BULLetin

Journal of the IUCN SSC Asian Wild Cattle Specialist Group

IUCN SSC Species Survival Commission AWCSG Asian Wild Cattle Specialist Group

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AWCSG Asian Wild Cattle Specialist Group

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EDITOR'S NOTE

By James Burton, AWCSG Chair &
Corinne Bailey, AWCSG Programme Officer

Welcome to the fifth issue of BULLetin, the newsletter of the IUCN SSC Asian Wild Cattle Specialist Group (AWCSG). In BULLetin, we present novel research on the ecology and conservation of Asian wild cattle species, and share stories about their conservation.

This year has certainly been a year for adapting to new circumstances. I am amazed by people's initiative and how much is possible in these times. Thanks for your continued efforts in conserving Asian wild cattle and buffalos.

At the start of the year, we were lucky to hold a meeting on tamaraw conservation with Philippine Congresswoman Sato and government representatives from the Biodiversity Management Bureau and the Regional Executive Office for MIMAROPA. We look forward to doubling our joint efforts in 2021.

The Saola Working Group has made strong progress with building in-country coordination in Lao PDR and Vietnam, with two National Coordinators. We are currently preparing for meetings in early 2021 with implementing partners to strengthen links and chart a plan for 2021 and 2022. More information is explained in this issue.

Many activities of the Action Indonesia partnership for anoa and banteng have moved online this year. We have summarised the progress of this collaboration over the last four years in an article in this issue.

This issue contains a wide range of reports from field conservation, including an account of the application of SMART to conserve tamaraw and the results of a camera trap survey to determine the relative abundance of banteng and gaur in Myanmar. We are also happy to feature a novel research piece on the ecological determinants of density patterns of gaur in the Western Ghats of India.

As we approach the end of the IUCN quadrennium I wish to share with you the steps ahead. I am very pleased to continue as Chair of the group for a further four years, following the invitation from the Chair of SSC, Jon Paul Rodríguez. We will soon begin planning our priorities for 2021-24. So do share your ideas of projects you would like to collaborate on, ways we can work together, or recommendations of how the group can operate more effectively. We will be in contact to propose our ideas to you. Membership of AWCSG will also be updated in the coming months and so you will need to respond to continue your membership.

I would like to share my thanks to everyone that have provided articles and news for BULLetin newsletter, since our first edition two years ago. Also thanks to Corinne Bailey, Johanna Rode Margono, Stu Young, Ellen Marandola, Lottie Siddle and Caitlin Cross for their editorial work to publish these.

The sixth issue of BULLetin will be published in mid 2021 and we look forward to receiving your interesting articles and updates. Get in touch via social media, our website or contact Corinne at c.bailey@chesterzoo.org.

We hope you enjoy this issue, and wish you all a safe end to the year and start of 2021.

NEWS AND UPDATES

Development of the Saola Working Group – refining our approach

By James Burton, AWCSG Chair

The Critically Endangered saola is one of the highest priorities of AWCSG; it's found in the Annamite mountains bordering Vietnam and Lao PDR. The lack of confirmed records in recent years means collaborative conservation action is urgently needed. The Saola Working Group (SWG), a group within AWCSG, has more than 30 voluntary expert members and a wide range of supporting partner organisations from range country NGOs, governments, zoos and universities. This update explains the broad approach that the SWG will implement in the coming two years. We are currently working with members and partners to define this in greater detail.

The SWG mission is to work collaboratively to conserve saola in nature, and to leverage Saola as a flagship for conservation of the bio-cultural diversity of the Annamite Mountains as a whole. SWG's approach is founded on four critical pillars:

- **Knowledge:** act as the global repository for knowledge on saola
- **Coordination**: developing a co-ordinated strategy and defining effective methods
- **Collaboration:** working through implementing partners on the ground to save saola
- **Support**: securing funding and support for priority saola conservation projects

We achieve the first of these by engaging with partners across detection, *in situ* protection and captive breeding to produce a single Saola Conservation Strategic Plan for 2021-22. Implementation of this One Plan will be coordinated by SWG. SWG members will provide technical expertise to recommend the most

Juvenile saola. Photo: Jonathan Eames

appropriate Saola detection methodologies.

We fundraise jointly with partners to increase the effort for saola detection and other areas of work. To achieve greatest impact, we identify highest priority projects for funding support.

We recognise the urgent need to secure evidence of this unique species through field detection, so catalysing all partners in this effort is essential. We appreciate that current times are challenging for many of you, but we hope that you will continue to support SWG in the coming years.

We collaborate with partners to implement saola detection. This is somewhat different from in past years where SWG has also conducted its own detection efforts. We believe we can generate greater impact by encouraging partner involvement and aligning and maximising effort. So we will now focus our efforts on supporting implementing partners to detect saola to give us a greater chance of successful saola detection.

To achieve this approach SWG will:

- Raise the profile of saola internationally
- Lead the One Plan Approach to saola conservation
- Catalyse saola conservation by implementing partners across the range
- Provide capacity for saola detection efforts through implementing partners
- Provide facilities for *ex situ* breeding
- Act as the global knowledge repository to enable information-led conservation actions
- Achieve positive political support for saola and Annamite Mountains conservation.

SWG has developed a new structure to work more closely with in-country partners. IUCN Lao and WWF Vietnam will host two National Coordinators, who will work with partners to catalyse them to contribute to saola detection work and also support their efforts where needed. The SWG's Governance Body, Fundraising Group and a revised technical advisory group will all work closely with the National Coordinators to deliver our approach.

We are currently working with partners and members to update a saola knowledge review to give us the best understanding of the status of saola and of the efforts already conducted to detect saola. We are also working with partners on a plan for saola detection for 2021-22, through partner meetings in Vietnam and Lao. Also, we are reaching out to donors / supporters to share more news about our exciting plans for the coming year. Please get in touch if you would like to offer support or learn more: saolawg@gmail.com

We would like to thank all members of SWG and partners for their work and support. Thanks to IUCN Lao and WWF Vietnam for their help in hosting the National Coordinators. Also, thanks to Bill Robichaud and Olivia Petre for their leadership of SWG over the past years and for the successes they have delivered. We recognise the urgent need to secure evidence of this unique species through field detection, so catalysing all partners in this effort is essential. We appreciate that current times are challenging for many of you, but we hope that you will continue to support SWG in the coming years.

Khe Nuoc Trong Nature Reserve – hope for the saola?

By Caitlin Cross, Field Programmes Intern, Chester Zoo

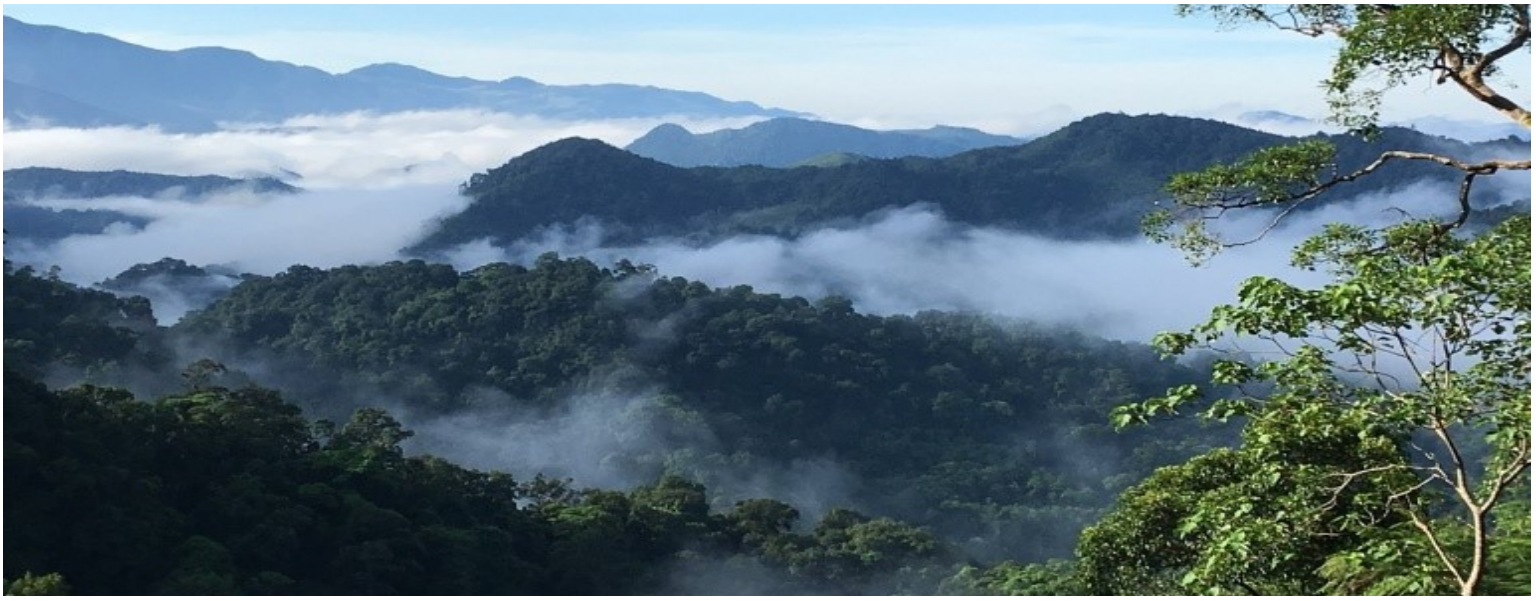
Summary of a press release by World Land Trust

A new nature reserve has been created in Dong Chau – Khe Nuoc Trong to protect over 40 globally threatened species, including the Critically Endangered saola (*Pseudoryx nghetinhensis*).

Conservation body Viet Nature were able to secure the highest government fortification for the 22,132 hectare forest – upgrading the watershed protection, which previously focused on preventing logging in the area, to include specific mandates for wildlife conservation.

For the saola, the continued protection of habitats such as the Khe Nuoc Trong forest may be vital for the survival of the species. They are one of the world's rarest mammals, only described to science in 1992, which reasons the nickname of the 'Asian Unicorn'. With fewer than 250 individuals thought to be remaining in the world, they are extremely vulnerable to threats such as poaching, snaring and habitat loss – destructive action that is strictly prohibited in the nature reserve.

Conservationists have monitored the area over the past decade, using surveys and camera trap data to better understand the biodiversity of the forest. Their results are encouraging and show that other threatened species still exist there, so this means that the saola could still persist in the area, despite there being no live records of the species due to their elusive nature. The hope is that with continued legislative support to decrease the likelihood of hunting, populations of the saola may increase, contributing to the conservation of the saola, the Critically Endangered large-antlered muntjac *(Muntiacus vuquangensis)* and other species under threat.



Khe Nuoc Trong Nature Reserve, Photo: Viet Nature Conservation Centre

Population decline of banteng and gaur in Keo Seima Wildlife Sanctuary 2010-2020

By Caitlin Cross, Field Programmes Intern, Chester Zoo

Summary of report: **Status of Key Species in Keo Seima Wildlife Sanctuary 2010-2020.** http://doi.org/10.19121/2020.Report.38511

Wildlife Conservation Society (WCS) Cambodia have published a report on the status of key species in Keo Seima Wildlife Sanctuary (KSWS) between 2010-2020. This includes figures for banteng (*Bos javanicus)* and gaur (*Bos gaurus)*, which show significant population declines.

KSWS is composed of a mosaic of habitat types, spanning a total of 292,690 hectares. Legal protection was first provided to the area in 2002 with the creation of 'Seima Biodiversity Conservation Area', which later became KSWS in 2016 under the management of the Ministry of Environment. It has the highest number of species recorded for any protected area in Cambodia, with over 1000 species recorded, 75 of which are globally threatened. The site was surveyed over 10 years using distance sampling methodology in 40 square transects throughout the core KSWS area. Each transect was surveyed multiple times during the survey season, with teams recording all observations of 13 key species.

With the exception of the wild pig, all ungulate species populations within the KSWS were found to be declining. Banteng and gaur are now at such low densities that future monitoring with line transects will not give robust population estimates. Rates of decline within KSWS (where REDD+ project management was implemented) are likely to be slower than outside of protected areas, nevertheless this slowed rate of loss will not be sufficient to retain healthy populations. Without large ungulates in KSWS, entire ecosystems would degrade, in turn degrading the natural resources that many Cambodians rely on.

The scale of threats to Cambodia's natural resources and biodiversity is very high, and hunting is a large threat to banteng and gaur. Management recommendations are in place, including the deployment of anti-snare teams in areas of high biodiversity. However, to be most effective, this must be combined with more direct intervention due to the severity of the decline. Captive breeding programmes and patrolled fenced areas may be required to allow time for species recovery.

Banteng, Preah Vihear, Photo:WCS Cambodia

RESEARCH AND REPORTS

Application of Spatial Monitoring and Reporting Tool (SMART) in tamaraw conservation

By Del Mundo, N[1].; Garcia, F.G.[2]; Schutz E.[2]; Santos, R.B.[2],Secreto, E[3]; Slade, J.L.[4]; and Tabanggay, M.K.[1]*

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Introduction

The tamaraw (*Bubalus mindorensis*) is a Critically Endangered species of dwarf buffalo found only on the island of Mindoro in the Philippines. The tamaraw population is currently estimated at less than 600 individuals, from an estimated population of 10,000 in 1900 (Harrison 1969 in Long et al, 2018). 80% of the current population is presumed to be in only one subpopulation in a restricted area of less than 3,000 hectares inside the Mts Iglit-Baco Natural Park (MIBNP), the largest protected area of the island. Traditional land-use practices from the residing Indigenous Communities and poaching incidents from lowlander Filipinos are currently the main threats to the viability of these subpopulations, limiting their chance to expand. In such a context, the capacity of rangers to conduct efficient patrols and collect relevant information is crucial to determine proper strategies for conservation and impede the killing of animals.

Since 2013, the D'Aboville Foundation and Demo Farm Inc. (DAF) have been supporting local authorities in their task to protect the species through its Mangyan-Tamaraw Driven Landscape Program. The urgent need to improve the monitoring capacity of the tamaraw rangers in the field was addressed through basic actions: provision of patrol gear, use of GPS devices and printed patrol maps with a coding system.

The formulation of two major plans in 2018 and 2019, the Tamaraw Conservation and Management Action Plan (TCMAP) 2019 - 2028 (DENR, 2019) and the MIBNP Protected Area Management Plan (PAMP) 2019 – 2028 (MIBNP-PAMO, 2020), called for the next step to upscale these initial attempts. SMART was already in use by the Philippines Department of Environment and Natural Resources (DENR), through their Lawin Forest and Biodiversity Protection System, led by the Forest Management Bureau (FMB). The DENR was eager to expand the use of this technology to protected areas. MIBNP therefore serves as a pilot site and the tamaraw as a focus species to test and establish SMART at a local scale. Global Wildlife Conservation (GWC), a DAF-supporting partner, took the lead in tackling this task through the provision of support and expertise. GWC is a SMART Partnership

member, supporting the development of the software and capacity building for SMART. Establishing SMART in tamaraw conservation is described in both major plans as a key activity to help improve the monitoring of the species across Mindoro and support the expansion of its range from its current distribution (baseline year: 2019). The implementation of SMART falls under Goal 8 (Strengthen Law Enforcement and Wildlife Crime Prevention of the TCMAP) and Program 4 (Wildlife Crime Prevention, Law Enforcement, and Compliance) of the MIBNP PAMP.

Baseline situation

Prior to the introduction of SMART, routine tamaraw-focused patrols in Mindoro were conducted by the rangers of the Tamaraw Conservation Program (TCP), a program established by the DENR in 1979 (Long et al, 2018). In MIBNP, DENR forest rangers were conducting patrols using CyberTracker and SMART, but these were focused on forest protection under Lawin (USAID/BWISER, 2018). There were 23 TCP rangers in 2018 and eight at the MIBNP Protected Area Management Office (PAMO). The TCP rangers conducted patrols in the Core Zone of Monitoring (CZM) for the tamaraw and the surrounding buffer area within the 106,655 hectare natural park. The CZM constitutes about 3% of the park. The rangers monitored and recorded the presence of wildlife as well as human activities. They recorded their observations and submitted these to the TCP headquarters. Records were written on paper and maps, using the rangers' knowledge and their navigation skills to position the events, as they lacked sufficient equipment, as well as structured data collection protocols and a system to record coordinates. This situation made it difficult to compile and track all the observed information, develop proper data management, and consequently visualize, conceptualize and analyze the data.

Inception and initial workshops

SMART was first discussed with stakeholders in Mindoro during the planning processes for both TCMAP and MIBNP PAMP during 2017 and 2018. This was followed by a series of meetings with staff of the Biodiversity Management Bureau and the Regional Office of DENR for Mindoro's Provinces in March 2019 to discuss the implementation of SMART for tamaraw conservation, and to get a copy of the existing SMART database from Lawin. Thereafter, a GWC and DAF-led team were invited by the Protected Area Management Board of MIBNP (PAMB-MIBNP) to propose and present a plan for implementing SMART in this Protected Area.

The first actions included a series of assessments, workshops, training and field-based activities conducted in April and May 2019 in order to introduce the SMART and its use to both the TCP and the MIBNP-PAMO. These activities included the creation of a data model suited specifically for both tamaraw conservation and management of the MIBNP, the testing of the data model and, at the same time, the coaching of the rangers in conducting patrols using sturdy mobile data collection devices to record patrol effort and observations. Data managers were selected among the staff and trained together with ranger team leaders and head officers. Training concluded with how to analyze and use data collected in the field to support information-based decision making and adaptive management in patrol planning.

Building capacity on the ground

Following this inception phase, both offices were provided with the necessary equipment to properly implement SMART through the support of GWC and DAF: One desktop computer placed at the TCP Office and another one at the PAMO, one laptop assigned for use at Station 2, where solar power is now available and 12 Blackview BV6000 rugged data collection devices, installed with CyberTracker software, for use by the rangers and DAF field team.

This enabled the rangers to collect field data, import it into the SMART database, store it first in the laptop at the Station, and later transfer it to the TCP and PAMO desktops through a USB stick. Capacity building involved two complementary layers: (a) training of the rangers assigned to the field to learn how to use CyberTracker to properly record observations and import the patrol data to the SMART database, but also how to prepare for patrols and how to react when confronted with certain situations during a patrol, and (b) office-based training focusing on data management (creating queries and reports) and using the results for adaptive management.

At a later stage, data managers were taught how to use the "independent incidents" feature of SMART. This feature allows the recording of data observed outside patrols. For example, when a ranger is off-duty and is doing extra work as a guide for trekkers. These were recorded as independent incidents, which explains why some observations of animals in the map (Fig. 5) do not fall within patrol routes.

The power of SMART progressively came to light as it encouraged stronger cooperation between the two offices and stimulated interaction between the field and office personnel. Joint meetings between TCP and PAMO are now organized on a regular basis to share data, visualize results of patrol efforts and discuss information collected. The results of analysis inform plans for the next patrol and help to assess actions needed.

Training and mentorship of TCP and PAMO staff is a constant, steady, and ongoing process, while rangers and officers are accumulating experience in using the devices and becoming familiar with computer-based systems.

Data Model and Metadata

The data model refers to the structure of the data that is collected during patrols; such as wildlife or human activities observed. Metadata, on the other hand, consists of information about the protected area; such as stations, patrol teams, mandates or patrol types. These data are not collected during patrols, but are instead necessary to better analyze patrol data specific to the efforts of MIBNP.

The data model in the SMART database of TCP and MIBNP PAMO was created based on the data model of DENR's Lawin system already in use. Two categories needed to be added, as the Lawin data model was designed mainly for forest protection, not wildlife conservation or protected area management. One of these categories is "Human Activities", which distinguishes between traditional and non-traditional practices. Traditional practices include the ancestral land uses of the Indigenous

People inhabiting the park, while non-traditional practices consist of the illegal practices which fall outside of the previous definition. The other category is “Biodiversity Monitoring” which includes wildlife that are not in the Lawin list of indicator species of forest health, such as the tamaraw.

The data model was created through an iterative process, via a series of meetings among the rangers and the TCP and MIBNP PAMO management. A configurable model, consisting of a representation of the data model to easily collect the data with the field devices, was designed and field tested. The rangers conducted scenario-driven patrols and recorded theoretical observations to determine if the configurable model was complete, appropriate, to identify areas of improvement, and get used to the process of exporting and importing patrol data between desktops and field devices.

Metadata included a list of all employees who would be using SMART in some capacity. This consisted of rangers, data managers, DAF field staff, and the trainers. Only the TCP Coordinator and the Protected Area Superintendent of MIBNP were given the full administrative permissions while data managers were given the access to analyse and enter data and patrol team leaders were given the ability to enter data collected from the field. Other rangers were not included as SMART users, but trained to collect data using CyberTracker using the field devices, with no need to access the database.

The metadata also included a list of ranger stations, patrol teams, patrol types, and patrol mandates (with patrolling and monitoring as the core objective). Maps, similar to those paper maps used in the field by rangers, were also designed for the database.

In the last quarter of 2019, the SMART database was upgraded from SMART 6.1 to SMART 6.2.3. For security, the mobile devices were locked, to ensure only the CyberTracker software would run, to avoid data loss or the misuse of DENR property. There are plans to upgrade the system in the future and shift to SMART Mobile for data collection, which is the latest version of CyberTracker.

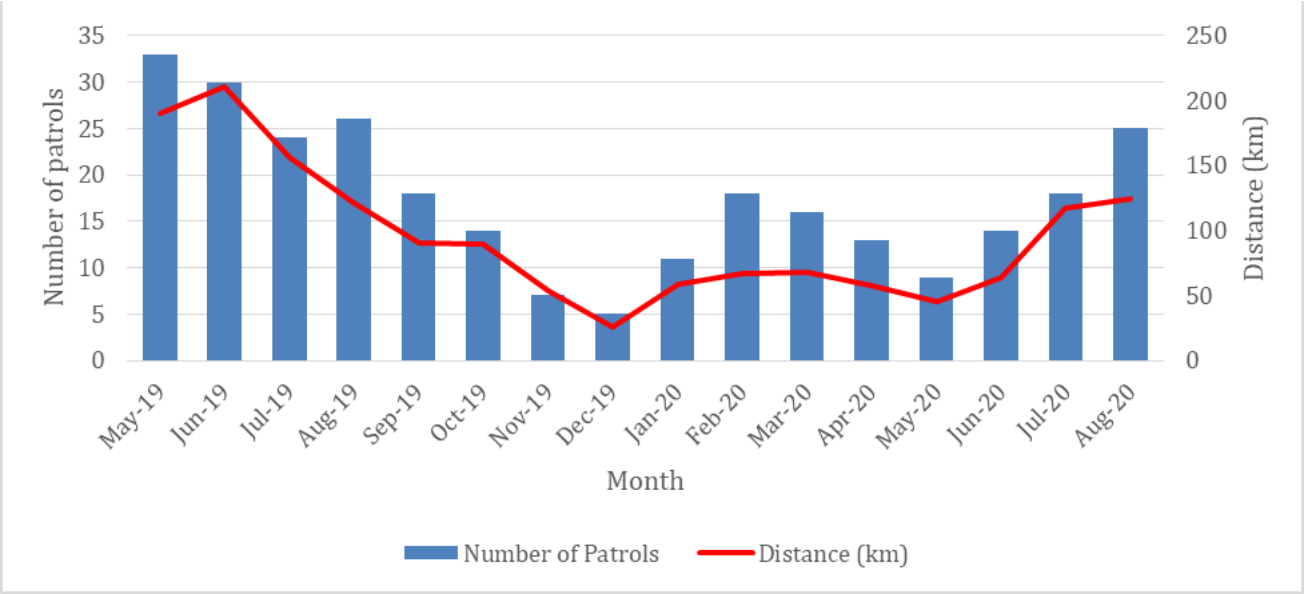

Figure 1. TCP patrol effort in MIBNP (May 2019 - August 2020)

Results

Patrol coverage and effort:

Patrols during the 16-month period from May 2019 to August 2020 covered the trails from Station 1 to Station 2, the area within and around the "Core Zone of Monitoring" where most of the tamaraws have been observed, and the area around the Tamaraw Gene Pool (see Patrol routes in Figs 3-5).

The area patrolled so far is confined to the elevations from 200 to 1400m and constitute approximately twice the area of the CZM or six percent of the total area of the park. Some higher elevation areas that have not been patrolled will be explored by TCP and DAF in the near future. Patrol efforts from May 2019 to August 2020 averaged 17 patrols, covering a distance of 96 kilometers for all the patrol teams of TCP and MIBNP per month, or four patrols and 24 kilometers per week for all the patrol teams (Fig. 1). Patrol effort, however, was not consistent. It decreased towards the end of 2019 due to rangers needing to prioritise other non-patrolling related tasks, then slightly increased in the beginning of 2020 before decreasing again during the start of the Covid-19 pandemic, when the Tau buid leadership prohibited rangers residing in towns with known Covid-19 cases from entering the park. Patrol effort has started to increase again in the last three months, focusing on areas where evidence of poaching collected with the SMART system were observed in previous patrols.

Recorded Observations:

Using CyberTracker installed on mobile devices, rangers record incidents and signs of activity that have an impact on tamaraw conservation. These include any of the illegal activities outlined in Section 20 (Prohibited Acts) of the Expanded National Integrated Protected Areas System Act of 2018; such as poaching, littering, illegal entry, or the traditional activities of the IPs, which are not regarded as illegal, but may affect tamaraw conservation if not carefully monitored. The rangers then record the actions that they carry out to address these activities. During patrols rangers also record the presence of three important mammals; tamaraw, Oliver's warty pig (*Sus oliveri*), and Philippine brown deer (*Rusa marianna*).

If the animals were seen outside patrols these were recorded as 'independent incidents' directly in the SMART database so that these can be included in the queries and reports. Signs of the presence of these animals (dung, tracks, etc.) were only recorded if these were found in areas outside of the 'Core Zone of Monitoring' and are therefore evidence of an increasing range.

Over a 16-month period, the rangers recorded evidence of 40 incidents of illegal activity in MIBNP, from eight of the 16 classifications of threat identified in the SMART data model (Fig. 2). The locations where these illegal activities were observed are shown in Fig. 3. Most of the illegal activities were observed outside the Core Zone of Monitoring. The identified locations of these illegal activities during patrols informed the design of the targeted areas for future patrol efforts.

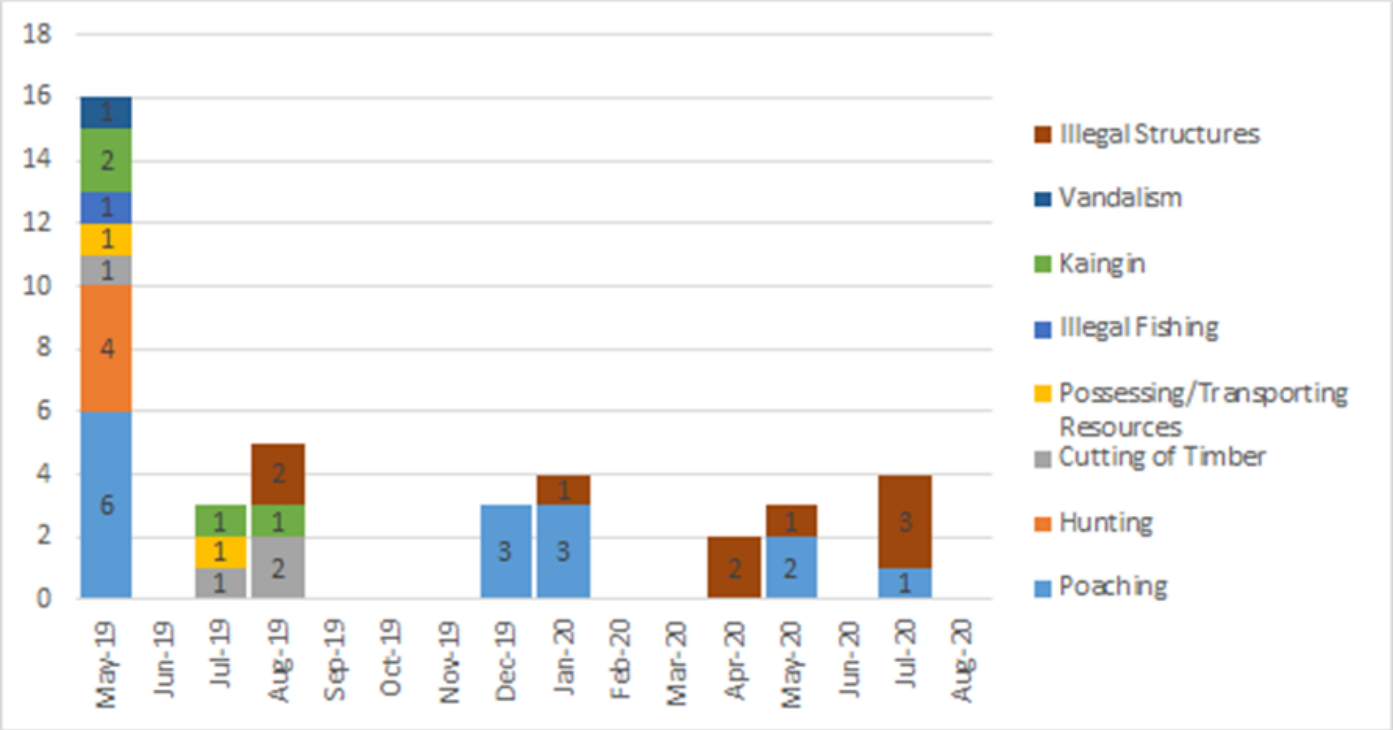

Figure 2. Illegal activities observed and recorded (May 2019 - August 2020)

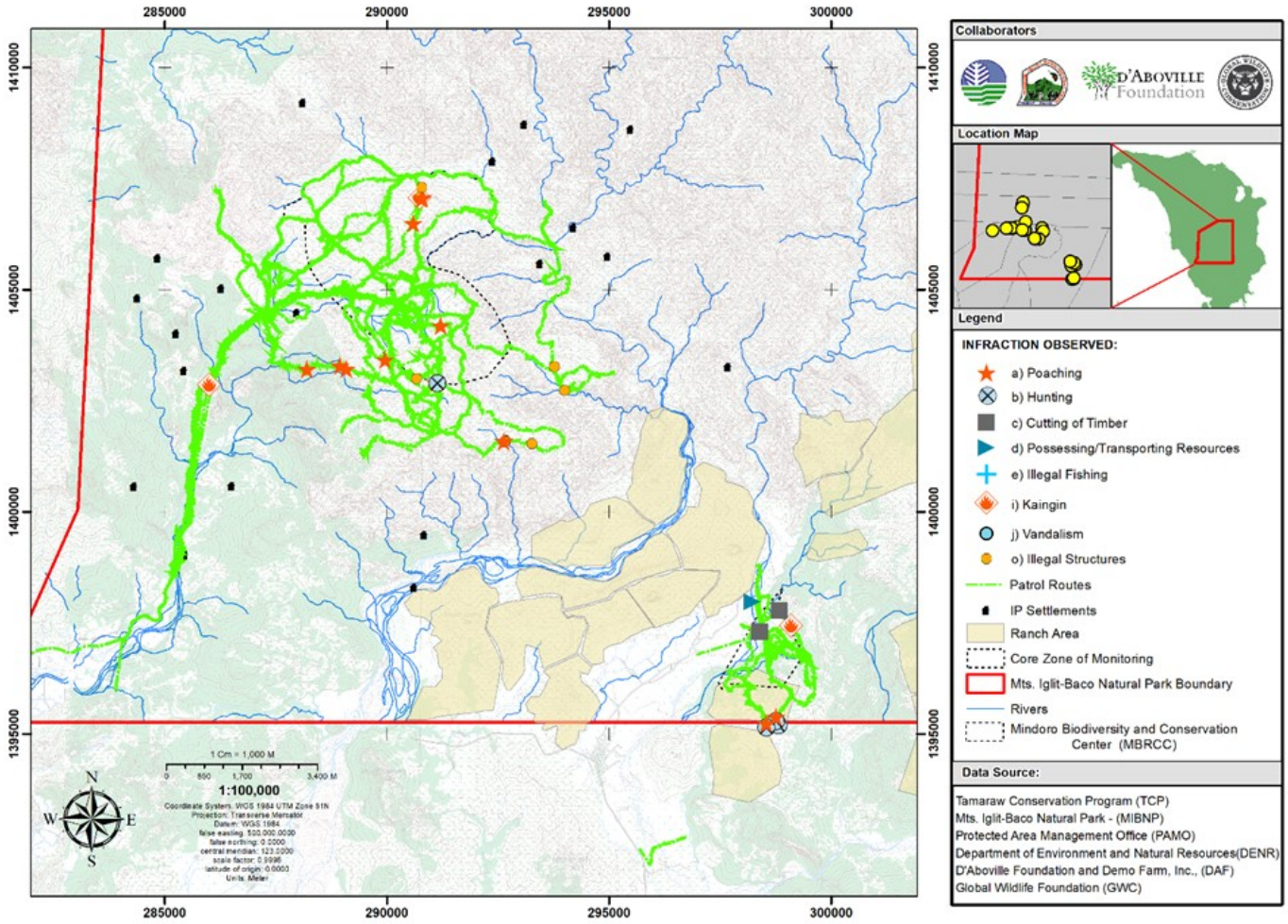

Figure 3. Locations of observed illegal activities (May 2019 - August 2020)

The rangers also recorded traditional practices of Indigenous Peoples (Tau buid) in the areas that they observed during patrols. During the 16-month period, they observed evidence of five types of traditional activities: kaingin (slash and burn agriculture), collection of non-timber forest products (NTFP), construction of temporary settlements, installation of traps and trap warning signs (Fig. 4). The majority of these activities were recorded outside the CZM. Those that were found inside were discussed with the Indigenous leaders in the area to determine the strategies for addressing and managing any activity which contravenes the agreements in place.

There were 290 tamaraw, 15 warty pig, and 18 Philippine brown deer encounters during patrols from May 2019 to August 2020 (Fig. 5)

The monthly tamaraw encounter rate averaged 0.07 individuals per kilometer (1 per 14.3 km) but this computation included 'patrols' conducted along the trails from Station 1 to Station 2 and Station 3.

Most of the observations of tamaraws were located in the CZM, although there were some observations outside the CZM. Warty pigs were observed mostly outside the CZM and around the Tamaraw Gene Pool Farm, while Philippine brown deers were observed inside and outside the CZM.

Recording and Monitoring Actions Taken

All the actions the rangers took were recorded and serious offences were communicated to local authorities. The rangers dismantled/ destroyed the traps located within the No

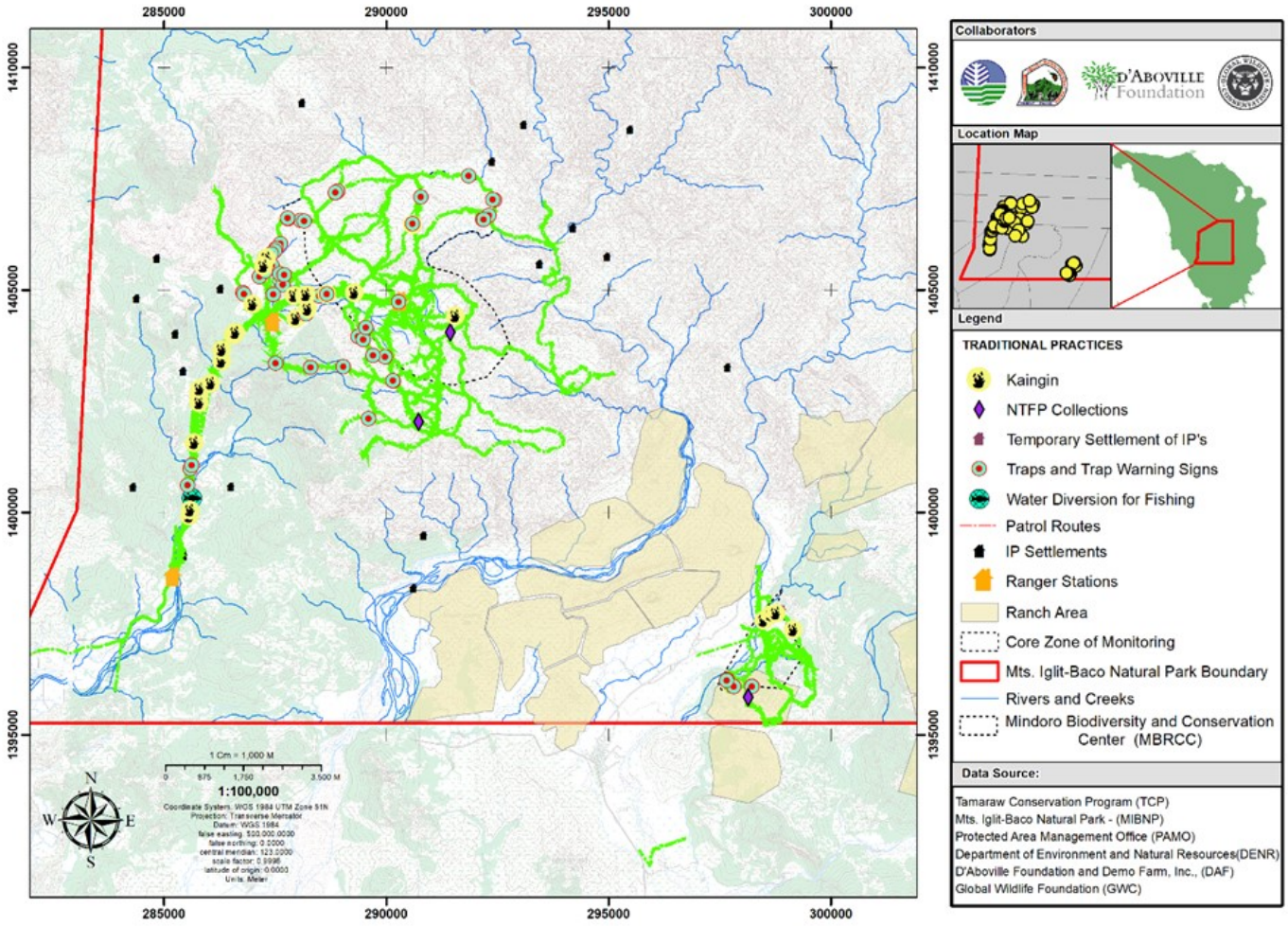

Figure 4. Observed traditional activities May 2019 - August 2020.

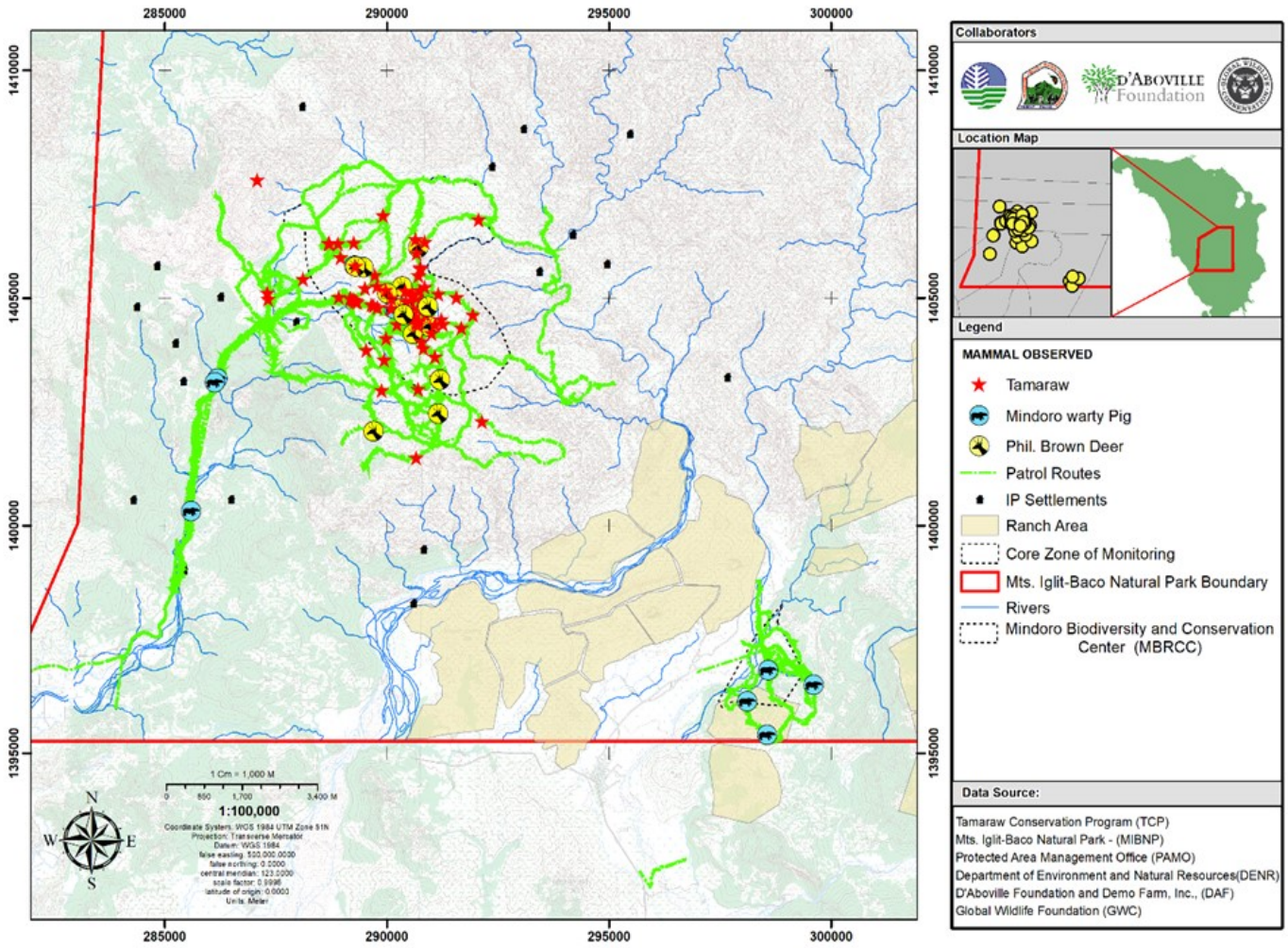

Figure 5. Mammals Direct Observation points (May 2019 - August 2020). Note: There is usually more than one tamaraw in an observation point.

Hunting Area and collected materials, such as nylons, that were used for the non-traditional practice of trapping animals (Table 1).

Table 1: Actions taken (May 2019 - August 2020)

Action taken	Number	%
Documented only	37	76%
Collected	7	14%
Dismantled/destroyed	5	10%
Total	49	

Summary after two years of experience

The implementation of SMART in tamaraw conservation resulted in two fundamental changes: 1) it enabled the geo-referenced recording of patrol effort, observations, and actions taken during and outside of patrols; and 2) allowed spatial and statistical analyses of the patrol data to inform further patrol planning and management decisions. Patrol data can now be queried, analyzed, and visualized in more ways than was shown in this article. SMART has so far only been used for patrolling and monitoring, but can also be used in ecological monitoring, visitor management, and in other aspects of protected area management. The way SMART is implemented in tamaraw conservation can still be improved in some aspects, such as ensuring better data quality assessment, better design of predetermined queries and reports used for monthly, quarterly, or annual reporting and on-

demand queries needed on a daily basis for quick decision-making.

However, the use of SMART for the past 16 months has provided a baseline that can be used in advancing patrol evaluations, impact monitoring and protected area management performance in the future.

The establishment of the SMART Technology for tamaraw conservation in Mindoro is coordinated by DAF and GWC with their local partners thanks to the financial support of the Mohamed Bin Zayed Conservation Fund, the National Geographic Society, Berlin Tierpark, ZGAP and the Association Française des Parc Zoologiques.

References:

Long, B. et al (2018). Review of tamaraw (Bubalus mindorensis) status and conservation actions. BULLetin, Issue Number 1, IUCN/SSC Asian Wild Cattle Specialist Group

DENR-BMB and DENR-MIMAROPA Regional Office (2019). Tamaraw Conservation and Management Action Plan 2019 – 2028. Department of Environment and Natural Resources-Biodiversity Management Bureau, Philippines.

MIBNP-PAMO (2020). Mounts Iglit-Baco Natural Park Protected Area Management Plan 2019 – 2028. MIBNP – Protected Area Management Office, Department of Environment and Natural Resources, Occidental Mindoro, Philippines.

SMART Partnership (2019). SMART Technical Training Manual, SMART 6.

USAID/BWISER (2018). The Lawin Forest and Biodiversity Protection System Manuals. Modules 1 to 4. DENR-Forest Management Bureau, Quezon City, Philippines

USAID/BWISER (2018). Lawin Forest and Biodiversity Protection System: Procedures for Responding to Observed Threats in Forest Conservation Areas. DENR-Forest Management Bureau, Quezon City, Philippines

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Status of two species of threatened wild cattle (*Bos gaurus* and *Bos javanicus birmanicus)* in North Zamari Wildlife Sanctuary, Bago Region, Myanmar

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Key Words: *Bago Yoma, Banteng, Camera trap, Capture rate, Gaur, Myanmar, Relative abundance, Wild cattle*

Abstract

We conducted a camera trap survey from March to June 2020 to determine the relative abundance of banteng and gaur in the North Zamari Wildlife Sanctuary (NZWS) in Bago region of Myanmar. The photo-captures suggested that the banteng was more widespread than the gaur, which was restricted to the southern part of the wildlife sanctuary. We present an assessment of their status in terms of spatial occupancy and relative abundance, the threats they face, and the conservation actions needed to secure their populations in the area. With increased protection and upon population recovery, NZWS could host a globally significant population of the endangered banteng.

Introduction

The current population status of gaur (*Bos gaurus)* and the banteng (*Bos javanicus birmanicus*), two species that occurred commonly in the past (Wharton 1968, Yin 1955) and still persist in a few locations in Myanmar, is poorly known. Wharton (1968) cites older literature and provides a map of known localities and probable distribution range of banteng in Myanmar. He included most of the relatively dry tropical lowland parts of Myanmar, comprising of dry and moist deciduous forests, including the Bago Yoma (Bago mountain range) in the probable range of banteng. Gaur distribution overlapped with banteng, but was stated to be much wider, including the hilly tracts and wet evergreen forests across Myanmar. Surveys completed nearly two decades ago indicated that gaur was widespread and found in 11 out of 17 sites that were surveyed across Myanmar while preparing the National Tiger Action Plan, while banteng was highly restricted and was found in only three out of the 17 sites (Lynam, Khaing and Zaw, 2006; Lynam, 2003). This list of sites includes the Bago Yoma in the extant range map, but does not consider any population in Myanmar as globally significant. Also, it considers the banteng population to be generally declining in Myanmar, in line with the rest of the banteng range in Southeast Asia.

We conducted camera trap surveys in North Zamari Wildlife Sanctuary (NZWS), Bago Yoma range in central Myanmar, to determine the diversity of large mammals, and confirm the persistence of gaur and banteng in the area. We also assessed their spatial occupancy and relative abundance. This was a collaborative effort of the Forest Department, WWF-Myanmar, and Friends of Wildlife (FOW).

Study Area

The NZWS has an area of 981 km^2, and is largely comprised of mixed deciduous and dry deciduous forests. It lies on the western side of the Bago Yoma range, which runs north to south in central Myanmar (Fig. 1). NZWS is severely degraded as a consequence of heavy logging (often for teak, *Tectona grandis*) in the past, accompanied by seasonal fires. Presently, it is a vast expanse of secondary growth, with a high abundance of bamboo.

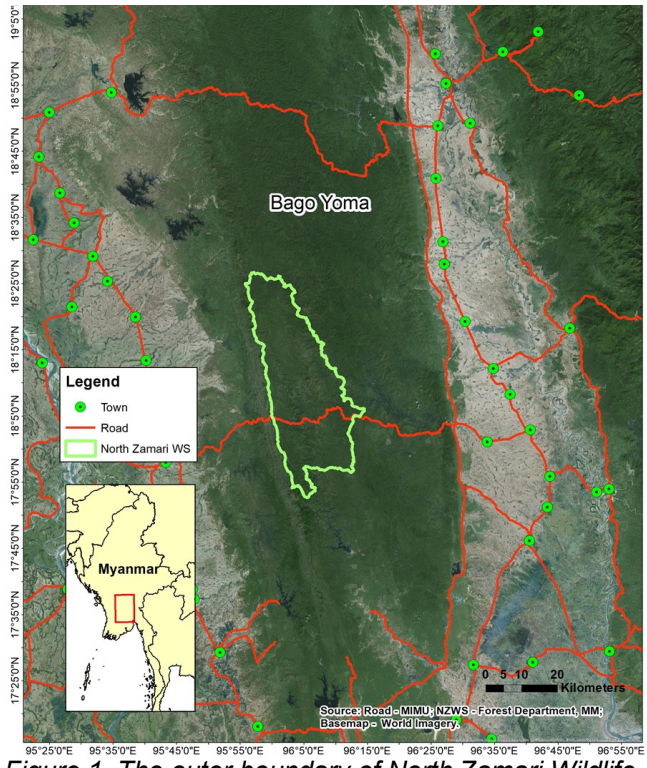


Figure 1. The outer boundary of North Zamari Wildlife Sanctuary (NZWS) laid over Google Earth satellite imagery showing the relatively abundant vegetation cover (green) of the Bago Yoma mountain range. The inset map shows the study area location in Myanmar.

A 10-year logging ban came into effect in Bago Yoma in 2017 and forest restoration efforts are being undertaken by the Forest Department. There is a two-lane road passing through the NZWS from east to west that has existed long before the NZWS was gazetted in 2014.

Methods

We conducted a camera trap survey in NZWS, between March and June 2020, for assessing the diversity of large mammals. An earlier unpublished survey conducted in 2018 by the Forest Research Institute (FRI) of Forest Department and FOW showed that large mammals, including the two wild cattle species, occurred in the area (Table 1). We divided NZWS into 63 grid cells of 4 x 4 km^2 each and deployed a camera trap in each cell to ensure survey coverage of all areas of the sanctuary (Fig. 4a,4b). We placed camera traps at or within 500 m of the centre point of each cell, in locations expected to be used by wildlife species (along trails, near stream-beds, etc.). In this way, the camera traps were evenly distributed and were approximately 4 km apart from each other. We assumed that this spacing would be suitable to cover the individual home ranges of many large mammals present in the area. Camera traps remained in the 'ON' state throughout the day (day and night) and 24-hours constituted a 'trap-day' of survey effort. Photographic captures were considered 'independent' detections only when animals of the same species were captured 30-minutes apart, unless they were of different sex or otherwise clearly individually distinguishable.

Results and Discussion

Although 63 camera traps were deployed for

the survey, data from only 57 camera traps could be retrieved, as six camera traps were either destroyed by fire or were stolen. This resulted in a survey effort of 4,267 camera trap days. 25 species of mammals and 14 species of birds were detected in the camera traps (Table 1, Figs. 2 and 3). In addition, domestic animals such as dogs, cattle, and humans (involved in different types of activities such as illegal hunting, illegal logging, and NTFP collection) were captured in the camera traps.

Previously unpublished data from the 2018 survey in NZWS is presented here for comparison with the results from this survey (Table 1).

Figure 2 (above): Solitary gaur captured in a camera trap in the southern part of NZWS in March 2020.

Figure 3 (below): Female banteng captured in a camera trap in the southern part of NZWS in March 2020.

Table 1. Key characteristics of the camera trap surveys and frequency of banteng detections in North Zamari Wildlife Sanctuary, Bago region, Myanmar.

Survey characteristics	2018	2020
Number of camera traps deployed	16	63
Number of camera traps retrieved and used in analysis	11	57
Survey duration	82 days (Feb – April 2018)	118 days (Mar – Jun 2020)
Number of medium and large mammal species identified from camera trap photos	15	25
Number of bird species identified from camera trap photos	4	14
Other animals, and activities of humans identified from photos	Dogs, cattle, humans (illegal hunters, illegal loggers, and NTFP-collectors)	Dogs, cattle, humans (illegal hunters, illegal loggers, and NTFP-collectors)
Camera trap effort (trap-days)	721	4,267
Area covered (minimum convex polygon area)	229 km^2	890 km^2
Number of banteng detections and number of camera trap locations with detections	4 captures in 3 locations	25 captures in 11 locations
Number of gaur detections and number of camera trap locations with detections	1 capture	14 captures in 2 locations
Minimum distance between banteng detections	5.9 km	3.8 km
Maximum distance between banteng detections	20.2 km	48.6 km
Minimum distance between banteng detections	5.9 km	3.8 km
Maximum distance between banteng detections	20.2 km	48.6 km

Due to the increased survey effort in 2020, in terms of area covered, camera traps placed, and survey period, banteng and gaur were detected at more locations and more frequently than in the 2018 survey (Table 1; Figs. 4a and 4b). There were 25 independent banteng captures in 11 camera trap locations in 2020, as opposed to four independent captures in three camera trap locations in 2018 (Fig. 4a). Out of eleven locations where banteng were detected in 2020, solitary animals were recorded in eight locations and groups of three animals were recorded in three locations. There were 14 independent captures of gaur in two camera trap locations in 2020, as compared to a single detection in 2018 (Fig. 4b). Out of the two locations where gaur was detected in 2020, solitary gaur were found in two locations, and a pair was captured in one location. These results indicate that the 2020 survey, covering whole of NZWS, gave a better representative picture of the occupancy and relative abundance of the wild cattle species.

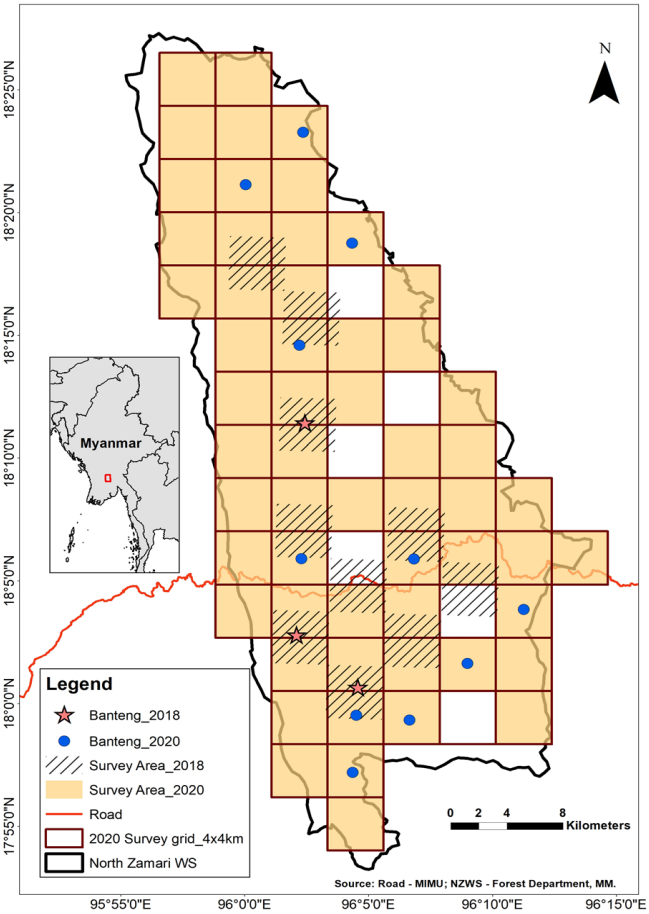
Banteng were distributed across the length of NZWS, with a naïve occupancy of 19.3% (Fig. 4a). On the other hand, gaur distribution appeared to be confined to a few locations, with a naïve occupancy of 3.5% (Fig. 4b). Gaur were detected only in the southern part of NZWS in both years. Hunters were recorded in several camera traps, indicating that hunting pressure may be high. Furthermore, our survey data showed that both banteng and gaur co-occurred in southern NZWS, where a single camera trap captured both the species, although at different times.

Both the wild cattle species were detected from early evenings to late mornings (3 PM to 9 AM), with very few detections between 9 AM to 3 PM during the survey period that is also the hot and dry season (Fig. 5). This concurred with the activity patterns reported from many sites in Asia where gaur were known to graze in the late evenings until late mornings in open grasslands *(A. Christy Williams, personal observations).* There was no discernible difference in activity pattern between banteng and gaur, but the limited number of detections of gaur limits the robustness of this comparison.

Threats

Evidence of human activities such as illegal hunting and illegal logging were detected in camera traps. Habitat loss and hunting are two major threats to the two wild cattle species across their distribution range in Southeast Asia (Gardner et al. 2016). Hunting may be a severe threat in NZWS, as hunters were recorded in 26 of the 57 camera trap locations. This indicated that both gaur and banteng maybe target species for the hunters in NZWS. In addition, detection of gaur only in the southern NZWS in both study years suggested that gaur maybe less resilient to hunting pressure than banteng.

Habitat loss from illegal logging may be a threat presently. However, the historical habitat loss may have played a more significant role than the recent habitat loss for both the species. NZWS comprises mostly of rougher



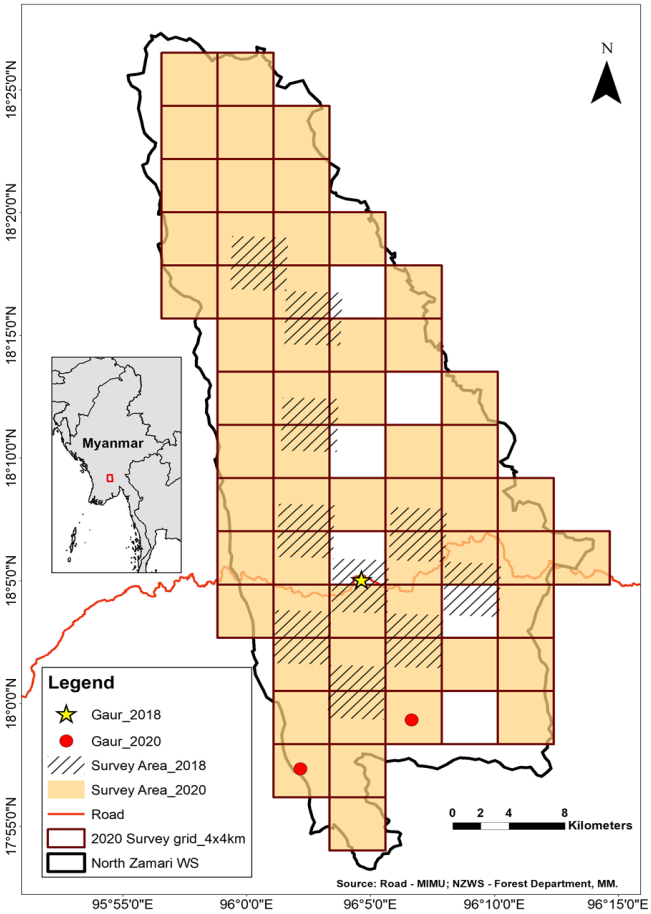


Figure 4a(left). Camera trap locations that captured banteng in 2018 and 2020 surveys, overlaid on the grid cells surveyed in the two years, and on the NZWS boundary.

Figure 4b(right). Camera trap locations that captured gaur in 2018 and 2020 surveys, overlaid on the grid cells surveyed in the two years, and on the NZWS boundary.

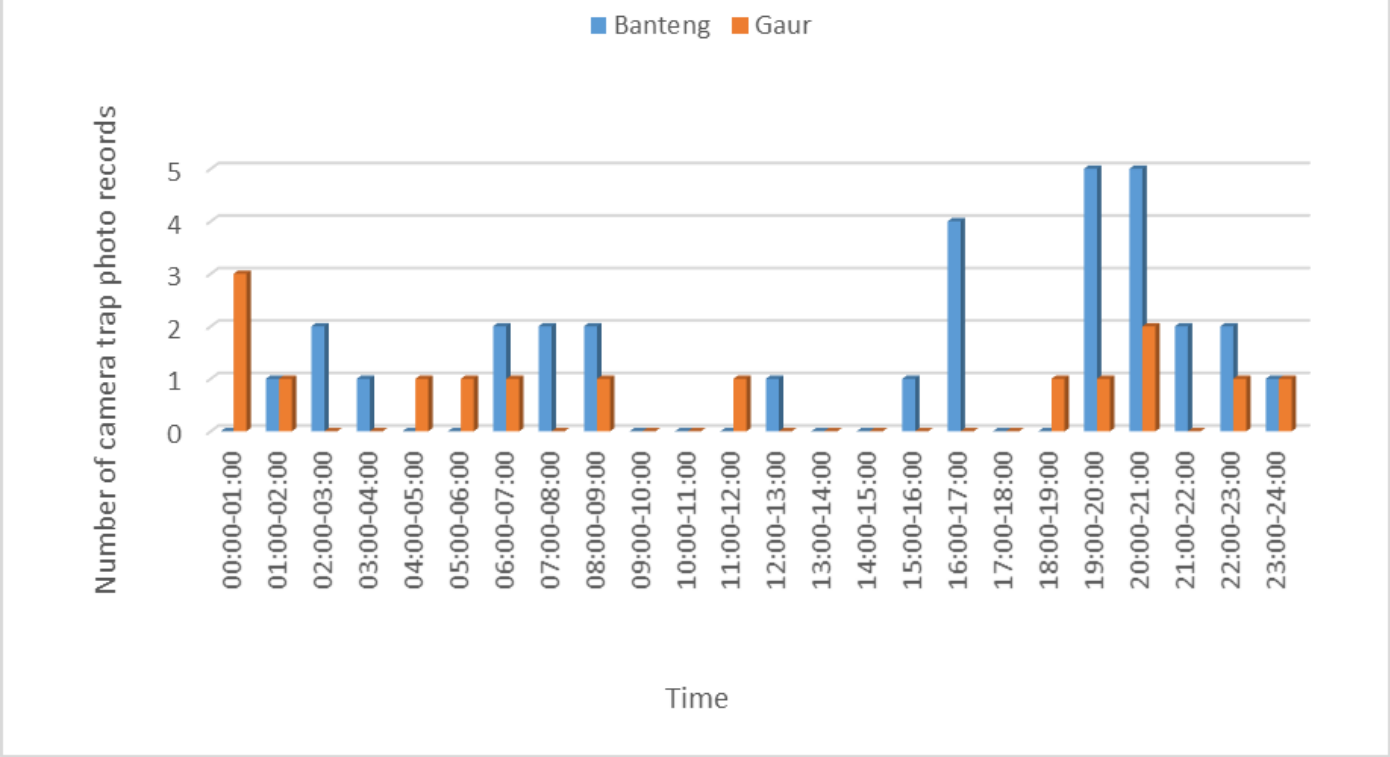


Figure 5: Activity pattern of banteng and gaur inferred from camera trap detections in NZWS in 2020.

terrain and is a less suitable habitat for both species, especially for banteng, which enjoy flatter terrain and is largely a grazer (Gardner *et al.*, 2016).

As the survey was conducted during the peak of hot and dry season, low intensity forest fires were widespread across the sanctuary, with fire incidents recorded in 29 camera traps. While low intensity forest fire is not a direct threat to either species and may even be helpful by creating grazing areas with new shoots, it creates open areas that provide people with easy access for hunting, or for farming in the forest periphery.

Farming was seen in the northern peripheries of NZWS, where banteng presence was also recorded. Farming poses a threat to the wild cattle populations where there is overlap with domestic cattle that can be a source of diseases and parasites. Domestic cattle can also pose a potential genetic threat to banteng as interbreeding is possible and if introgression occurs.

Conservation significance of the banteng population in NZWS

Camera trap photo capture rate (a.k.a detection rate) of banteng from the 2020 survey was estimated as 0.59 captures per 100 trap-days of effort. This rate was compared with other sites in mainland Southeast Asia where suitable data is available to allow the estimation of capture rates (Table 2). The comparative data suggests that the banteng population in NZWS may be substantially lower in abundance than some of the populations considered globally significant, such as the Mondulkiri Protection Forest of Cambodia, and Huai Kha Khaeng Wildlife Sanctuary of Thailand (Phan, Prum and Gray 2010, Gray and Phan 2011, Gardner et al. 2016, Saisamorn et al. 2019).

Table 2. Camera trap capture (detection) rates of banteng and gaur in North Zamari Wildlife Sanctuary, Myanmar, in comparison with sites surveyed by various authors across mainland Southeast Asia over the past decade.

Study Sites		No. of independent captures	Camera trap effort	Capture rate (No. independent captures / camera trap effort)*100	Study period	Reference
Banteng	North Zamari Wildlife Sanctuary, Bago region, Myanmar	25	4,267	0.59	March to June 2020	**This study**
	Green Island, Sambour district of Kratie Province, Cambodia	31	6,515	0.48	January 2017 – December 2019	Chan *et al.* 2020
	Phnom Prich Wildlife Sanctuary, Mondulkiri province, Cambodia	65	2,717	2.39	December 2008 – August 2009	Gray and Phan 2011
	Mondulkiri Protection Forest and Phnom Prich Wildlife Sanctuary, Mondulkiri province, Cambodia	160	7,295	2.19	January – December 2009	Phan, Prum and Gray 2010
	Pang Sida National Park, Thailand	7	28,698	0.02	2010 – Feb 2017	Ash et al. 2020
	Ta Phraya National Park, Thailand	11	5,764	0.19	2013 - 2015	Ash et al. 2020
	Huai Kha Khaeng Wildlife Sanctuary, Thailand	137	6,225	2.2	Jan – May 2013, and Jan – May 2015	Saisamorn et al. 2019
Gaur	North Zamari Wildlife Sanctuary, Bago region, Myanmar	14	4,267	0.33	March to June 2020	**This study**
	Phnom Prich Wildlife Sanctuary, Mondulkiri province, Cambodia	9	2,717	0.33	December 2008 – August 2009	Gray and Phan 2011
	Mondulkiri Protection Forest and Phnom Prich Wildlife Sanctuary, Mondulkiri province, Cambodia	26	7,295	0.36	January – December 2009	Phan, Prum and Gray 2010
	Dong Yai Wildlife Sanctuary, Thailand	119	4,871	2.44	2012 – Feb 2017	Ash et al. 2020
	Khao Yai National Park, Thailand	292	7,621	3.83	2010 – 2016	Ash et al. 2020
	Pang Sida National Park, Thailand	815	28,698	2.84	2010 – Feb 2017	Ash et al. 2020
	Thap Lan National Park, Thailand	422	32,955	1.28	2008 – Feb 2017	Ash et al. 2020
	Ta Phraya National Park, Thailand	173	5,764	3.0	2013 - 2015	Ash et al. 2020

While the population in Mondulkiri, Cambodia is facing a serious threat from intensive and indiscriminate snaring and other forms of poaching (Gray et al. 2018), the population in Huai Kha Khaeng continues to be well protected. The capture rate of banteng in NZWS is also lower than the populations in the severely logged and re-growing rainforest habitats of Borneo (Journeaux et al. 2018).

However, the NZWS capture rate is higher than other sites such as the Ta Phraya National Park in Thailand (Table 2; Ash et al. 2020). Moreover, the NZWS population has persisted despite severe hunting pressure and inade-

quate conservation attention, and it still has relatively widespread occupancy in NZWS.

This suggests that banteng population recovery is likely and it has potential to become a significant global population, given protection and assisted in population recovery through habitat and population management measures. The capture rate of gaur in NZWS, as expected, is substantially lower than most populations in Thailand (Ash et al. 2020), but comparable to the already suppressed populations of gaur in Mondulkiri, Cambodia (Table 2).

We acknowledge that the camera trap detection rate is not a robust indicator of animal abundance, particularly for cross-site comparisons, given the differences in detection probability, vegetation cover, incomparable survey design, and other influencing factors among the different sites. However, given that the effort to estimate more robust indices of abundance is yet to begin in NZWS, and the general paucity of data on local population abundance of the species across its range, we present this comparison to highlight the conservation significance of this little known population.

Conclusion

There is significant potential for recovery of this banteng population and this would contribute to the global effort to conserve the banteng. There is an urgent need for better protection of this little-known population. NZWS was primarily established as an elephant reserve, a species that prefers flat terrain. Therefore, expanding the boundary to include the surrounding flatter areas that include grasslands will benefit both wild cattle species and the elephant population surviving along the Bago Yoma range.

WWF is currently working with Forest Department to set up Myanmar's first Ranger Training Institute in NZWS and this will contribute to improved protection for the wildlife in NZWS. Further, we need more robust estimates of banteng and gaur populations in NZWS. Therefore, continuing the camera trapping surveys regularly is necessary to understand the population sizes, the occupancy dynamics of these two species, and their response to threats. This camera trap survey has provided an important update on the occurrence of 25 species of mammals, as well as the extent of key threats. It is our expectation that this information will be used by the Myanmar Forest Department to take management actions to secure the viability of the banteng and gaur populations in the area. With increased protection and upon population recovery, this area could host a globally significant population of banteng.

References

Ash, E., Kaszta, Ż., Noochdumrong, A., Redford, T., Chanteap, P., Hallam, C., Jaroensuk, B., Raksat, S., Srinoppawan, K. and Macdonald, D.W. 2020. Opportunity for Thailand's forgotten tigers: assessment of the Indochinese tiger Panthera tigris corbetti and its prey with camera trap surveys. Oryx, pp.1-8.

Chan, B.P., Li, F., Reaksmey, S. and Yang, J.H. 2020. Preliminary study on the basic ecology and conservation of Banteng Bos javanicus) in a land concession of eastern Cambodia. Research Bulletin, 4: 10-17.

Gardner, P., Hedges, S., Pudyatmoko, S., Gray, T.N.E. & Timmins, R.J. 2016. Bos javanicus.The IUCN Red List of Threatened

Species 2016: e.T2888A46362970.

Gray, T. N., & Phan, C. 2011. Habitat prefere -nces and activity patterns of the larger mammal community in Phnom Prich Wild life Sanctuary, Cambodia. *The Raffles Bul letin of Zoology*, *59*(2), pp.311-318.

Gray, T.N., Hughes, A.C., Laurance, W.F., Long, B., Lynam, A.J., O'Kelly, H., Ripple, W.J., Seng, T., Scotson, L. and Wikinson, N.M. 2018. The wildlife snaring crisis: an insideous and pervasive threat to biodiver sity in Southeast Asia. *Biodiversity and Conservation*, 27(4), pp.1031-1037.

Journeaux, K. L., Gardner, P. C., Lim, H. Y., Wern, J. G. E., and Goossens, B. 2018. Herd demography, sexual segregation and the effects of forest management on Bornean banteng Bos javanicus lowi in Sabah, Malaysian Borneo. *Endangered Species Research*, *35*,pp.141-157.

Lynam, A.J., tun Khaing, S. and Zaw, K.M., 2006. Developing a national tiger action plan for the Union of Myan mar. *Environmental Management*, 37(1), pp.30-39.

Lynam, A. J. 2003. A National Tiger Action Plan for the Union of Myanmar. Myanmar For -est Department, Ministry of Forestry, My anmar and Wildlife Conservation Society, International Program. Report: 1-76.

Phan, C., Sovanna, P. and Gray, T.N.E., 2010. Recent camera trap records of globally threatened species from the Eastern Plains Landscape, Mon dulkri. *Cambodian Journal of Natural His tory*, 2, pp.87-8.

Saisamorn, A., Duengkae, P., Pattanavibool, A., Duangchantrasiri, S., Simcharoen, A. and Smith, J.L., 2019. Spatial and tem poral analysis of leopards (Panthera par dus), their prey and tigers (Panthera tigris) in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Folia Oecologica*, 46(2), pp.73-82.

Wharton, C. H. 1968. Man, fire and wild cattle in Southeast Asia. In *Proceedings of the annual tall timbers fire ecology confer ence,* Vol. 8, No. 1, pp. 7-167.

Yin, U. 1955. Wild Life Preservation in Bur ma. *Oryx*, 3(2), pp.89-98.

Ecological determinants of density patterns of gaur (*Bos gaurus*) in Nagarahole-Bandipur reserves in the Western Ghats of India

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Keywords: *Hierarchical spatial distance sampling; habitat relationships; 'hot spots' of local abundance; management effectiveness*

Abstract

Gaur (*Bos gaurus)* is among the most vulnerable Asian wild cattle species. Intense anthropogenic impacts such as hunting, habitat loss and degradation have caused severe range contractions and local declines of gaur populations in ~ 98% of unprotected habitats. Yet, there have been few rigorous assessments of their relationships with habitat to identify the key drivers of these declines, primarily because of methodological and environmental challenges of conducting population-level studies of such low-density species. In this study, we investigated ecological processes that likely govern patterns of gaur densities in a high conservation-priority site in India. We constructed a Bayesian hierarchical spatial model to separate the 'signal' (ecological process of interest) from the 'noise' (the sampling process obscuring the 'signal'), which is often confounded in such studies. We confront the model with rigorous data from field line transect surveys to test *A priori* hypotheses proposed based on gaur ecology. We collected population count data from 77 systematically-placed transects covering 1400-km^2 of study area and data on six covariates that together described the habitat conditions available for gaur. Our model fitted the data well and could reliably predict gaur densities at both local and landscape scales. Our results showed that the effectiveness of protection from hunting and other human disturbances together with terrain topography strongly influenced local densities of gaur that varied between 0.4 and 10.5 / km^2 within the study area. We submit that significant opportunities exist for attempting range-wide gaur population recoveries through conservation actions that reduce hunting and other human impacts.

Introduction

The Asian wild cattle species, gaur (*Bos gaurus)*, is among the vulnerable species within that taxonomic group (Duckworth et al. 2016). Hunting, habitat loss and degradation due to intensive anthropogenic pressures have resulted in dramatic range contraction and severe population declines throughout the distributional range of gaur (Ahrestani and Karanth 2014). In India, gaur has among the most restricted distributional range of large herbivores (Karanth et al. 2009). Local extinctions of gaur populations range between a low of 7% in protected reserves and a high of 98% in unprotected habitats in India (Karanth et al. 2010). Consequently, gaur populations are now re-

stricted to protected reserves within extensive human-dominated multiple-use landscapes.

In the tropical deciduous forests of India, ecological densities of gaur vary greatly (from 0.2 to 11.3 animals per km^2; Karanth and Nichols 2000; Karanth et al. 2001, 2008; Karanth and Kumar 2005; Rayar 2010; Jhala et al. 2015). In contrast, gaur naturally occur at lower densities in the alluvial floodplains and dense evergreen forest habitats (Karanth and Nichols 2000), and are entirely absent in arid and semi-arid regions (Karanth et al. 2009). Even in protected reserves, gaur abundance varies depending on local habitat conditions (e.g., Gangadharan 2005).

Madhusudan and Karanth (2002) demonstrated that occurrence and intensity of hunting depress gaur densities locally. Gaur densities also show greater declines compared to other sympatric wild ungulates in areas heavily grazed by livestock as well as impacted by extraction of forest biomass by people (Madhusudan 2004, 2005). Furthermore, other environmental features such as hilly terrain and seasonal availability of water also influence gaur densities (Ahrestani and Karanth 2014). Large-scale habitat modifications and allied disturbances also appear to reduce local gaur densities. *Prima facie*, the elimination or reduction of all such anthropogenic disturbances has driven the recovery of populations of gaur and other animal species in India (Karanth et al. 1999; Karanth et al. 2008).

A rigorous, quantitative evaluation of likely drivers influencing local gaur abundance patterns within large areas (> 1000 km^2) is therefore currently of fundamental importance to recovery and management of this species, particularly in the context of the rapid economic and human population growth in Asia. There are, however, several methodological challenges to the conduct of such rigorous, quantitative assessments of gaur populations. Typically, animal count data used in such analyses are a combined outcome of the ecological, spatial and observation processes. As such, the ecological processes ('signal') of interest to managers and conservationists get often obscured by the sampling processes ('noise') involved in such assessments (Royle and Dorazio 2008). While there are reasonable sampling methods to individually deal with each of these process components, methods to deal with all three processes simultaneously have rarely been employed. Recent advances in hierarchical modeling approaches have filled this need (Royle and Dorazio 2008; Kéry and Royle 2016, 2021).

In this study, we use a Bayesian Hierarchical Spatial model to identify key ecological factors that affect abundance of gaur populations, while simultaneously accounting for the observation and spatial sampling process parameters also. To meet this goal, we first formulate *A priori* hypotheses about the effects of some key landscape and local scale factors related to the physical environment, habitat features and management practices on abundance of gaur populations.

Next, we confront these plausible models with visual field count data on gaur collected using rigorous line transect survey protocols. We also incorporate into the modeling, data on covariate factors, both remotely sensed and sampled in the field. We specifically aim to identify

ecological determinants of gaur abundance patterns and estimate local densities of gaur to identify local 'hot spots' of their abundance, useful for management and conservation actions.

Materials and Methods

Study Area

The Nagarahole-Bandipur protected area landscape is nested within the Western Ghats region, a recognized global biodiversity hot spot of conservation priority. This study area comprises of the Nagarahole (area: 644 km^2; 76° 00′ and 76° 15′ E Longitude, 11° 50′ and 12° 15′ N Latitude) and Bandipur (area: 880 km^2; 76° 12′ and 76° 46′ E Longitude, 11° 37′ and 11° 57′ N Latitude) National Parks. The study landscape is fully described in Kumar (2011) and Kumar et al. (2021). Both the altitudinal (ranging between 400 and 1450 m above mean sea level) and rainfall (ranging between 625 mm in the southeast and 1500 mm in the northwest) variations together with other bioclimatic factors (Meher-Homji 1990) have supported tropical mixed deciduous forests (Pascal *et al.* 1982) in the study area. More than 400 villages and 250,000 heads of livestock are present within a 5-km distance from the boundaries of the study area (Directorate of Census Operation 2004, Government of India) together with a few non-agricultural human settlements inside Nagarahole National Park (Karanth *et al.* 1999) exert a multitude of anthropogenic pressures across the study area.

The study area has also been reasonably well protected for over three decades (Karanth *et al.* 1999), with levels of law enforcement effectiveness varying spatially. Thus, the study area offered a good opportunity to quantitatively examine ungulate-habitat relationships across a gradient of ecological, environmental and management factors.

Determinants of Gaur Abundance

Based on our familiarity and earlier work with the species and habitats (Karanth et al. 2008, 2020; Kumar et al. 2021), we hypothesized that six variables related to the forest habitat type, physical environment and management factors likely influenced gaur densities at both local and/or landscape scales. The two identified habitat variables were 'eco-climatic distance' and a 'forage availability index'.

The eco-climatic distance is a remotely-sensed surrogate for the forest vegetation type and is defined based on forest habitat structure and composition across a moisture gradient at landscape-level (Krishnaswamy et al. 2009). The forage availability index is a field-based measure of the potential palatable forage available to gaur at the local scale. The physical environment variables we selected included a GIS-based measure of distance to water sources, and, a remotely-sensed measure of variance in slope, which is indicative of terrain undulation. The management variables we chose included a field-based measure of human disturbance index at the local scale and a categorical disturbance index at the landscape level indicating likely hunting pressures.

We note that the last two variables describe two distinct forms of anthropogenic disturbances. Their measured levels are inversely related to effectiveness of management efforts to curb human impacts. We hypothesized that the direction and strength of these variables will

Field Methods

Gaur count data

Gaur count data were collected using rigorous line transect survey protocols relying on visual detection and counts of gaur (Buckland et al. 2001; Thomas and Karanth 2002; Karanth et al. 2002) as a part of a macro-ecological study of predator-prey population dynamics (Karanth et al. 2020). The line transect survey system consisted of 77 square samplers, each 3.2 km long, systematically placed at a bi-directional spacing of 3 km covering the study area (Fig. 1) and the field surveys were conducted in April 2005 (in Nagarahole) and in April 2006 (in Bandipur), within a span of <30 days each. Detailed field protocols used in this study are described in Karanth et al. (2002) and Kumar et al. (2017). The surveys yielded counts of 154 clusters of gaur on 464 replicated transect walks that added up to a cumulative distance of 1404 km.

Covariate data

Among the six covariates identified by us *A priori*, the forage availability index and the human disturbance index were measured along the same transect lines during separate surveys conducted in the same season (March – May).

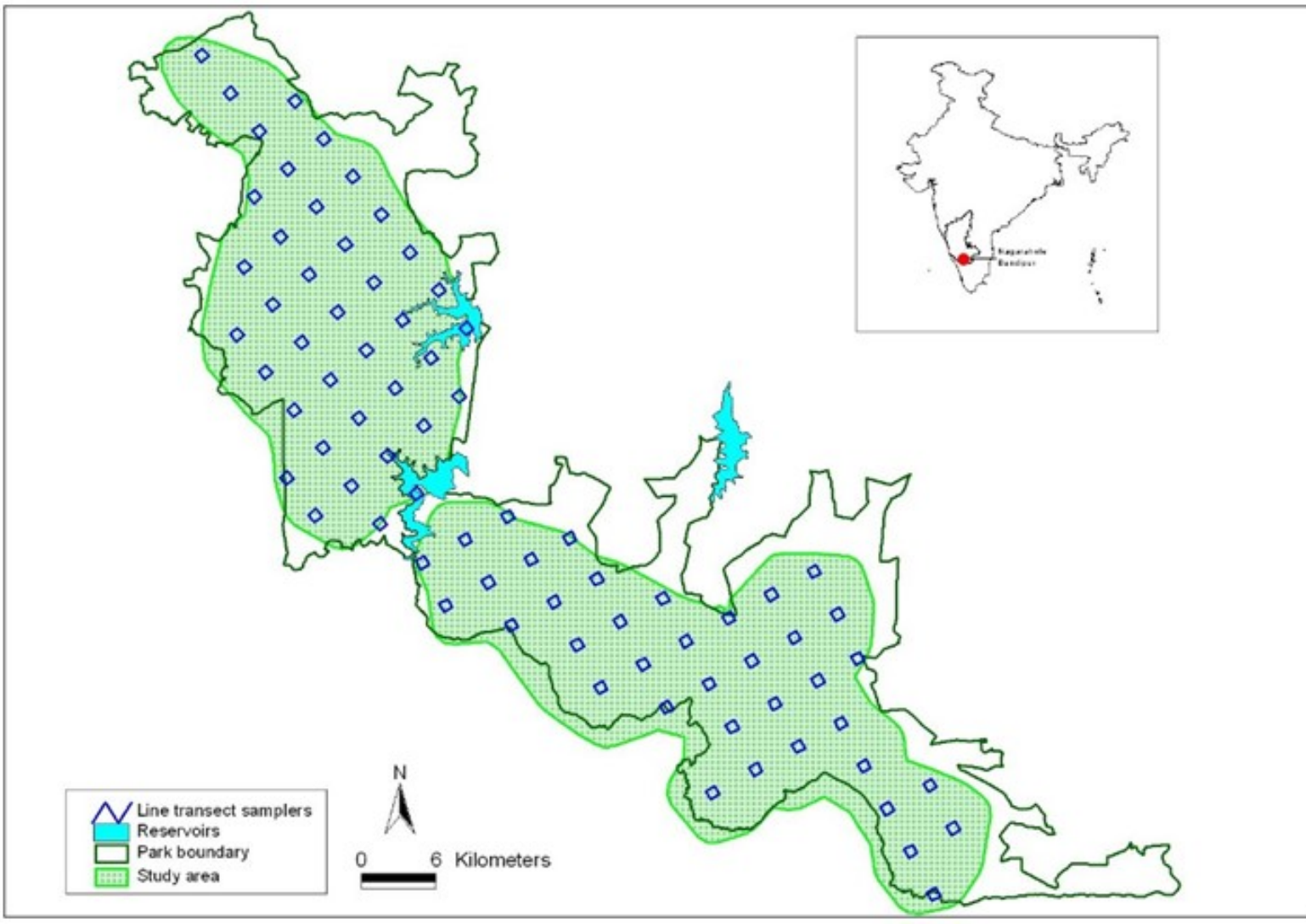

Figure 1: Map showing the system of line transects in the Nagarahole-Bandipur study area. Inset map shows the location of the study area in India.

We used a nested plot design (Reddy et al. 2016) to enumerate plants encountered within the primary, secondary and tertiary plots, which are fully described in Kumar (2011) and Kumar et al. (2021). We assessed palatability of each plant species to gaur based on published information, ethno-botany and empirical observations and then computed an index of palatable forage plants available/m^2 for each line transect. We hypothesized that this index will positively influence gaur density at transect level.

To compute the human disturbance index, we recorded all signs of activities, such as, cut plant stems, logged trees, lopped trees, tree-notches, fire, cattle dung, poaching, dead wood extraction, soil extraction, etc., detected along each 100 m transect segment during a separate survey conducted in the dry season and constructed a composite human disturbance index for each line transect as the product of the intensity and the frequency per km of survey effort (see Kumar et al. 2021 for details). We hypothesized that the gaur density would be negatively influenced by human disturbances at local (transect) scale.

We also measured four variables at the landscape scale for each of the 1-km^2 grid-cells superimposed over the study area. Eco-climatic distance is a quantitative, remotely sensed metric derived from the multi-date Normalized Difference Vegetation Index (NDVI) to describe variability in forest type at an ecologically relevant continuous scale (Krishnaswamy et al. 2009). Very high values of eco-climatic distance corresponded to dry deciduous forests and degraded scrub with low plant productivity and high seasonal variation, while lowest values represented tropical wet evergreen forests with high plant productivity and low seasonal variation. However, tropical evergreen forests support lower abundance of ungulates due to lower nutrient quality in plants (Olff et al. 2002). Therefore, we expected a quadratic relationship between ungulate abundance and eco-climatic distance, with ungulate abundance initially increasing with eco-climatic distance up to a threshold level representing moist deciduous forests and then declining with increasing eco-climatic distance. We extracted eco-climatic distance values for each of the 1-km^2 grid-cells of the study area from the data layers developed separately for another conservation study (Das et al. 2006) and hypothesized gaur density to decline with increasing eco-climatic distance.

To measure the variable, distance from water, at landscape-level, we first mapped all perennial water sources in the study area using a GARMIN 12 XL GPS unit. We then overlaid the digital overlays of streams, rivers and reservoirs, and computed the mean distance from the center of each 1-km^2 grid-cell to nearest water source. We expected gaur density to increase with shorter distances to water sources.

We used remotely sensed Shuttle Radar Topography Mission (SRTM) elevation data at 200 m pixel resolution (Jarvis et al. 2008) to extract variance in slope for each 1-km^2 grid-cell. The variance in slope best described the topography, with higher values indicating more undulating terrain. We predicted the variance in slope to positively influence gaur density.

We used a categorical measure of protection effectiveness as the last variable in our model.

A number of factors viz., the history of protection in the reserve, available protection infrastructure, proximity to human settlements, frequency of patrols, the number of forest offence cases booked per patrolling effort etc., influence the overall effectiveness of protection. We categorized the effectiveness of protection level in each 1-km^2 grid-cell as low, medium or high based on an assessment of such factors, using both published (Karanth *et al.* 2001) and unpublished sources. We used an inverse index as a measure of lack of effectiveness of protection in our model structure. We expected higher densities of gaur in grid-cells with lower management ineffectiveness.

Analytic Methods

We used a Hierarchical Distance Sampling model that was developed for assessing ungulate-habitat relationships (Kumar 2011), the details of which are available in Kumar et al. (2021). Briefly, the Bayesian hierarchical spatial model we used has two components; a process model that describes the ecological processes determining gaur abundance and an observation model describing the line transect sampling process involved in our field surveys. The abundance process model used a Poisson regression to assess the effects of covariates on gaur abundance at both local (transect) and landscape (grid-cell) levels. The model included a Gaussian Conditional Autoregressive (CAR) prior for modeling the spatial variation in density. This model enabled incorporation of both deterministic and stochastic effects for explaining the spatial variation in gaur abundance. We used a standard half-normal detection function to model the observation process. Additionally, the observation model included cluster size as an individual covariate that affected the detectability of gaur groups counted. We specified a zero-truncated Poisson distribution for modeling the cluster size. Thus, the detection probability of gaur was an increasing function of its cluster size and a decreasing function of its distance from the transect line. Although the perpendicular distance measured and cluster size observed were exact, we assigned detections to discreet classes of distance and cluster size to account for measurement errors and for computational ease. Detailed formulations of the models together with the model philosophy used for this analysis are fully described in Kumar et al. (2021).

We implemented the model in R (version 3.6.1; R Core Team 2019) using the NIMBLE package (version 0.8.0; NIMBLE Development Team 2019). We scaled and centered all covariates to improve MCMC convergence (Gelman et al. 2004). We used non-informative priors to specify the prior probability distributions of the model parameters and used a single long Markov chain with plausible initial values to improve mixing of parameters. We ran the model specification code for 200,000 iterations after specifying an initial burn-in of 20,000 iterations. The posterior distribution summaries of the parameters along with their associated Monte Carlo errors were estimated using R package 'mcmcse' (Version 1.3-2; Flegal et al. 2017). We used Monte Carlo error estimates to assess the reliability of posterior summaries (Dorazio 2016). We assessed the direction and magnitude of the influence of individual predictor variables on gaur density by examining the posterior summaries of the regression parameters.

Using the effects of covariates, we predicted density of gaur clusters in each 1-km^2 grid-cell and multiplied by its estimated mean cluster size to compute expected number of individual gaurs in each grid-cell. We then derived the posterior summaries of gaur density for the study area, as well as for Nagarahole and Bandipur parks separately. Using GIS software QGIS (version 3.10.0-A Coruña; QGIS Development Team 2019), we mapped variations in density across the study area to identify local 'hot spots' of gaur abundance.

Results

Gaur encounter rate, detectability and cluster size

We encountered 154 clusters of gaur over a cumulative sampling effort of 1404 km, during 464 replicate walks along 77 transects lines. We sighted gaur on 48 transects and the total number of clusters detected in each transect ranged between 1 and 26. The naïve mean encounter rate was 0.11 clusters per km walked, indicating the sparse nature of data arising from such surveys of tropical forest ungulates even in a reasonably well-protected area. The counts of detected clusters, and, the absence of sightings in 29 line transect spatial replicates, show substantial spatial variation in encounter rates.

The probability of detection of clusters of gaur decreased with greater distances from the transect line, whereas it increased with higher cluster size. Thus, the estimated detection probabilities of smaller clusters declined with perpendicular distance much more rapidly at shorter distances than the estimated detection probabilities of larger groups at longer distances (Fig. 2). Nearly 70% of the observed clusters of gaur were at <60 m perpendicular distance and these clusters had <8 individuals. However, the maximum observed perpendicular distance, and cluster size, were respectively 249.9 m and 25 individuals. The probabilities of detecting clusters with >8 individuals, at distances >60 m were substantially lower.

The estimated posterior mean of the effective strip width for gaur detections was 71.4 m (posterior median 71.1; 95% credible interval 54.6 – 92.5). This is in stark contrast to the naïve mean strip width of 38.6 m computed when detection probability was ignored. The ~ 46% downward bias in the naïve estimate of strip width shows why it is critically important to estimate detection probability in line transect surveys to obtain unbiased estimates of gaur densities.

Although the largest detected cluster consisted of 25 individuals, ~ 80% of the clusters had ≤ 6 individuals. Because of the smaller sample sizes of larger clusters, the uncertainty in the detection probability of larger cluster sizes was higher.

The posterior mean and posterior median of the overall cluster size was 4.8 individuals (95% credible interval 4.49 – 5.21), which is marginally higher than the observed mean (4.2 individuals). The underestimation of the cluster size at greater perpendicular distances is likely to be due to the screening effect of thick understory vegetation prevalent in the study area.

Determinants of gaur density

The effects of all predictor variables on gaur density were in the same directions as we hypothesized *A priori*, except for the two covari-

ates representing eco-climatic distance and distance to water. The strength of these estimated relationships varied considerably between the transect-level and landscape-level covariates. Densities of gaur clusters were associated positively with terrain undulation as well as with protection effectiveness and negatively with human disturbances. The effects of all other covariates were not significant. The summaries of the posterior distributions for the effects of all hypothesized determinants on expected cluster densities are reported in Table 1.

Between the two habitat covariates, the transect-level covariate of forage quantity positively, but somewhat weakly, influenced gaur density, while the landscape-level covariate of eco-climatic distance had no effect. Increasing terrain undulation had a strong positive effect on gaur density. Another physical environmental covariate, the distance to water, had no effect.

Gaur density was influenced positively by more effective protection at the landscape level, whereas human disturbance depressed gaur densities locally.

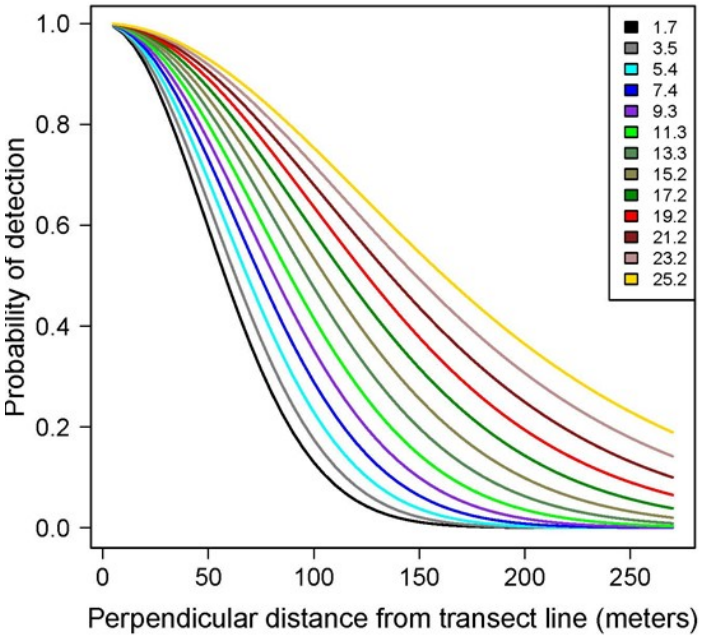

Figure 2: Estimated relationship between the probability of cluster size detection and the perpendicular distance from the transect line for each of the cluster size categories (depicted in different colors) of gaur in the Nagarahole-Bandipur study landscape in India. Expected number of individual animals in each cluster size category is in the legend.

Table 1: Estimated posterior mean, standard deviation (SD) and Monte Carlo standard error (MCse) with 95% credible intervals for the effects of covariates on expected cluster density of gaur in the Nagarahole-Bandipur study landscape.

Covariate	Mean	SD	MCse	95% Credible Interval
Forage quantity	0.16	0.21	0.006	(−) 0.27 – (+) 0.58
Eco-climatic distance	0.01	0.38	0.012	(−)1.06 – (+) 0.43
Terrain undulation	0.73	0.29	0.009	(+) 0.13 – (+) 1.29
Distance to water	0.10	0.21	0.004	(−) 0.31 – (+) 0.51
Human disturbance	−0.38	0.35	0.005	(−) 1.16 – (+) 0.20
Protection ineffectiveness	−0.50	0.28	0.007	(−) 1.07 – (+) 0.05

Spatial variation in gaur density

The estimated density of gaur in each 1-km^2 grid-cell showed a positively skewed distribution. Hence, we used median values to map the spatial variation of gaur density in the study area (Fig. 3).

This map clearly shows local 'hot spots' of gaur abundance within the study area. We provide (Table 2) a summary of the spatial distribution of the posterior median estimates of the local densities of gaur within the study area as well as in Nagarahole and Bandipur National Parks separately.

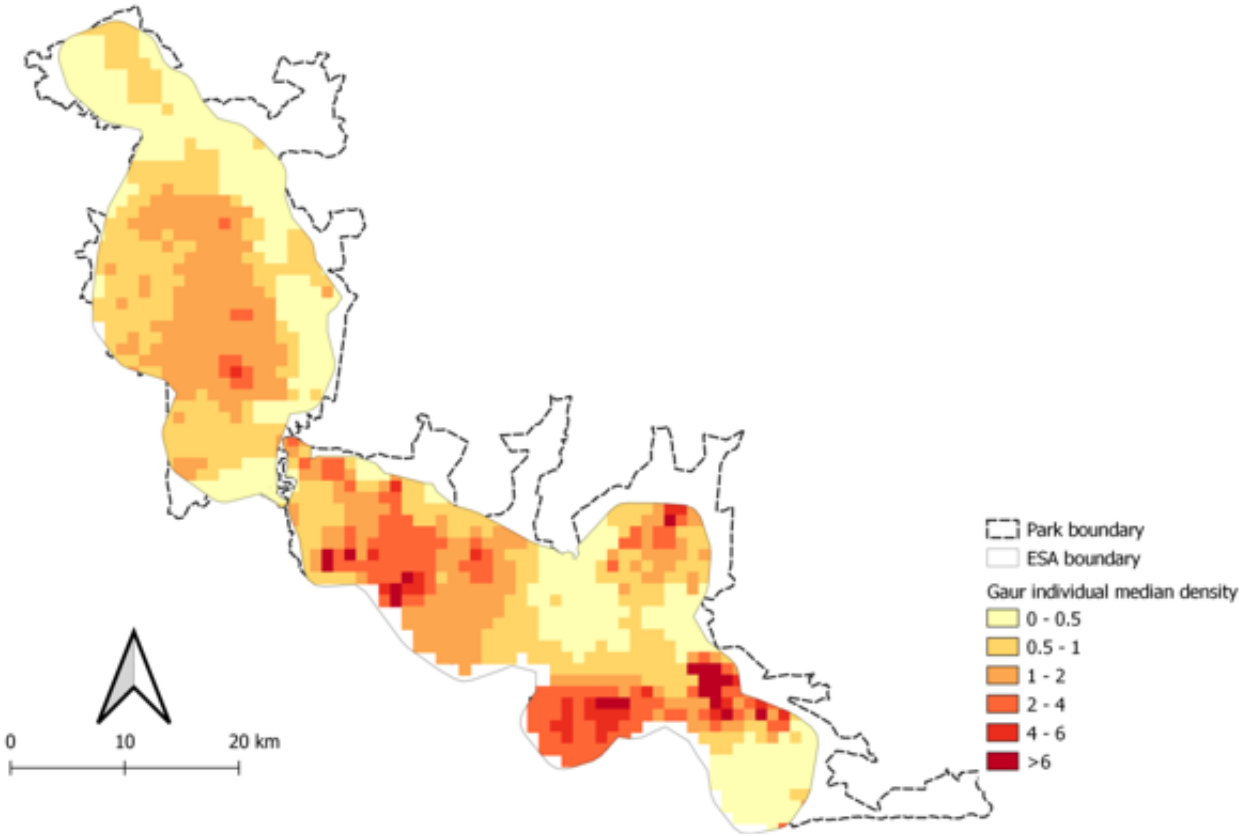

Figure 3: Spatial distribution of the estimated fine-scale (1-km^2 grid-cell level) density of gaur (posterior median; number of individuals / km^2) and its local 'hot spots' of abundance in the Nagarahole-Bandipur study landscape.

Table 2: Posterior Summaries of the spatial distribution of fine-scale (1-km^2 grid-cell level) cluster density (number of clusters / km^2) and individual density (number of individuals / km^2) of gaur within the sampled area

Species		Posterior mean	Posterior median	95% Credible Interval
Nagarahole	Cluster density	0.28	0.26	0.08 – 0.66
	Individual density	1.36	1.26	0.39 – 3.19
Bandipur	Cluster density	0.70	0.36	0.09 – 2.82
	Individual density	3.39	1.74	0.44 – 13.65
Overall Study Area	Cluster density	0.50	0.29	0.08 – 2.16
	Individual density	2.42	1.40	0.39 – 10.45

The estimated density of gaur (posterior median 1.7 / km^2) was higher in Bandipur than in Nagarahole (posterior median 1.3 / km^2). The estimated posterior mean density of gaur in the study area was 2.4 / km^2 (posterior median 1.4; 95% credible interval 0.4 – 10.5).

Discussion

Modeling gaur density: Application of hierarchical spatial models

Our hierarchical spatial model fitted the data well and accurately predicted spatial distribution of gaur densities within the study area. The Bayesian density surface model was able to predict abundance for each 1-km^2 grid-cell, enabling us to derive gaur density estimates for any subset area of interest. This facilitates comparison of gaur densities across different management regimes or spatial units. Such rigorous assessments help wildlife managers to identify optimal habitat requirements, attain targeted abundance levels and estimate potential carrying capacities.

The hierarchical spatial model is able to handle smaller sample sizes typical in ungulate surveys. In standard distance sampling, such low numbers of detections of animal clusters prevent investigators from estimating local densities and examining their spatial distribution. Our hierarchical spatial model augmented classical distance sampling method despite sparse data (gaur encounter rate 0.11 clusters per km walked) employed. The model permitted estimation of gaur density at the large landscape scale (1400 km^2), spatial distribution of the local densities, and effects of habitat, physical environment and management factors on density at multiple spatial scales. These are important ecological information necessary for management and conservation of gaur populations.

Determinants of gaur density

The six covariates together captured the spatial variation in gaur densities, although eco-climatic distance did not influence abundance in the study area. Gaur is a large-bodied bulk feeder (Hofmann 1989, Ahrestani and Karanth 2014) and its diet consists of coarse and dry grasses including bamboo, browses such as leaves and twigs of shrubs, forbs and trees (Schaller 1967, Ahrestani *et al.* 2012). Thus, gaur abundance is more likely to be dependent on quantity rather than quality of forage, compared to selective feeders. Density of gaur, a grass roughage eater (Schaller 1967), was moderately influenced by the availability of forage. This is likely due to the fact that surveys were conducted in dry season when most grasses dry up and large ungulates opportunistically shift to browse.

The variance in topographic steepness positively affected gaur density. This result is consistent with natural history observations and scientific studies (Schaller 1967; Ahrestani 2009). The weak relationship between gaur abundance and distance to water was possibly due to the widespread availability of water in the form of three large reservoirs, several streams and more than 250 natural and man-made ponds spread throughout the study area. Gaur density was depressed where illegal hunting pressure was likely high. The human disturbance index we used is a quantitative measure of anthropogenic impacts at local levels. Gaur appears to avoid areas where such human impacts were higher.

Synthesis

India appears to be the most important refuge for gaur range-wide, with 15 of its states harboring populations (Duckworth et al. 2016). Presently, four large landscapes (Western Ghats, Eastern Ghats, Central Indian and Northeast forests) and smaller ones in Bihar and West Bengal states support gaur populations and the most extensive among these is in the Western Ghats. Mixed deciduous forests cover ~ 140,000 km^2 (65%) in India (Roy *et al*. 2015). These are the most productive habitats for gaur and other large ungulate species (Kumar et al. 2021). Although an area of ~ 40,000 km^2 of these deciduous forests are covered by wildlife reserves, overall, the status of most gaur populations across these habitats is low or declining due to various anthropogenic pressures. In this context, the strong evidence we present here on the importance of effective protection is critical for securing and recovering remaining gaur populations. Our results also highlight the significant opportunities that still exist to manage these forests to support much higher gaur densities. We submit that focused protection efforts rather than habitat modification or enrichment measures should be the primary recovery strategy for gaur in India as well as in the rest of its distributional range.

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References

Ahrestani, F. S. 2009. *Asian Eden – Large herbivore ecology in India*. PhD Thesis, Wageningen University, The Netherlands.

Ahrestani, F. S. and K. U. Karanth. 2014. Gaur (*Bos gaurus* C. H. Smith, 1827). Species accounts. Pages 174-193. In *Ecology, Evolution and Behaviour of Wild Cattle: Implications for Conservation*. Eds. M. Melletti and J. Burton. Cambridge University Press.

Ahrestani, F, S., I. M. A. Heitkonig, and H. H. T. Prins. 2012. Diet and habitat-niche relationships within an assemblage of large herbivores in a seasonal tropical forest. *Journal of Tropical Ecology*, 28: 385-394.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations.* Oxford University Press, Oxford, UK.

Das, A., J. Krishnaswamy, K. S. Bawa, M. C. Kiran, V. Srinivas, N. S. Kumar, and K. U. Karanth. 2006. Prioritization of conservation areas in the Western Ghats, India. *Biological Conservation*, 133: 16-31.

Directorate of Census Operation. 2004. *Primary Census Abstract for Andhra Pradesh, Karnataka & Lakshadweep*. Technical Report Vol. X.

00-063-2001-Cen-CD.Office of the Registrar General and Census Commissioner, Government of India, New Delhi.

Dorazio, R. M. 2016. Bayesian data analysis in population ecology: motivations, methods and benefits. Population Ecology 58: 31-44. <doi:10.1007/s10144-015-0503-4>

Duckworth, J. W., K. Sankar, A. C. Williams, N. S. Kumar, and R. J. Timmins. 2016. *Bos gaurus. The IUCN Red List of Threatened Species 2016*: e.T2891A46363646. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T2891A46363646.en

Flegal, J. M., J. Hughes, D. Vats, and N. Dai. 2017. mcmcse: Monte Carlo Standard Errors for MCMC. R package version 1.3-2. Riverside, CA, Denver, CO, Coventry, UK, and Minneapolis, MN.

Gangadharan, A. 2005. *Density estimation and time trend analysis of large herbivores in Nagarahole, India,* MSc dissertation, University of St. Andrews, UK.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2004. *Bayesian Data Analysis*. Second edition. Chapman & Hall/CRC, USA.

Hofmann, R. R. 1989. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: A comparative view of their digestive system. *Oecologia*, 78: 443-457.

Jarvis A., H. I. Reuter, A. Nelson, and E. Guevara. 2008. *Hole-filled seamless SRTM data* V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org.

Jhala, Y. V., Q. Qureshi, and R. Gopal. (eds). 2015. *The status of tigers, copredators and prey in India 2014*. National Tiger Conservation Authority, New Delhi and Wildlife Institute of India, Dehradun. TR 2015/021.

Karanth, K. K., J. D. Nichols, J. E. Hines, K. U. Karanth, and N. L. Christensen. 2009. Patterns and determinants of mammal species occurrence in India. *Journal of Applied Ecology*, 46: 1189–1200.

Karanth, K. K., J. D. Nichols, K. U. Karanth, J. E. Hines, and N. L. Christensen. 2010. The shrinking Ark: Patterns of large mammal extinctions in India. *Proceedings of the Royal Society-Biological Sciences*, 227: 1971-1979.

Karanth, K. U., and J. D. Nichols. 2000. *Ecological Status and Conservation of Tigers in India*. Final Technical Report to US Fish and Wildlife Service - Division of International Conservation and Wildlife Conservation Society. Centre for Wildlife Studies, Bangalore, India.

Karanth, K. U., and N. S. Kumar. 2005. *Distribution and dynamics of tiger and prey populations in Maharashtra, India*. Final Technical Report. Centre for Wildlife Studies, Bangalore, India.

Karanth, K. U., Kumar, N. S., and Karanth, K. K. 2020. Tigers against the odds: Applying macro-ecology to species recovery in India. *Biological Conservation*, 252: 108846. https://doi.org/10.1016/j.biocon.2020.108846

Karanth, K. U., L. Thomas, and N. S. Kumar. 2002. Field surveys: Estimating absolute densities of prey species using line transect sampling. Pages 111-120 in Karanth, K. U., and J.D. Nichols (eds). *Monitoring Tigers and their Prey: A manual for researchers, managers and conservationists in tropical Asia*. Centre for Wildlife Studies, Bangalore, India.

Karanth, K. U., M. E. Sunquist, and K. M. Chinnappa. 1999. Long term monitoring of tigers: Lessons from Nagarahole. Pages 114-122 in *Riding the Tiger: Tiger conservation in human dominated landscapes* (Editors: J. Seidenstricker, S. Christie and P. Jackson). Cambridge University Press, Cambridge, UK.

Karanth, K. U., N. S. Kumar, A. M. Gopalaswamy, and V. Srinivas. 2008. *Distribution and dynamics of tiger and prey populations in Karnataka*. Final Technical Report. Wildlife Conservation Society – India Program, Centre for Wildlife Studies, Bangalore, India.

Karanth, K. U., P. Bhargav, and N.S. Kumar. 2001. *Karnataka Tiger Conservation Project*. Final Report to Save The Tiger Fund – National Fish and Wildlife Foundation, ExxonMobil Corporation and other donors. Wildlife Conservation Society, International Programs, Bronx, NY-10460-1099, USA.

Kéry, M., and J. A. Royle. 2016. *Applied hierarchical modeling in ecology: analysis of distribution, abundance and species richness in R and BUGS*, vol 1: prelude and static models. Academic Press, Cambridge, MA

Kéry, M., and J. A. Royle. 2021. *Applied hierarchical modeling in ecology: analysis of distribution, abundance and species richness in R and BUGS*, vol 2: dynamic and advanced models. Academic Press, Cambridge, MA

Krishnaswamy, J., K. S. Bawa, K. N. Ganeshaiah, and M. C. Kiran. 2009. Quantifying and mapping biodiversity and ecosystem services: Utility of a multi-season NDVI based Mahalanobis distance surrogate. *Remote Sensing of Environment*, 113: 857−867.

Kumar, N. S. 2011. Assessment of distribution and abundance of ungulate prey using spatial models in Nagarahole and Bandipur tiger reserves of India. PhD thesis. Manipal University, Manipal.

Kumar, N. S., A. Harihar, H. J. O'Kelly, and A. Pattanavibool. 2017. Field Practices: Estimating abundance of prey species using line transect sampling. Pages 121-136 in *Methods for Monitoring Tiger and Prey Populations* (Eds: K. U. Karanth and J. D. Nichols). Springer Nature Singapore Pte. Ltd. DOI 10.1007/978-981-10-5436-5_7

Kumar, N. S., K. U. Karanth, J. D. Nichols, S. Vaidyanathan, B. Gardner, and J. Krishnaswamy. 2021. *Spatial Dynamics and Ecology of Large Ungulate Populations in Tropical Forests of India*. Springer Nature Singapore Pte Ltd., Singapore. https://doi.org/10.1007/978-981-15-6934-0

Madhusudan, M. D. 2004. Recovery of wild large herbivores following livestock decline in a tropical Indian wildlife reserve. *Journal of Applied Ecology*, 41: 858-869.

Madhusudan, M. D. 2005. The global village: Linkages between international coffee markets and grazing by livestock in a south Indian wildlife reserve. *Conservation Biology*, 19: 411-420.

Madhusudan, M. D., and K. U. Karanth. 2002. Local hunting and the conservation of large mammals in India. *Ambio*, 31: 49-54.

Meher-Homji, V. M. 1990. Vegetation types of India in relation to environmental conditions. In Daniel, J. C., and J. S. Serao (eds). *Conservation in developing countries: Problems and prospects*. Proceedings of the centenary seminar of BNHS, Bombay Natural History Society, Oxford University Press, Bombay.

NIMBLE Development Team. 2019. "NIMBLE: MCMC, Particle Filtering, and Program mable Hierarchical Modeling." doi: 10.5281/zenodo.1211190, R package version 0.8.0, https://cran.r-project.org/package=nimble.

Olff, H., M. E. Ritchie, and H. H. T. Prins. 2002. Global environmental controls of diversity in large herbivores. *Nature*, 415: 901-904.

Pascal, J. P., S. Shyam-Sunder, and V. M. Meher-Homji. 1982. *Forest Map of South India*

(Mercara-Mysore). French Institute, Pondicherry, India.

Prater, S. H. 1985. *The book of Indian animals*. Bombay Natural History Society, India.

QGIS Development Team. 2109. QGIS Geographic Information System. QGIS version 3.10.0-A Coruña. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rayar, K. 2010. *Assessing potential tiger habitats in Cauvery Wildlife Sanctuary, Karnataka using occupancy modelling approaches*. MSc dissertation. Tata Institute of Fundamental Research, National Centre for Biological Sciences, India.

Reddy, G. V., K. U. Karanth, N. S. Kumar, J. Krishnaswamy, and K. K. Karanth. 2016. *Recovering Biodiversity in Indian Forests*. Springer Briefs in Ecology, Springer. DOI 10.1007/978-981-10-0911-2

Royle, J. A., and R. M. Dorazio. 2008. *Hierarchical modeling and inference in ecology: the analysis of data from populations, metapopulations and communities*. Academic Press, San Diego

Roy, P. S., M. D. Behera, M. S. R. Murthy, A. Roy, S. Singh, S. P. S. Kushwaha, et. al. 2015. New vegetation type map of India prepared using satellite remote sensing: Comparison with global vegetation maps and utilities. *International Journal of Applied Earth Observation and Geoinformation*, 39: 142-159.

Schaller, G. B. 1967. *The deer and the tiger: A study of wildlife in India*. University of Chicago Press, Chicago, USA.

Thomas, L., and K. U. Karanth. 2002. Statistical concepts: Estimating absolute densities of prey species using line transect sampling. Pages 87-110 in *Monitoring Tigers and their Prey: A manual for researchers, managers and conservationists in tropical Asia,* Karanth, K. U., and J. D. Nichols (eds), Centre for Wildlife Studies, Bangalore, India.

Progress of the Action Indonesia GSMPs 2016-2020: Global collaboration to conserve the anoa, banteng, babirusa and Sumatran tiger

Burton, J.[1,11], Bailey, C.[1,11 *], Yonathan, Y.[2], Andrews, J.[3], Chandra, I.[4], Forys, J.[5], Fitzpatrick, M.[6], Frantz, L.[7], Mustari, A. H.[8], Holland, J.[9], Hornsey, T.[10], Humphreys, A.[11], Hvilsom, C.[12], Leus, K.[12.,13,21], Metzler, S.[14], Pentawati, S.[15], Rode-Margono, E. J.[20, 21], Rowlands, T.[11], Semiadi, G.[2, 16], Smith, C.[11], Sumampau, T.[2,4,17], Traylor-Holzer, K.[18], Tri Hastuti, Y.[17], Tumbelaka, L.[2,19], Young, S.[11]

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Abstract

Action Indonesia is a collaborative partnership for the conservation of anoa, banteng, babirusa and Sumatran tigers. The aim of the partnership is to contribute to the conservation of these species *in situ* to prevent species extinction and to achieve genetically and demographically healthy *ex situ* insurance populations, providing future options for restoration of wild populations. Action Indonesia uses the International Union for Conservation of Nature Species Survival Commission Conservation Planning Specialist Group (IUCN SSC CPSG) “One Plan Approach” to species conservation (Byers et al. 2013), partnering with key organisations to bring together a group with wide-ranging expertise, knowledge sharing and decision making authority to address the ongoing conservation challenges of these species. This

group consists of Indonesian government departments, national and international zoos, NGOs and research institutions. Significant achievements have been made in the past four years of the collaboration. These include working with Indonesian institutions to develop and implement breeding and transfer

recommendations for collaborative breeding of the four taxa to strengthen Indonesian *ex situ* populations. Other achievements include the creation of a global awareness-raising day for the Action Indonesia species, as well as planning and delivering education and husbandry training in Indonesian zoos and raising funds for projects supporting *in situ* populations of the species. Action Indonesia will continue to strengthen the global *ex situ* populations of these four taxa through globally aligned collaborative breeding programmes. Long-term support will be provided to increase capacity in animal husbandry, education, population management, and institutional development. We anticipate that lessons learned during this process can act as a model for expansion to other Indonesian species as well as elsewhere that require global conservation action across the *in situ-ex situ* continuum.

Conservation rationale

Anoa (*Bubalus depressicornis* and *B. quarlesi*), banteng (*Bos javanicus*), babirusa (*Babyrousa* ssp.) and Sumatran tigers (*Panthera tigris sumatrae*) are some of Indonesia's most threatened large mammals. Primary threats to these charismatic, protected species and subspecies (hereafter referred to collectively as species) include illegal hunting for trade and consumption, habitat loss and, for Sumatran tigers, depleted prey base and human-tiger conflicts. The Indonesian government has listed all four species as national priority taxa that are threatened with extinction (KKH, 2015). The Sumatran tiger is listed as Critically Endangered (Linkie et al., 2008) on the IUCN Red List, with anoa (Burton et al.; 2016a, Burton et al., 2016b), Togian island babirusa (Macdonald et al., 2016) and banteng (Gardner et al., 2016) listed as Endangered and Sulawesi (Leus et al., 2016) and hairy babirusa (Macdonald et al., 2008) listed as Vulnerable.

The long-term survival of these species in the wild requires increased management intervention that includes research, protection and genetic management of populations in the wild as well as building up genetically viable *ex situ* populations to strengthen the genetic diversity of the global meta-populations. Therefore, key partners must work together to develop holistic conservation strategies for the four species and ensure that these strategies are implemented. For anoa, babirusa, banteng and Sumatran tigers it was decided that the most effective way to organise conservation interventions was to develop a Global Species Management Plan (GSMP) for each of the species, administered by the World Association of Zoos and Aquariums (WAZA). GSMPs bring together zoos, governments, and conservation organisations from multiple regions to achieve globally agreed *ex situ* and *in situ* conservation goals for a species (WAZA, 2019).

The banteng, anoa and babirusa GSMPs were initiated under the Action Indonesia name to promote these lesser known species. Since 2018, the Sumatran tiger GSMP – the longest running GSMP joined forces with Action Indo-

nesia to align the processes for governmental and organisational evaluation and approvals and endorsements of initiatives and to maximise opportunities for training, education, awareness raising and fundraising. This is the first time that multiple GSMPs have been developed as a single partnership. The Action Indonesia partnership has chosen to follow CPSG's

One Plan Approach concept (Byers et al., 2013; Vanzer et al., 2018), which promotes positive conservation outcomes through building and maintaining strong national and international institutional links, sharing of knowledge and expertise between partners, and strengthening the links between *in situ* and *ex situ* organisations.

Development of the Action Indonesia partnership

Starting with the first planning workshop in January 2016, Action Indonesia has evolved into a global partnership of organisations, with representatives from Indonesia, Europe and North America (Leus et al., 2017), driven by the IUCN SSC Asian Wild Cattle Specialist Group (AWCSG). By following the GSMP concept, the partners produced a masterplan in 2016 to guide conservation interventions and activities for anoa, banteng and babirusa. This masterplan was developed using the *IUCN SSC Guidelines for the Use of Ex situ Management for Species Conservation* (IUCN, 2014), and is aligned to the priorities described in the Indonesian National Species Conservation Strategy and Action Plans (SRAK) for these taxa (Ministry of Forestry Indonesia, 2014a; Ministry of Forestry Indonesia 2014b; Ministry of Forestry Indonesia, 2012). Among the top priorities identified by partners were to facilitate husbandry and education skills sharing, and draft the first ever breeding and transfer recommendations for anoa, banteng and babirusa in Indonesian zoos. The second Action Indonesia planning workshop took place in February 2018, and the Sumatran tiger GSMP was invited to join (Fig.1). The workshop was attended by 91 participants from 50 institutions, including Indonesian, European and US zoos as well as NGOs, universities and the Indonesian Ministry of the Environment and Forestry (KLHK). During this phase, a second three-year masterplan was developed.

The complexity of this programme and the collaborative working entails that many steps over a

Figure 1: Participants of the second GSMP Planning Workshop, February 2018. Photo: PKBSI

activities to the long-term aim on a strategic level. A Theory of Change process was used to develop a monitoring framework to guide activities (Weiss, 1995). In addition to identifying and prioritising activities that address threats to the species, the framework acts as a tool for monitoring and evaluating progress. Since 2018, nine thematic working groups (WGs) have been implementing sets of activities described in the monitoring framework. These WGs consist of experts from partner organisations that volunteer their time and skills, often representing all three regions involved. Partner organisations are defined as a) those whose staff provide technical advice, b) whose staff participate in planning and training or c) organisations that donate funds for activities, or d) organisations conducting breeding and transfers according to recommendations. The number of partner organisations has increased greatly in the past four years, growing from 29 in 2016 to 51 partners in 2020. The greater number of partners is due to many Indonesian zoos subscribing to the GSMP concept and following the breeding recommendations, as well as the increased awareness about the GSMP species and programme.

In addition to the implementing partners, there are six organisations that make up the organisational partners for the ungulate GSMPs: European Association of Zoos and Aquaria (EAZA), Association of Zoos & Aquariums (AZA), Indonesia Zoo and Aquarium Association (PKBSI), IUCN SSC, AWCSG, and IUCN SSC Wild Pig Specialist Group. These partners also are the signatories of a five-year MOU describing the partnership in Indonesia, signed and witnessed by the Indonesian Ministry of Environment and Forestry in 2014, and then extended for a further five years in 2019.

The coordination of the WGs and alignment to the monitoring framework is carried out by PKBSI and the AWCSG, as well as leaders of each WG. PKBSI leads on the planning and implementation of many of the activities. In PKBSI, strategic direction is provided by the Board and thematic divisions (1. Conservation, 2. Education and Training and 3. Organisation, Law, Membership, and Research). Implementation of activities is conducted by the PKBSI-GSMP Programme Officer (50% time working on GSMP activities) and the Board and divisions.

Alignment of the Sumatran tiger GSMP and the Action Indonesia GSMP:

The Sumatran tiger GSMP collaborates closely with the Action Indonesia activities; however, this GSMP was initiated much earlier. The Sumatran tiger GSMP was established in 2008, based on the Tiger Global Animal Survival Plan developed in 1992 by the IUCN SSC Conservation Breeding Specialist Group (now known as CPSG) and subsequent international *in situ-ex situ* collaborations in Indonesia. The partners for the Sumatran tiger GSMP include EAZA, AZA and PKBSI as well as the Zoo and Aquarium Association Australasia (ZAA), Japanese Association of Zoos and Aquariums (JAZA), and CPSG. Sumatran tiger GSMP meetings were held in 2010, 2012, and 2016 to assess *ex situ* conservation contributions for Sumatran tigers using the *IUCN SSC Guidelines for the Use of Ex situ Management for Species Conservation* (IUCN, 2014) and to make breeding and transfer recommendations

to meet these programme goals.

Achievements

One of the Action Indonesia partnership's main achievements is the realisation of a strong partner network that raises greater interest in the species and implements priority activities more effectively working collaboratively than institutions working in isolation of each other. An additional principal achievement has been the international support to PKBSI in access to resources, funding support for selected activities, and strategic planning. This has led to the development of greater capacity within PKBSI that is in turn delivering more leadership and support to Indonesian zoos. An example of this includes the enrolment of the PKBSI GSMP Programme Officer in the IUCN CPSG Mentoring Program to support the development of his skills in facilitation and conservation planning. There also has been a lot of learning by European and North American colleagues from our Indonesian partners.

Understanding differences among regions and institutions has been essential to the GSMPs' development. Over the past four years, we have learned to work together and be flexible to the variations in our timeframes, resources and the speed at which things happen in our collaborative approach. Regular communication and coordination without an overly rigorous structure has helped to encourage and foster participation with the GSMPs.

Ex situ:

A primary aim of the Action Indonesia GSMPs is to achieve healthy backup *ex situ* populations for each species. This is particularly important for Indonesian zoos, as they have a number of founder animals, whose genetics are underrepresented in the Indonesian and global zoo population. National target sizes for *ex situ* populations of anoa, banteng and babirusa were developed within Indonesia during the planning workshop in 2016, and have also been established for the Sumatran tiger population (Table 1). Achieving these target population sizes requires population management, including maintaining accurate studbook data, cooperative breeding and the development of breeding recommendations for the Indonesian zoo population.

Cooperative breeding is a method of *ex situ* management that focuses on building relationships among participating institutions to help everyone meet their needs and for the goal of healthy self-sustaining populations. This enables the species to be managed at the population level rather than at the institution level. Cooperation involves making your animal collection available and providing data to make recommendations on breeding often necessitating transferring animals between zoos. This is a new process for Indonesia, which requires a strong commitment from participating institutions to follow breeding recommendations in their own facilities and transfer animals among institutions for *ex situ* conservation. In order to do this effectively, institutions and governing bodies need to commit to a significant change in perspective towards working together. A significant financial input is required to transfer animals, and in some cases zoos do not own and keep one animal for its entire lifespan, but commit to working together with other institutions to improve the health of the population,

rather than focusing on a single animal. Facilitating cooperative breeding in Indonesia also requires the development of new administrative procedures to enable the completion of effective and efficient animal transfers in line with recommendations. PKBSI is developing new processes to align with cooperative breeding and working closely with the Directorate of Biodiversity Conservation (KKH), Directorate General of Natural Resources and Ecosystem Conservation (KSDAE), Ministry of Environment and Forestry of Indonesia to allow animal transfers to happen as effectively as possible. Continued support from PKBSI, KSDAE and the GSMPs will help to facilitate more transfers in the future.

A key milestone towards the *ex situ* aim of Action Indonesia was the development of two sets of breeding and transfer recommendations for the ungulate species in 2016 and 2018. The recommendations were developed and agreed collaboratively during the large planning workshops. So far, recommendations have resulted in 30 recommended births in Indonesian institutions (at the time of writing), including nine anoa, 17 banteng, and four babirusa (e.g. Fig. 2). New recommended births are important steps forward in the goal of achieving genetically diverse global *ex situ* populations and reaching national population size targets (Table 1). It is recognised that an increase in breeding efforts will take time to happen, as zoos become familiar with the cooperative population management approach and identify how they can increase space to hold offspring of the GSMP species.

***Table 1**: Indonesian National ex situ cooperative breeding targets and the current ex situ population of anoa, banteng and babirusa.*

Species	Current population (Nov 2020)	Target
Banteng	86	100
Anoa	37	75
Babirusa	75	100
Sumatran tiger	103	140

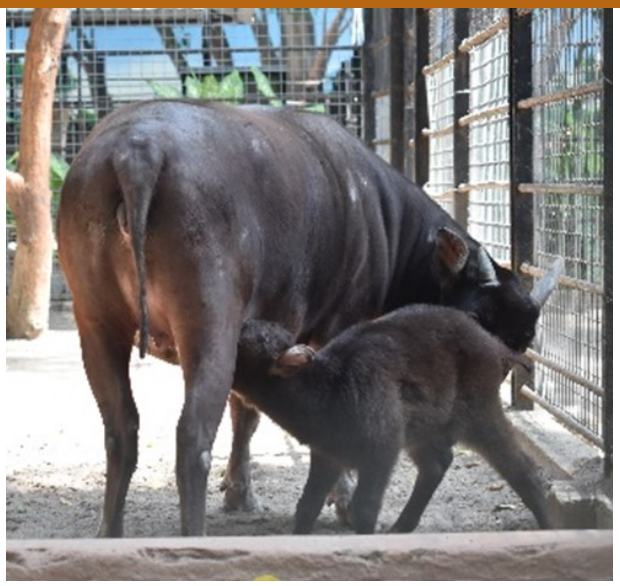

Figure 2: Anoa calf, born at Surabaya Zoo in July 2020 following GSMP breeding recommendations. Image: Surabaya Zoo

The Sumatran tiger GSMP has also demonstrated progress in implementing breeding and transfers in PKBSI zoos in recent years. Population goals for the PKBSI Sumatran tiger population are to maintain at least 90% gene diversity for 100 years with a population of ~140 managed tigers (Table 1). A short-term goal is to increase reproduction to stabilize the age structure of the population and prevent decline and to breed potential founders. Five of the six breeding recommendations made in 2016 had been attempted by the February 2018 meeting, 15 months later. Since then, seven litters have been born (14 births, 8 still living). Other recommended breedings have been attempted, but some are on hold waiting for institutional transfers to be approved. Similarly, although there has been positive progress with some

ungulate transfers completed under the collaborative breeding ethos, other transfers are still in process or delayed.

Supporting the development and implementation of cooperative breeding processes is an ongoing activity of the Action Indonesia GSMPs, and it is acknowledged that the socialisation, administration and implementation of cooperative breeding will take time to achieve successfully

Genetics:

One of the most important long-term threats to the survival of the GSMP species is the loss of genetic diversity, a common issue in endangered large mammal species (Lacy, 1997). Tigers generally have low genetic diversity (Luo et al. 2004), and recent work on anoa and Sulawesi babirusa suggests that they have lost a significant amount of genetic diversity in the wild over the last few hundred years (Frantz et al. 2018). Due to the alarming threats to the survival of the GSMP species, *ex situ* populations have become important backup populations, should the wild populations need future supplementation. In order to serve as backup populations, effective *ex situ* population management is needed to preserve genetic diversity representative of that of the wild populations. To achieve this goal there is a need for genetic analyses of both *ex situ* and *in situ* populations. This is where the fruitful collaboration of the Genetics WG between Indonesian and international partners comes into play, fostering knowledge sharing and technical capacity.

PKBSI has developed a collaboration with the Indonesian Institute of Science (LIPI) to sample the founder animals of the PKBSI member zoo populations of anoa, banteng and babirusa. The genetic diversity of the Sumatran tiger *ex situ* population may be assessed in future. Once samples have been collected, international GSMP partners will provide support to Indonesian scientists to develop the skills necessary for the genetic analyses, empowering Indonesian scientists to utilise these skills in the future with other species. Verified and accurate studbook data are needed to assess genetic status of zoo populations in order to set management goals to preserve gene diversity in *ex situ* populations for some of the GSMP species.

Husbandry:

Maintaining a high standard of husbandry and animal care is essential to zoo management and to the success of cooperative breeding efforts and *ex situ* conservation of the GSMP species. Extensive on-site husbandry and veterinary training efforts were conducted in 1992 -1995 for Sumatran tigers in Indonesian zoos (Tilson et al. 1997, 2001); however, staff have changed since then and further training may be required.

Training workshops were designed by Action Indonesia to build capacity, optimise husbandry and to facilitate successful cooperative breeding practices within Indonesian zoos. During three workshops in 2017, 53 participants gained skills in the husbandry and transportation of anoa, babirusa and banteng, which they have been able to use in their own institutions. Further, in a 2018 workshop, 32 participants built their capacity in enclosure design and collection planning. This workshop

familiarised PKBSI zoos with the processes that ensure that there is more space available for healthy *ex situ* populations of anoa, banteng, babirusa, Sumatran tigers and other priority species. Pre- and post-training surveys have been used to monitor the effectiveness of the training and to help to identify areas of future training. Tailored advice and guidance has also been delivered through zoo visits to 17 zoos, which have included on-site discussions and follow-ups with keepers, curators, vets and directors. This combination of formal workshop and more informal, tailored in-person advice has been successful in increasing the reach of the capacity building efforts to give broad training as well as specific input to many zoos that may not have joined the workshops.

Virtual husbandry training webinar sessions have been trialled in 2020 as a response to the Covid-19 pandemic and are being delivered by experts and practitioners from PKBSI and the GSMPs. This continued global collaboration demonstrates the motivation of GSMP members to adapt and progress with the husbandry training. Thus far, the virtual training sessions have had high participation, with up to 76 participants from up to 33 institutions attending per session. A range of participants have joined the webinars, including zookeepers, vets, curators, managers and directors. Pre- and post- questionnaires to participants have demonstrated an overall increase in knowledge during the sessions (Fig. 3). The virtual training sessions will be available to Indonesian zoos in the future and will be a valuable resource in the development of a sustainable, more widely accessible and cost-effective husbandry training programme. The range of husbandry topics taught will be part of a framework of learning, as a comprehensive zoo professional training programme is developed by PKBSI.

A further ongoing achievement of the GSMP Husbandry Working Group and PKBSI is the development of comprehensive husbandry

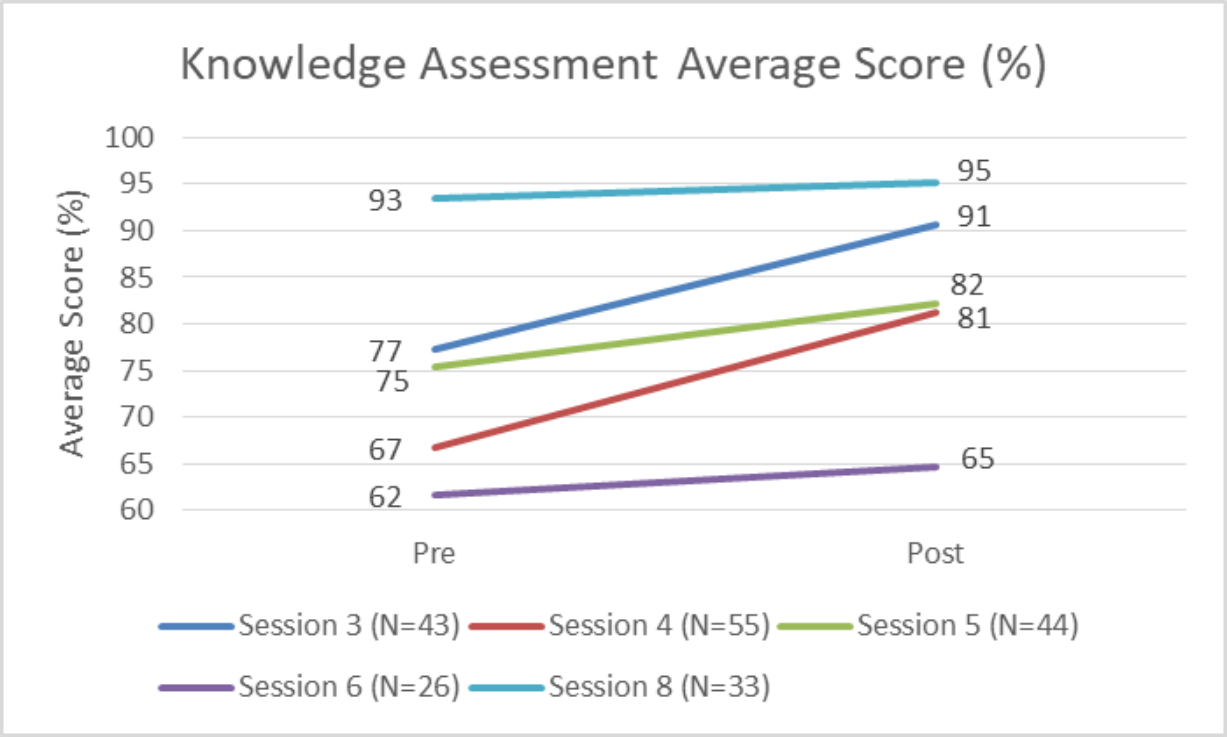

Figure 3: Average percentage score achieved in the pre- and post- knowledge questionnaires for each session (1-8)

guidelines for banteng, anoa, and babirusa in Bahasa Indonesia to support the improvement and standardisation of zoo practices for these species. These guidelines are being developed as a manual, along with other resources that can be used by all zoo staff for their daily husbandry care. A care manual for Sumatran tigers in Bahasa Indonesia was provided as part of the 1990s training but would benefit from being updated.

In situ:

Effective population monitoring of *in situ* populations of the GSMP species is essential to increasing knowledge of population sizes and trends, helping to identify potential threats to the population and informing conservation actions.

In early 2019, the banteng GSMP, PKBSI and Alas Purwo National Park – a priority location for banteng conservation in East Java – agreed to collaborate on a monitoring project for Javan banteng. The project will begin in 2020, with the objective to provide longitudinal data of banteng population density of at least four years to inform future management in Alas Purwo National Park. The data will also inform future conservation planning at a Conservation Strategy and Action Plan (SRAK) Population and Habitat Viability Assessment (PHVA) workshop.

Another priority area for banteng conservation is Baluran National Park (NP) in East Java. Until 30 years ago, it was by far the main stronghold, being home to almost 300 banteng. Due to habitat loss and extensive poaching, the population decreased to approx. 20 individuals in 2012. In 2013, the Directorate of Biodiversity Conservation (KKH) and Copenhagen Zoo commenced on a joint project to restore Baluran NP to its original ecological condition, including restoring the park's banteng population. An extensive camera trapping monitoring system was set up in 2014 covering the entire park. The system delivers annual population trends and sizes and detects the magnitude of

Figure 4: A Baluran staff team effort, with the Baluran NP vet Rudiar Anisa darting her first ever banteng for collaring and genetic sampling. Image credit: Copenhagen Zoo / Baluran National Park

Figure 5: Guiding an adult anoa during the Anoa and Babirusa Rescue Training in Makassar

the poaching in the park too. These data are essential for the park management to address habitat restoration and anti-poaching activities. In 2018, the Baluran NP management and Copenhagen Zoo team became the first ever to sedate a wild Javan banteng and fit it with a GPS-radio-collar (Fig. 4). To date, nine wild banteng have been fitted with a GPS-collar and they form part of a long-term study about banteng ecology.

With the added vigilance in Baluran NP, the banteng population has increased to 70-80 individuals in 2019 (Traeholt pers. comm.). In 2016, Baluran NP was declared as the national banteng conservation breeding centre. Basic breeding facilities were set up and the first three banteng were transferred from Taman Safari Indonesia in 2016. Currently, Copenhagen Zoo and Baluran NP are looking into developing a dedicated banteng breeding and rehabilitation plan.

In the recent years, we achieved a greater understanding of how zoo expertise can be transferred to support *in situ* projects, for example through providing husbandry training in which 29 participants learned to improve the handling and health assessment of rescued and confiscated anoa and babirusa in Sulawesi (Fig. 5). The GSMPs and PKBSI also aim to provide KKH with recommendations about how to implement an island-wide strategy for the management of rescued anoa and babirusa with a network of transit centres at KSDA offices. The GSMP has also supported *in situ* work through providing small grants to projects carrying out conservation and awareness raising activities in Sulawesi. An example of this includes supporting a survey on Buru island in 2017 that confirmed the presence and some biological traits of babirusa on the island (Macdonald & Pattikawa, 2017).

Education:

Effective conservation education has been shown to increase knowledge of species and conservation (Nekaris et al. 2017) and can influence public behaviour through fostering

connectedness to nature and sense of environmental responsibility (Ancrenaz et al. 2018; Van den Born et al. 2017). The Education Working Group aims to increase global awareness and support for conservation and to build capacity to deliver conservation education for these species in Indonesia. The education programme of activities was developed with the involvement of educators from AZA and EAZA institutions, and from a survey of Indonesian zoo educators carried out in 2016. This foundation of understanding about education being delivered by Indonesian zoos established the resource and capacity building requirements for raising awareness of the target species. Over the last four years, an educational toolbox of resources and materials has been developed to support zoo educators and others engaged in educating about these species in the design and delivery of their education programmes:actionindonesiagsmp.org/educate.

Through multiple training sessions and workshops over the last four years, 67 participants have gained skills in conservation education, which has helped to build a global network of zoo educators that are sharing materials and ideas to improve their engagement of visitors.

In 2019, the Education WG developed an annual global awareness raising day 'Action Indonesia Day', to maximise education efforts and communication about the species and their conservation. This was a major achievement in raising awareness and in the collaboration between regions. Over 40 organisations across four continents got involved for a day of events and activities to connect people to anoa, banteng and babirusa and raise awareness about the global efforts to conserve them. The events held in zoos, and posts on social media (searchable with the #ActionIndonesiaDay hashtag), helped to increase the profile of these largely unknown and under-appreciated threatened taxa. Many participants utilised the educational resources available to download from the Action Indonesia website, with some zoos also using the day as an opportunity for fundraising (Figs. 6 and 7).

Figure 6 (left): Action Indonesia Day signage at Bandung Zoo. Image: James Burton.

Figure 7 (right): Action Indonesia Day Activities at Bali Safari & Marine Park. Image: TSI Bali Safari

It was particularly successful in that there were 22 Indonesian organisations involved in Action Indonesia Day 2019. This is a positive indicator of the strong engagement of Indonesian institutions with the GSMPs. This year, as engagement in many zoos was challenging due to Covid-19, Action Indonesia Day was held virtually, with over 30 institutions from three continents sharing their animal facts, images, keeper talks and other content on social media.

Looking ahead

In the next five years, we aim to reach the national *ex situ* population targets for the three ungulate taxa in Indonesia. This will then mean that a more integrated global population can be developed, through transfers between regions to maximise the genetic diversity across all regions. The Sumatran tiger GSMP already is collaborating internationally and currently is focusing on improving the demographic and genetic health of the PKBSI population. These targets need to be supported by demonstrable improvements in welfare standards and husbandry expertise. For *in situ* populations further focused planning is needed, underpinned by reliable data on population trends and threats. Action Indonesia will support this for at least one population for each of the ungulate species, and we hope that local or international partners can cover other key populations. Greater awareness of these species and change in behaviour of key groups should be achieved through targeted awareness raising activities using social marketing approaches to mitigate the threats to the species.

In the coming two years we will plan and implement the third set of breeding and transfer recommendations for the ungulate taxa. In parallel, we will also work with specific Indonesian zoos to discuss how they can maximise their capacity to hold larger populations of GSMP species, so that they can continue to conduct breeding. We hope that permissions for zoos to start DNA sampling for the PKBSI-led genetic assessment on zoo populations is granted from the Ministry of Environment and Forestry and that sampling can begin in 2021. We plan to continue with webinar husbandry training courses for Indonesian zoos within a wider training framework developed with PKBSI. We are excited to continue holding annual Action Indonesia Day events to raise awareness globally. We are also planning more *in situ* activities, including supporting outreach about GSMP species in Sulawesi, with the aim to promote behaviour change to protect babirusa and anoa from illegal hunting for consumption and trade.

The considerable awareness of the GSMP framework in Indonesian conservation community means that there is a strong opportunity to expand this to include additional Indonesian species that require *in situ* and *ex situ* efforts. This should be done once the current objectives are well underway, capacity is in place and processes are working effectively. We recommend that the process for developing a more coordinated One Plan approach to conservation of any species should begin with following the decision-making framework outlined in the IUCN SSC *Guidelines on the Use of Ex situ Management for Species Conservation* (IUCN SSC, 2014).

There has been strong involvement from many zoos and other conservation organisations to

date, and Action Indonesia has benefited hugely from all the support provided. We hope that this network of partners will grow further with more organisations offering their support through breeding the species, sharing their expertise and skills in husbandry and education, or contributing funds or technical expertise to the *in situ* projects. We have made major progress since 2016 and all partners and individuals should be proud of what has been achieved through collaboration. We rely on all the partners' continued support to deliver the amount of work that still needs to be done over many more years. Together, we can achieve our aim of stable and healthy populations of banteng, anoa, babirusa and Sumatran tigers.

References:

Ancrenaz, M., Barton, C., Riger, P. & Wich, S.A. 2018. Building relationships: how zoos and other partners can contribute to the conservation of wild orangutans. International Zoo Yearbook, 52. ISSN 0074-9664

Burton, J., Wheeler, P. & Mustari, A. 2016a. Bubalus depressicornis. The IUCN Red List of Threatened Species 2016: e.T3126A46364222. Downloaded on 30 August 2020.

Burton, J., Wheeler, P. & Mustari, A. 2016b. Bubalus quarlesi. The IUCN Red List of Threatened Species 2016: e.T3128A46364433. Downloaded on 30 August 2020.

Byers O., Lees C., Wilcken J. & Schwitzer C. 2013. "The 'One Plan Approach': The philosophy and implementation of CBSG's approach to integrated species conservation planning." WAZA Magazine 14: 25.

Frantz, LAF., Rudzinski, A., Nugraha, AMS., Evin, A., Burton, J., Hulme-Beaman, A., Linderholm, A., Larson, G., et al. 2018 Synchronous diversification of Sulawesi's Iconic artiodactyls driven by recent geological events. Proceedings of the Royal Society B: Biological Sciences, 285 (1876), DOI: 20172566. 10.1098/ spb.2017.2566 .

Gardner, P., Hedges, S., Pudyatmoko, S., Gray, T.N.E. & Timmins, R.J. 2016. Bos javanicus. The IUCN Red List of Threatened Species 2016: e.T2888A46362970. Downloaded on 30 August 2020.

IUCN SSC. 2014. Guidelines on the Use of *Ex situ* Management for Species Conservation. Version 2.0. Gland, Switzerland: IUCN Species Survival Commission.

IUCN 2020. The IUCN red list of threatened species. Version 2020. Available at: http://www.iucnredlist.org [Date accessed: 27 July 2020]

Lacy, R. C. 1997. Importance of genetic variation to the viability of mammalian populations. Journal of Mammology, 78(2):320-335

Leus, K., Holland, J., Nugroho, J., Semiadi, G., Sumampau, T., Kauffels, T., Mustari, AH., Meijaard, EE., Burton, J. & RodeMargono, J. (2017). Global collaboration to conserve three threatened Indonesian animal taxa: Babirusa, Anoa and Banteng. Suiform Soundings 15(1) 27-31.

Leus, K., Macdonald, A., Burton, J. & Rejeki, I. 2016. Babyrousa celebensis. The IUCN Red List of Threatened Species 2016: e.T136446A44142964. Downloaded on 30 August 2020.

Linkie, M., Wibisono, H.T., Martyr, D.J. & Sunarto, S. 2008. Panthera tigris ssp. sumatrae. The IUCN Red List of Threatened Species 2008:

e.T15966A5334836. Downloaded on 30 August 2020.

Luo S-J., Kim, J-H., Johnson, WE., Walt, Jvd., Martenson, J., Yuhki, N. et al. 2004 Phylogeography and Genetic Ancestry of Tigers *(Panthera tigris)*. PLoS Biol 2(12): e442.https://doi.org/10.1371 journal.pbio.0020442

Macdonald, A.A., Burton, J. & Leus, K. 2008. Babyrousa babyrussa. The IUCN Red List of Threatened Species 2008: e.T2461A9441445. Downloaded on 30 August 2020.

Macdonald, A., Leus, K., Masaaki, I. & Burton, J. 2016. Babyrousa togeanensis. The IUCN Red List of Threatened Species 2016:e.T136472A44143172. Downloaded on 30 August 2020.

Macdonald, A. & Pattikawa, M. 2017. Babirusa and other pigs on Buru Island, Maluku, Indonesia. Suiform Soundings 16 (1), IUCN/SSC Wild Pig, Peccary and Hippo Specialist Groups

Ministry of Forestry Indonesia. 2014a. Strategy and Action Plan for Anoa Conservation 2013-2022. Indonesian Ministry of Environment and Forestry. pp. 50. https://www.asianwildcattle.org/uploads/1/2/1/8/121825577/strategy_and_action_plan_for_anoa_conservation_2013-2022_english.pdf [Date accessed: 27 July 2020]

Ministry of Forestry Indonesia. 2014b. Strategy and Action Plan for Babirusa Conservation 2013-2022. Indonesian Ministry of Environment and Forestry. pp. 48. https://www.asianwildcattle.org/uploads/1/2/1/8/121825577/strategy_and_action_plan_for_babirusa_conservation_2013-2022_english.pdf [Date accessed: 27 July 2020]

Ministry of Forestry Indonesia. 2012. Strategy and Conservation Action Plan for the Banteng (Bos javanicus) Conservation 2010 to 2020. Indonesian Ministry of Forestry. pp. 46. https:// www.asianwildcattle.org/uploads/1/2/1/8/121825577/strategy_and_action_plan_for_banteng_conservation_2010-2020_english_fina....pdf

Nekaris, K., McCabe, S., Spaan, D., Imron Ali, M. & Nijman, V. (2018). A novel application of cultural consensus models to evaluate conservation education programs. Conservation Biology 32(2): 466-476.

Tilson R., Manansang J., Traylor-Holzer K., Brady G., Armstrong D., Byers O., & Nyhus P. 2001. Training, transferring technology, and linking *in situ* and *ex situ* tiger conservation in Indonesia. AZA Field Conservation Resource Guide. Association of Zoos and Aquariums: Silver Springs, MD, USA.

Tilson, R., Siswomartono, D., Manansang, J., Brady, G., Armstrong, D., Traylor-Holzer, K., Byers, A., Christie, P., Salfifi A, Tumbelaka L, Christie S, Richardson D, Reddy S, Franklin N, & Nyhus P. 1997. International co-operative efforts to save the Sumatran tiger. International Zoo Yearbook 35: 129-128.

Traylor-Holzer K, Leus K & Byers O. 2018. Integrating *ex situ* management options as part of a One Plan Approach to species conservation. in: Minteer BA., Maienschein J., Collins JP. (eds.) The Ark and Beyond. University of Chicago Press, Chicago.

Van den Born, R.J.G., Arts, B., Admiraal, J., Beringer, A., Knights, P., Molinario, E., Horvat, K.P, Porras-Gomez, C., Smrekar, A., Soethe, N., Vivero-Pol, J.L., Ganzevoort, W.,

Bonaiuto, M., Knippenberg, L. & De Groot, W.T. 2018. The missing pillar: Eudemonic values in the justification of nature conserva tion. Journal of Environmental Planning and Management 61(5-6): 841-856.

World Association of Zoos and Aquariums 2019. Global Species Management Plans (GSMP) Fact Sheet. https:// www.waza.org/ wp-content/uploads/2019/02/2019-GSMP-Fact-Sheet.pdf [Date accessed: 27 July 2020]

Weiss, C. H. 1995. Nothing as practical as good theory: exploring theory-based evaluation for comprehensive community initiatives for children and families. Pages 65-92 in J. P. Connell, J. L. Aber, and G. Walker, editors. *New approaches to evaluating community initiatives: concepts, methods, and con texts.* Aspen Institute, Washington, D.C., USA.

AUTHOR GUIDLINES

Aim & Scope

BULLetin is the official, peer-reviewed publication of the IUCN/SSC Asian Wild Cattle Specialist Group. It aims to provide information on all aspects of natural history for the relevant species (Anoa, banteng, gaur, kouprey, saola, tamaraw, water buffalo and yak), with a particular focus on their conservation and management, both *in* and *ex situ*.

BULLetin accepts manuscripts of original research findings that have not been published or submitted simultaneously to other journals, and with a minimal overlap of contents with other published papers. As well as these, *BULLetin* also accepts and encourages submission of other relevant news, thesis abstracts, book reviews, summaries from workshops and meetings as well as a "notice-board" to publicise relevant upcoming conferences, funding opportunities etc.

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We prefer manuscripts in English. If English is not your first language, then please have your text thoroughly reviewed by a native speaker before submitting. Abstracts must also be in English, but we encourage an additional abstract in the language of the country where the project has been conducted. We will consider manuscripts in other languages; speed of publication in that case depends on availability of reviewers. If the article is not in English, then an English abstract must be provided.

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News and field notes

Relevant news and notes from the field that may contain figures and tables (up to 2,500 words)

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Short evaluations of recently published books and monographs of interest to the AWCSG (up to 1,500 words)

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Original research articles (up to 8,000 words including all text, references and legends). Manuscripts should adhere to the following structure:

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Figures and tables should be cited in the text in the order that they should appear. Figures and images should be in one of the following file formats:

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