method
Mts Iglit-Baco Natural Park (annual count zone)	401	2017 annual tamaraw count	5 days' simultaneous counts from multiple vantage points
Aruyan-Malati Tamaraw Reservation	10 - 12	2015 verification survey + regular reports of rangers	Indirect signs of presence + Interview of residing indigenous communities
Upper Amnay River	5-70+	2018, three consecutive verification surveys	Indirect signs of presence + Interview of residing indigenous communities
Mount Calavite Wildlife Sanctuary	Unknown, possibly zero	2017	Interview
One tributary of the Bongabong River	Unknown, possibly zero	2017	Suggested by local communities
Mt. Halcon Range	Unknown, possibly zero	2016	Suggested by local communities

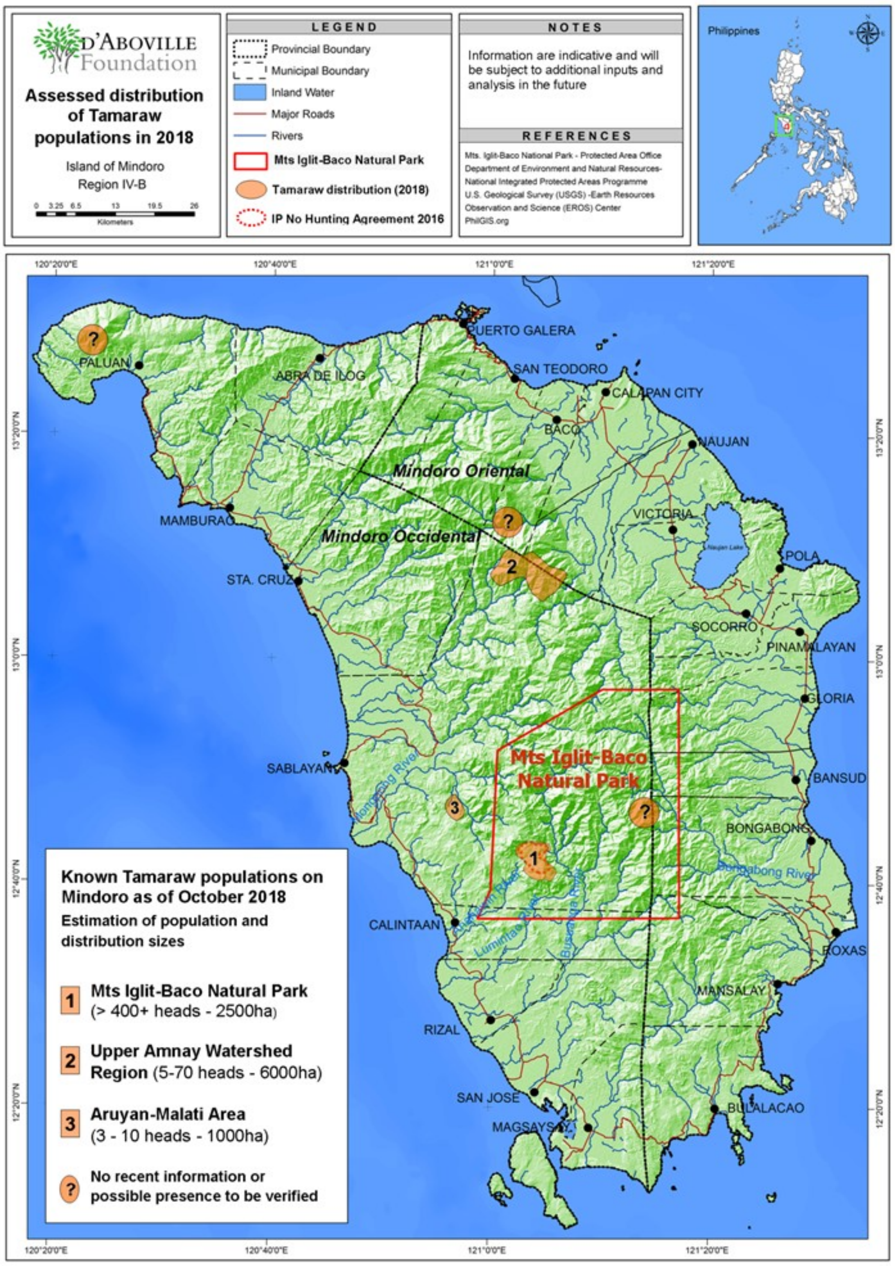

Figure 2. Distribution of current possible Tamaraw sub-populations

When the Philippine authorities introduced formal and regular monitoring through an annual census method in 2000 (Tamaraw Annual Population Count), the area inhabited by tamaraw was estimated around 5,000 ha within the core zone of monitoring. The aim of the count is to define a minimum realistic number of tamaraw within the suspected core area of presence of the species; the "tamaraw counting zone" encompasses 18 vantage points, covering nearly 2,200 hectares. A simultaneous multi-vantage point count method is used over five days every April. The method involves the burning of the grasslands a few weeks ahead of each count in order to increase visibility and attract tamaraw to the new grass growth (Ishihara et al., 2014).

The first count in 2000 reported the presence of 154 animals. Since then, numbers recorded have increased steadily to reach 401 individuals in 2017 (Figure 3) (TCP, consolidated data of the Annual Tamaraw Population Count Operation). These population estimates have been a valuable indicator for determining the population trend (see Figure 3), but there are concerns on the method and its accuracy. The population estimates for 2000 and 2001 may not have been as reliable as those from following years, as staff were becoming familiar with the survey method and few binoculars were available. The method is probably highly sensitive to weather conditions, as well as to how many experienced observers are participating and the way they are assigned among the different vantage points. The risk of double counting is substantial and the possibility of error increases as the tamaraw population and animal density increases within the counting zone. In 2018, the count established the presence of 523 animals, raising additional concerns on the accuracy and reliability of the method. The drastic increase from 401 to 523 (30% increase) in one year could be explained by a decrease in off-take from poaching in recent years, an over estimation in 2018, or an underestimation in previous counts, but changes in TCP management and changes in personnel conducting the count might have influenced the result as well. More accurate analysis of the 18 years of count data shall help to identify a margin of error and the method's limitations.

While the tamaraw population in MIBNP has been increasing in size over the past two decades, it has been contracting in distribution (Figure 4). The area of presence was estimated to be around 5,000ha in 2000, but only 2,500 ha in the dry season (outside traditional Mangyan hunting season) of 2017, a 50% decrease. (Schütz 2018; Figure 4). Meanwhile, the result of the annual count more than doubled. This raises multiple questions including: (1) does the annual count accurately assess the tamaraw population in the Core Zone of Monitoring; (2) is the population increasing or is a more dispersed population being concentrated into the Annual Count Zone; (3) is the population contracting in area of occupancy due to external threats, habitat changes, or better protection; (4) what is the impact on the population of current habitat management, especially the annual grassland burning conducted to enable the counts; and (5) what is the impact of the establishment of the 1,600 ha No Hunting Zone. This written agreement was the result of talks in 2016 with residing Tau-buid communities and subsequent ground delineation with GPS.

Aruyan-Malati Population

The Aruyan-Malati Tamaraw Reservation is situated immediately adjacent to the Sablayan Prison and Penal Farm in the Municipality of Sablayan, Occidental Mindoro, West of MIBNP (Figure 5). The area is characterized by its hilly landscape dominated by secondary forest, interspaced with open areas from slash and burn agriculture conducted by resident Mangyan communities. The results of a field survey conducted in 2007 by local authorities indicated the presence of an estimated 15 to 20 tamaraw, with an area of occupancy of 3,600 ha (R.M. Boyles, unpublished). In 2015, the population was estimated to be only 10 to 12 animals (DENR TCP (2015) Memorandum: Report on the Tamaraw population assessment in Aruyan-Malati. Latest reports from ranger patrols suggest the presence of two or three family groups and a few solitary males with a scattered distribution due to a high degree of disturbance (Schütz, 2018; Figure 5). In December

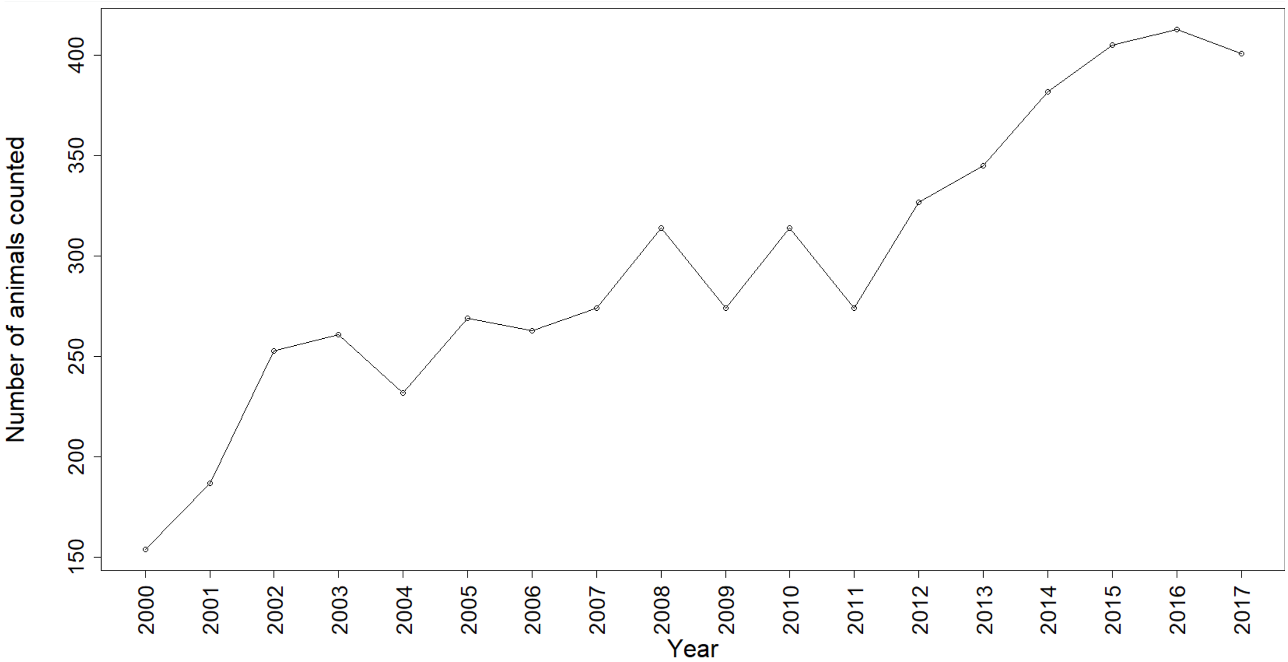

Figure 3. Population size and growth of tamaraw population in Mounts Iglit-Baco Natural Park from 2000 to 2017 from consolidated data of the Annual Tamaraw Population Count

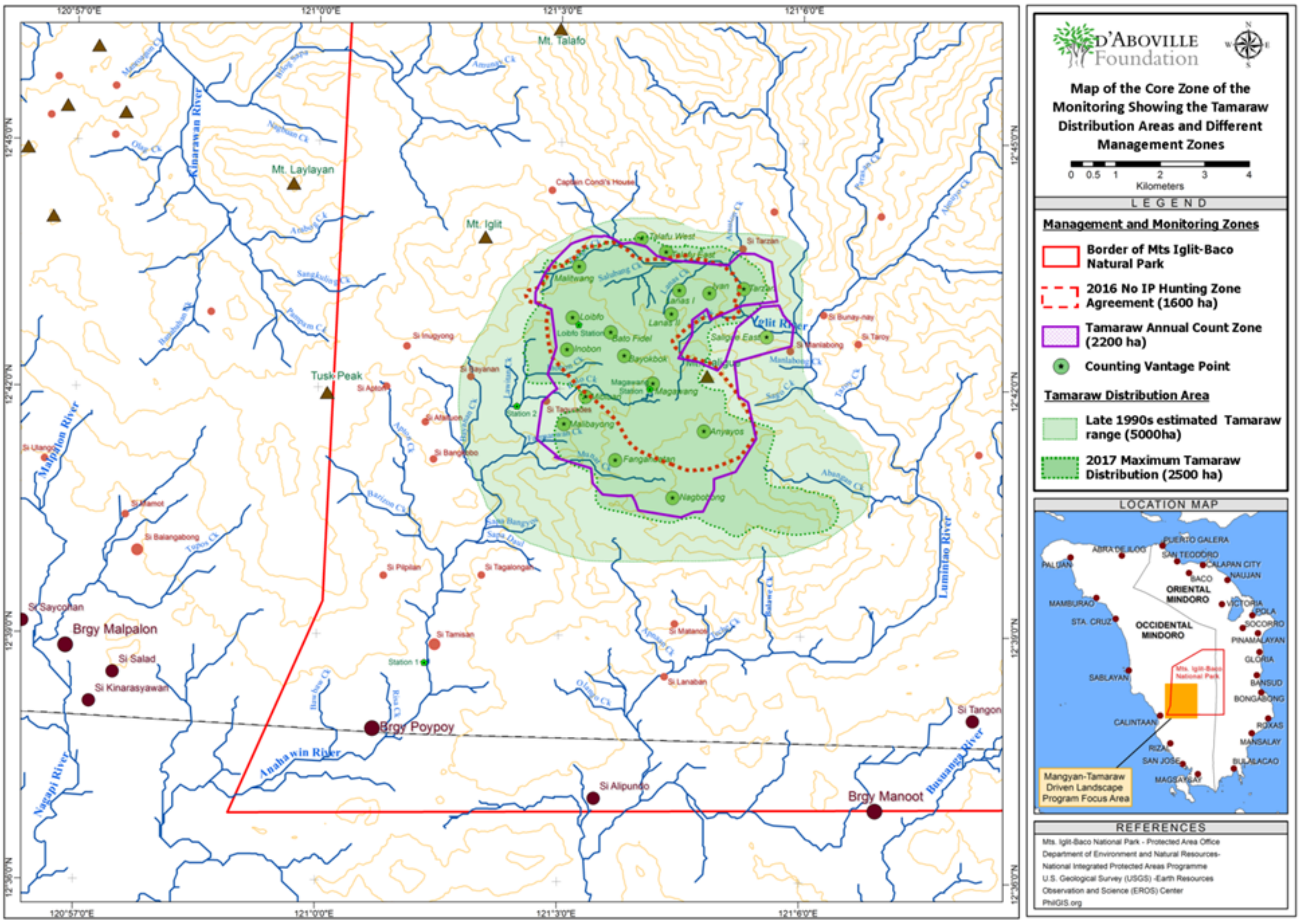

Figure 4. The distribution of Tamaraw within the Core Zone of Monitoring in Mounts Iglit-Baco Natural Park between late 1990s and present day and different Management Zones

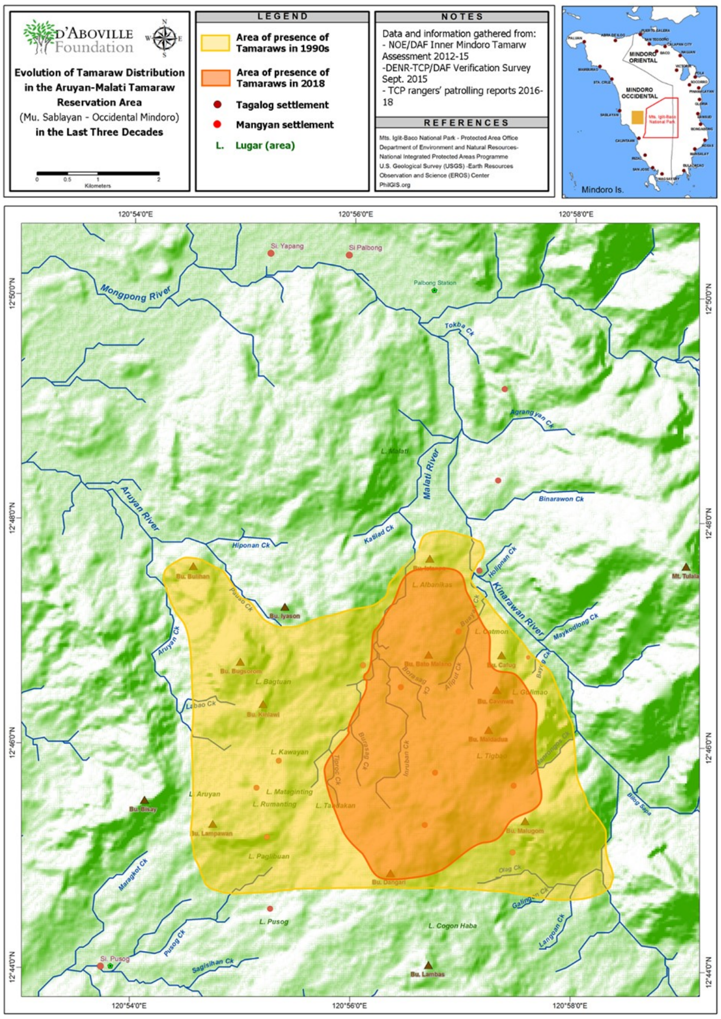

Figure 5. The Aruyan-Malati Tamaraw Reservation subpopulation

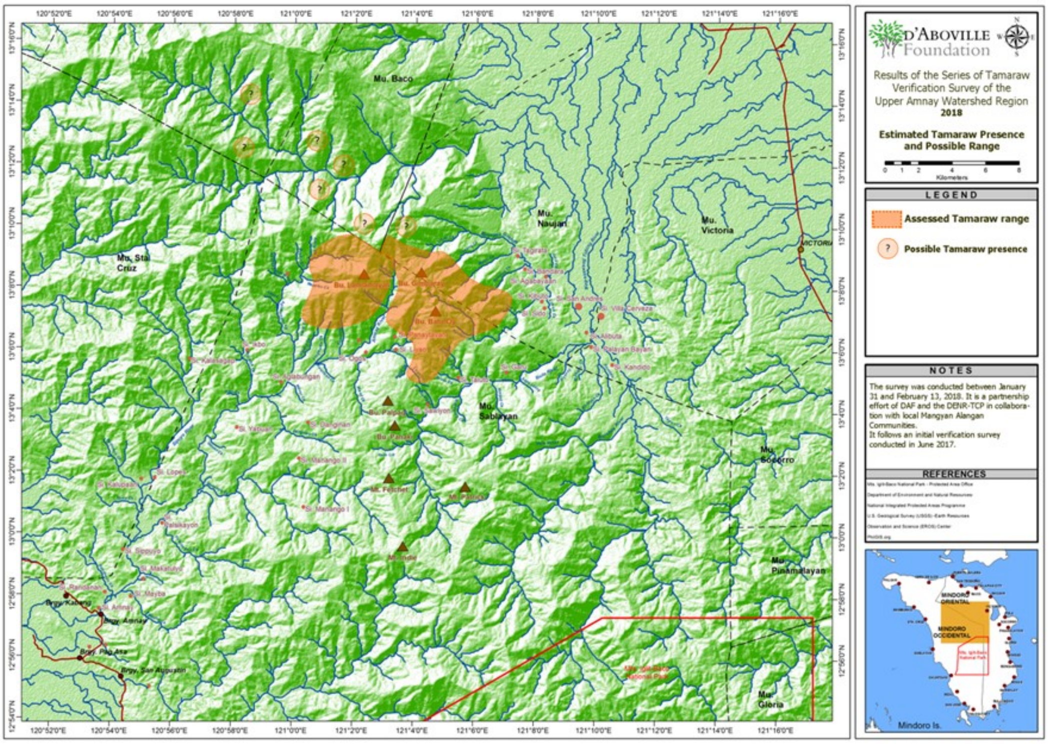

Figure 6. Location and possible range of the Tamaraw population of the Upper Amnay Watershed Region

2017 a group of 3 animals were caught on a camera trap (DENR TCP, 2017a). This area benefits from a local ordinance from the Municipality of Sablayan to protect the tamaraw. However, there is still a need to enhance the capacities of local stakeholder for the protection of the area. There is an ongoing process that this area be proclaimed as a Critical Habitat by the DENR that will further improve its protection.

Eagle Pass Region

The Eagle Pass region on the border between Oriental and Occidental Mindoro has been producing regular reports of tamaraw presence for decades (E. Schütz, unpublished). In 2017 and 2018, a series of four surveys in the Upper Amnay Watershed Region (Municipality of Sablayan and Naujan) confirmed the presence of a tamaraw population much larger than the Aruyan-Malati Tamaraw sub-population, with an area of occupancy greater than 6,000 ha (Figure 6). This finding makes it the second largest known tamaraw population in Mindoro and the largest in terms of distribution (TCP/DAF 2018, unpublished). Here, tamaraw are confined to mountain habitats (mossy forest, mountain tropical forest and dwarf vegetation), adopting browsing behaviour and a more fibre rich diet than the grassland populations. This demonstrates the ecological flexibility of the species. Additional surveys should provide a clearer picture of the status of this sub-population in terms of size and distribution. This finding substantiates the "rediscovery" of the species in Oriental Mindoro. This tamaraw population is located on the officially recognized Ancestral Domain of the Mangyan Alangan Tribe and is outside of any protected area (but there is a move since 2017 to legally protect Amnay Watershed, among other watershed areas in Mindoro provinces through the proposed "Mindoro Watershed Reservation Act" – please see House Bill No. 4617 authored by Hon. Cong. Josephine Ramirez-Sato). Besides these main population sites, Mt. Halcon and the area east of Mt. Wood still produce sporadic reports of tamaraw (E. Schütz, unpublished). However, it is hard to validate such information, so further investigation is required.

Causes of the range and population collapse

Habitat degradation and land-use pressure

Throughout the twentieth century there was a progressive decline in the tamaraw's range, probably due to conversion of natural habitats into agricultural lands. The San Jose Sugar Hacienda was established in 1910 under the American administration, and copra (dried coconut flesh used to extract oil) became the island's predominant cash crop (Helbling and Schult, 1997), promoting immigration from other islands and so further accelerating clearance of the lowland forest of Occidental Mindoro.

The Philippines shifted from being a timber importer to an exporter in 1900, but it was not until after 1946 that commercial logging, driven by the world timber market, accelerated deforestation in the Philippines (Maohong, 2012). Deforestation in this case was a two-step process; forest degradation by logging, followed by forest removal for agriculture, mainly small, subsistence cultivation. It was the logging industry's encroachment into inner Mindoro that drove both the range contraction and the fragmentation of the tamaraw population. By 1960, forest cover on Mindoro was down to forty percent of its original extent (Gonzalez *et al.* 2000).

Deforestation combined with poor soil, recurrent fire, and the long dry season has facilitated the development and persistence of grasslands dominated by *Imperata cylindrica* (Cogon grass) across the middle elevations of Occidental Mindoro. Following this drastic habitat shift in the first decades of the 20th century, major land owners, including international companies, established cattle ranches on these mid-elevation grasslands. Tamaraw were considered competitors to cattle, and combined with the impact of trophy hunting, their population was reduced and the lowland habitats were lost, restricting the species to more mountainous terrain, including the Mounts Wood, Baco, Sinclair, Halcon and Calavite areas. The decline in ranching activity in the 1970s was an opportunity for the indigenous Mangyan communities to re-occupy their Ancestral Lands, bringing these communities into conflict with tamaraw over land and so restricting the species' expansion.

Today, frequent grassland burning, both by Mangyans and local authorities, is likely to result in the progressive reduction of the quality and diversity of the habitats in the long term. Observations suggests the expansion of several invasive plant species within these managed grasslands, in particular *Chromolaena odorata* (locally called Hagonoy) which may reduce the suitability of the grassland for tamaraw (E. Schütz, unpublished).

Hunting and poaching

Since World War II, traditional hunting using spears and pit-traps, along with poaching using high-powered rifles and automatic weapons appears to have been rife despite tamaraw being protected by law since 1936 (Rabor, 1961; Talbot & Talbot, 1966; National Research Council, 1983). In the late 1960's there were reports that hunting intensified. Due to their aggressive behaviour, tamaraw were considered a prized game species, and were hunted by prominent Philippine families and by foreigners alike; until the 1980s trophy hunting remained a 'gentleman's sport' for the elite and there are even reports of the use of helicopters (E. Schütz, unpublished). Concurrently, there are anecdotal reports that insurgent groups based in the mountains were hunting tamaraw for food, but the scale of this is not known (E. Schütz, unpublished).

The inhabitants of lowland areas of Mindoro are reported to poach deer and pigs, using guns and dogs, which can also kill tamaraw. Mangyan indigenous communities maintain traditional hunting practices such as spear and snare trapping for deer or pigs, with tamaraw being occasionally killed (E. Schütz, unpublished). A population and habitat viability study (de Leon et.al., 1996) demonstrated that even low off-take levels are likely to have a major impact on survival of tamaraw populations.

The newly confirmed tamaraw population of the Upper Amnay Watershed Region is increasing in size according to the local IP communities. At present, it is likely to be relatively safe from poaching and hunting disturbance due to its remoteness and decreasing land-use pressure from residing Mangyan Alangan communities. However, this population remains under threat in the medium-long term due to unrestricted access by poachers into the area, and the cross-Mindoro road, currently under construction, which will greatly facilitate access to this part of the island (Tabaranza, *et al*. in prep). The "Mindoro Watershed Reservation Act" under House Bill No.4617 will hopefully provide stronger protection for the Amnay Watershed.

On a general manner the improvement of infrastructure on Mindoro is facilitating access to the remaining natural areas, therefore putting tamaraw at further risk.

Disease

Disease is thought to have had a significant negative impact on the tamaraw population. Multiple cattle diseases were found in the domestic livestock herd of the Philippines throughout the early 1900s with Rinderpest and Surra reported to be common across the country, and foot-and-mouth present in a few provinces in 1913 (Anon, 2015). The sharp decline in the population of tamaraw from 1900 to 1949 was attributed to the outbreak of rinderpest in the Philippines around 1930 (Grzimek, 1990); no specific evidence exists to confirm this decline or the attribution to rinderpest, although it seems quite plausible.

It is believed that the risk to tamaraw from disease is lower than in the recent past, as cattle no longer occur in the same areas as current tamaraw populations. However, cattle grazing in MIBNP continues in areas close to the Core Zone of Monitoring, and areas where there is risk of habitat crossover should be monitored.

Effects of small population size

As populations decline to low numbers they become increasingly at risk from stochastic events. Small, localised populations are more likely to be lost in catastrophes such as fires or floods; their numbers are more likely to fluctuate dangerously in response to otherwise normal year-to-year variation in environmental conditions, or as a result of variability in sex-ratios, birth and survival rates; and the inevitable genetic deterioration of small populations can result in depressed fitness and reduced adaptability (Frankham et al., 2002). Further, where populations are both small and living at low density, the difficulty of locating potential mates and the inflated risks associated with isolation from conspecifics may further depress population growth (referred to as the “Allee Effect”) (Allee and Bowen, 1932; Courchamp et al., 2008). As a result of these effects, the current small size and fragmentation of the tamaraw population poses a serious threat to its long-term survival, with populations at Upper Amnay River and at Aruyan-Malati particularly at risk.

Indigenous Peoples and their relationship with tamaraw

Among the eight Mangyan tribes of Mindoro, two still share their living space with the tamaraw, and will strongly influence the long-term fate of the species. The Mangyan Alangan Tribe gained recognition of its Ancestral Domain Claim following the enactment of the Indigenous People Right Act of 1997 or IPRA law (Republic Act No. 8371). This gives them full authority over their land and use of its natural resources, covering most of the Amnay Watershed, in the Municipality of Sablayan, Occidental Mindoro and Bucayao Grande River in the Municipality of Naujan, Oriental Mindoro, thus encompassing the entire distribution of the tamaraw subpopulation. Specifically, these tamaraw are located within the living space of several upland communities, numbering a few hundred people. These communities participated in the tamaraw verification surveys in 2017 and 2018. The livelihoods of these communities mainly depend on subsistence use of local natural resources and shifting agriculture, but they are expressing a desire for access to a more modernized life (E. Schütz, unpublished). Consequently, they are progressively reducing their pressure on higher elevation forests where the tamaraw are distributed. The territory of the Mangyan Tau-buid tribe encompasses the tamaraw sub-population of Aruyan-Malati and MIBNP. Half of their territory is inside the MIBNP and extends on the western side across the Aruyan Malati range and Sablayan Penal and Prison Farm (SPPF). The Tau-buid have to date been unsuccessful in securing their Certificate of Ancestral Domain Title (CADT) partly because their ancestral land claims overlap with the SPPF and MIBNP.

The Tao-buid are the most heterogeneous of the Mangyan tribes. Communities residing at lower elevations are progressively moving to permanent settlement and adopting perennial agriculture (including rice and corn), while restricting access of non-residents. Upland communities on the other hand continue traditional hunting and shifting agriculture (mostly sweet potatoes, mongo beans and a few other crops), with little engagement with outside communities and authorities. Young people are increasingly moving to lower Tau-buid settlements, while a few members have chosen to move further inland to find free space for their families. Today, the range of the tamaraw is restricted within the territories of six communities, where traditional hunting is still being practiced outside the agreed no-hunting zone. The Buhid Tribe has secured its Certificate for Ancestral Domain Title (CADT) which covers large areas in the East of MIBNP, including areas which were formerly occupied by tamaraw and could be suitable for recolonization.

The National Commission on Indigenous Peoples (NCIP) is the agency of the Government of the Philippines responsible for protecting the rights of indigenous peoples, as established by the Indigenous Peoples Rights Act of 1997. This Act provides that any programme affecting or targeting IPs or IP land must go through an NCIP mediated processes, including obtaining the Free and Prior Informed Consent (FCIP) from the concerned IP community.

Many of the pressures affecting the tamaraw have also impacted the indigenous Mangyan communities. During World War II, Mangyans retreated further inland as coastal settlers moved into their lowland forest territories during Japanese occupation. As peace returned, these areas were permanently occupied and soon converted into agricultural land. Expansion of cattle ranching further restricted Mangyan living space. The alternative to proposed resettlement by the authorities, was to occupy the remaining forested areas of inner Mindoro, further encroaching on the remaining tamaraw range. Meanwhile, the Mangyan population increased from around 35,000 people in 1940 to nearly 75,000 in 1990 (Helbling and Schult, 1997).

Despites above statement which result from recent situation, it is likely that the traditional swidden agricultural system of the Mangyans (burning of forest plots, cropping, fallow period and forest regeneration over long cycles), which creates a spatial and temporal mosaic of habitats at different successional stages, created suitable ecological conditions for tamaraw. Yet, this 'harmonious co-existence' progressively reached its limits as the human population grew, the extent of the wilderness shrank and swidden cycles became necessarily shorter. Today, most Mangyan communities are beginning to engage with conventional agriculture to address the limitations of their traditional land-use system. This may result in additional permanent land conversion with detrimental effects on the possible range of tamaraw, but decreasing pressure on surrounding forest. Based on their experiences and in the absence of the security provided by Ancestral Domain, the Taubuid remain distrustful of the plans, actions and motivations of outsiders.

Conservation interventions

Protection

The killing of tamaraw, their wounding, or removal from their habitat were first prohibited under the Commonwealth Act No. 73 of 1936 (subsequently amended by Republic Act No. 1086 of 1954). DENR Administrative Order No. 48, S. of 1991 established the national list of threatened Philippine wildlife, which includes the tamaraw (Cebrian et. al., 2014). (This list has been updated and superseded by DAO 2004-15).

Mts. Iglit-Baco Game Refuge and Bird Sanctuary was established through Proclamation No. 557 of 1969, and was upgraded to a National Park by Republic Act No. 6148 in 1970. This area held the largest known population of tamaraw at the time of its establishment, and still does today. Mts Iglit-Baco National Park was declared an ASEAN Heritage Park in 2003.

Mounts Iglit-Baco National Park predates the National Integrated Protected Area System (NIPAS) Act (1992), which established a new categorization of protected areas. The anachronistic category and function of the National Park (an area "withdrawn from settlement, occupancy or any form of exploitation") was inconsistent with the presence of Mangyan communities and complicated planning and management. The Expanded National Integrated Protected Areas System Act of 2018 finally declared Mts Iglit-Baco as a Natural Park. This new status should facilitate recognizing the presence of the different Mangyan communities residing within the boundary of the Protected Area and legitimizing their rights to use and manage natural resources.

An initial Management Plan and system of zones for the Park was produced in 2003, but no full management plan exists for MIBNP. A formal management planning and rezoning process began in 2018. Hopefully it will be implemented from the beginning of 2019 that would greatly help guide and articulate conservation measures and habitat management in the area. The park was assigned a Management Effectiveness Tracking Tool (METT) (Stolton et al., 2002) score of 72.2% in 2013, just below the average score for ASEAN Heritage Parks of 74.8% (Mardiastuti et al., 2013).

Mount Calavite Wildlife Sanctuary, which was first established in 1920 as Mount Calavite Game Refuge and Bird Sanctuary, primarily to conserve the tamaraw and other wildlife species found in the area. At present, all other known tamaraw populations are found outside of protected areas.

Coordination of Tamaraw Conservation

In 1979, the Presidential Committee for the Conservation of the Tamaraw was formed, which led to the creation of the Tamaraw Conservation Program (TCP) under the supervision of the DENR. However, the establishment of the TCP did not include creation of regular personnel specifically assigned to the program and instead the DENR has only delegated a regular personnel from other units to become the program coordinator. Additional personnel are hired on contractual basis. The program's original mandate has not been reviewed despite changes in governance, policies and conservation challenges. Between 1995 and 2005, the TCP was managed under the Protected Area and Wildlife Bureau (DENR-PAWB; now Biodiversity Management Bureau or BMB), then moved to the management of the DENR Regional Office (MIMAROPA Region). Due to limited resources, the TCP gradually concentrated its efforts on the MIBNP sub-population. In 2018, the TCP has 30 staff and one coordinator, including 4 support staff (office), one Field Operation Officer and 25 rangers deployed in 2 different Locations (5 in Aruyan Malate and 15 in MIBNP) and 5 in the Gene Pool Farm.

Captive population management

In 1980, the TCP established the Gene Pool Farm as a captive breeding facility for the Tamaraw in Mindoro. This facility is a 280 ha fenced enclosure in Manoot, Municipality of Rizal in Occidental Mindoro. Between 1982 and 1984, twenty tamaraw were captured from Aruyan-Malati (Custodio et al., 1996), consisting of at least ten males and six females (Escalada, 1996). However, currently only a single adult male, who was born at the facility, remains in captivity. The lack of successful breeding is likely due to a combination of the management and husbandry methods used, to disease, and to regular changes in management responsibility. (Oliver, 1993; Lawas and De Leon, 1996; Callo, 1999).

The first two animals were captured in February 1982, an adult male and female, subsequently mostly adult males were captured. Of the 20 animals captured, a few died during transportation, or during the days or months after release. The reason for these deaths is attributed to dehydration during transport and injuries during capture in pit fall traps. Further captures occurred in 1984. Additional captures were attempted in 1986 in the rainforest near Eagle Pass, Municipality of Naujan and in Mt. Halcon, but two individuals died in the process, due to simultaneous capture in a single trap (Escalada, 1996).

By 1990, 11 animals remained; eight were transferred from the 280 ha enclosure to individual enclosures, with one pair being housed together ("Charlie" and "Mimi"). The remaining three animals not recaptured eventually escaped. The smaller enclosures were to facilitate study and animal husbandry. A total of five tamaraw calves were born between 1990 and 1999. The first calf survived for one year, with the cause of death being due to internal parasites. The same pair bred again and the female produced two calves which were stillborn. This same female was re-paired with another male and bred once again, but this pregnancy resulted in an aborted calf. Testing revealed that this female had become infected with the Blue Tongue Virus and Leptospirosis which causes stillbirths and abortions. In 1997 one of the females gave birth to the fourth tamaraw calf, which died during the birthing process. By 1999 the captive population consisted of only four tamaraw (two males and two females) and the only reproducing female gave birth to the fifth calf, which is the sole remaining tamaraw in captivity today. Although considered a failure by many, the fact that animals were able to breed and live to old age demonstrates that with better and more modern animal husbandry techniques, a conservation breeding program could, in fact, play a very valuable role in tamaraw recovery efforts.

Population Modelling and Conservation Planning

In 1996, at the invitation of the Department of Environment and Natural Resources, a three-day tamaraw conservation planning workshop was facilitated by the IUCN SSC

Conservation Planning Specialist Group (CPSG), working in partnership with the University of the Philippines Los Banos Foundation and the IUCN SSC Asian Wild Cattle Specialist Group. The workshop followed a process known as Population and Habitat Viability Assessment (PHVA), which was designed by CPSG with the explicit aim of enabling diverse groups of stakeholders to build achievable species conservation plans quickly and collaboratively, using the best available information and relevant science-based tools. Key to the PHVA process is the integrated use of population simulation models, built using the software tool VORTEX (Lacy and Pollak, 2017), which help workshop participants to visualise and evaluate the relative impact on the species' long-term viability, of specific threats and of alternative management strategies. To ensure that the views and values of relevant stakeholders are accounted for in the planning process, workshops are carefully designed and facilitated to encourage full participation. This is particularly important for ensuring uptake and support for the implementation of recommended activities.

The results of the 1996 modelling work emphasized the vulnerability of all remaining tamaraw populations due to their small size and particularly when challenged by even relatively low rates of poaching. For example, modelled populations of 50 tamaraw showed a 100% probability of extinction at poaching rates of three animals per year, with a mean time to extinction of 18 years (de Leon *et al*., 1996).

At the time of the 1996 PHVA it was considered possible that as many as six extant populations of tamaraw remained in Mindoro, but only two were confirmed to exist. Those were in Iglit-Baco National Park (est. n=20-175 individuals) and Aruyan (est. n=14-30 individuals) (de Leon *et al*., 1996). The PHVA made some critical recommendations for the conservation of remaining populations, including creating a dedicated protection force in the Iglit Ranges and Aruyan, island-wide surveys and regular censuses using appropriate methods, filling important data gaps relating to tamaraw and the threats to its persistence, developing management plans for key sites, and increasing the participation of and benefits to local communities of tamaraw conservation initiatives (de Leon *et al*., 1996).

Twenty-two years after the PHVA workshop, it is clear that measures to implement its recommendations have achieved success for the tamaraw. In MIBNP for example, where all the recommendations have been implemented to varying extents, by the TCP and the park staff (with assistance from all concerned local government units and recent support from the D'Aboville Foundation, Mindoro Biodiversity Conservation Foundation, Inc., WWF-Philippines, and the Far Eastern University), the number of tamaraw has increased steadily over the years (Table 1). However, in areas where recommended conservation action has not been taken, or has been insufficient, populations are now presumed extirpated (e.g. Mount Calavite, Santa Cruz, and Bongabong), at high risk (e.g. Aruyan -Malati), or at risk of further decline (e.g. Upper Amnay Watershed Region).

In December of 2018, the DENR and provincial government offices will host a second PHVA workshop which will review progress since 1996, evaluate new information, assess current challenges and opportunities, towards a new Mindoro Multi-Population Conservation Plan for Tamaraw which will re-invigorate and re-direct efforts to support recovery and conservation of the species.

Discussion

The metapopulation of the tamaraw has collapsed in the past hundred years, and even in the twenty years since the first PHVA workshop was conducted. At least one sub-population has been lost and two others are approaching extirpation, while exchange of animals between subpopulations has ceased.

Seeing the increase in the MIBNP population as an unqualified conservation success is not however wise at this point. Although numbers appear to have been increasing annually, the distribution of the population has undergone a significant contraction (Figure 4). It is not clear whether the population has really increased, or whether we are just observing an increase in density of the population within the count area. Urgent studies are required to answer this question and understand the population dynamics in the count zone. Whatever the answer, the population is clearly not free from pressure, and new solutions are needed to stabilize and then reverse this concentration of the population, enabling the species to expand again in both number and distribution.

These solutions will have to include the clarification of the zones of use within MIBNP, strengthening the collaboration with the IP communities inside the park and enforcing protection of tamaraw against illegal activities by those entering from outside the park. The implementation of the Park Management Plan in 2019 will be a first step to achieving this.

The increase of the Iglit-Baco population of tamaraw provides hope that the small, isolated populations remaining in the Upper Amnay Watershed Region and in Aruyan-Malati could also recover. However, it is clear from the PHVA models that this cannot occur if even low levels of hunting or poaching are allowed to continue. Therefore, urgent measures are required at both sites to eliminate all hunting or poaching; otherwise it is likely that the tamaraw will soon be isolated to a single population, concentrated in a decreasing area. Putting all the tamaraw in one shrinking basket is not a strategy that is likely to lead to effective recovery of the species.

Twenty-two years after the 1996 PHVA workshop, it is clear that measures to implement its recommendations have achieved some success for the tamaraw. However, continuing assessment and adaptation of conservation actions are necessary in the fast-changing human and environmental landscape of Mindoro. In December 2018, the DENR and provincial government offices will host a second PHVA workshop to create the Mindoro Tamaraw Action Plan. Coordinating conservation management of all tamaraw populations as a meta-population will be essential for successful implementation of the recommendations from this workshop. This multi-site planning and implementation approach requires the resources of a range of partner organisations, working in collaboration with local communities and other stakeholders, coordinated by a single lead body.

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