

Bridging the Gap in *ex situ* and *in situ* population management of anoa

By John Andrews^a, Marcel Alaze^b, and Yohana Tri Hastuti^c

^aAZA Population Management Center at Lincoln Park Zoo, Chicago, USA; ^bWestfälischer Zoologischer Garten Muenster, Germany;

^cTaman Safari Indonesia, Bogor, Indonesia

Anoa (*Bubalus Sp.*) are the smallest wild cattle species and live wild only on the islands of Sulawesi and Buton in Indonesia. Two species are identified; the lowland anoa (*Bubalus depressicornis*) and the mountain anoa (*B. quarlesi*). Currently, both species are listed as 'Endangered,' (Burton et al. 2016a; 2016b) and face threats of agricultural conversion, hunting and increased mining activities (Rejeki, 2018). Locally known as "demons of the forest," anoa are elusive and secretive. Mountain anoa are thought to be lighter in color than lowland anoa and as the name suggests, one species is thought to be distributed in more mountainous habitat than the other. However, it is not yet well understood whether the distribution of the two species overlap. With these species declining rapidly, conservation of the species on a global level is critically needed. In 2016, a global effort began to conserve anoa as well as babirusa (*Babyrousa sp.*) and banteng (*Bos javanicus*) in Indonesia in a unique One Plan Approach (Byers et al., 2013) of developing a joint *in situ* and *ex situ* conservation plan and incorporating partners involved in both areas.

The One Plan Approach framework initiated in 2016 is called the Global Species Management Plan (GSMP) administered by the World Association of Zoos and Aquariums (WAZA). New GSMPs were started for each of these ungulates, later joined by the long running Sumatran Tiger (*Panthera tigris sondaica*) GSMP, and together this group is known as the Action Indonesia partnership. The goal of this collaborative group is to achieve safe and stable populations of these species in the wild. Action Indonesia aims to contribute to the conservation of these species *in situ* and to achieve genetically and demographically healthy *ex situ* assurance populations, which provide future options for restoration of wild populations.

Zoos and aquariums are often underused resources for species of conservation concern. They have much to contribute to conservation of the species they hold and breed. *Ex situ* populations can be great resources for rich biological data that are sparse for wild populations and valuable resources to observe or discover behaviors and husbandry knowledge that may be hard to glean from the wild.

Assurance populations are those that are maintained and managed in zoos with at least part of the purpose being to ensure a species does not go extinct and can be reintroduced into the wild. Zoo populations of Threatened, Critically Endangered or even Extinct in the Wild species are valuable for this purpose. Guam rails (*Hypotaenidia owstoni*) and Guam Kingfishers (*Todiramphus cinnamominus*) are both extinct in the wild and reintroductions have been supplemented in the past from zoo breeding populations. California Condors (*Gymnogyps californianus*), once close to extinction, were all brought into human care for intensive breeding

for reintroduction in zoos and today are roaming wild in California again. Przewalski's horse (*Equus ferus przewalskii*) and Arabian Oryx (*Oryx leucoryx*) are classic ungulate examples of animals that disappeared from the wild and were brought back from well maintained zoo populations. As a stated goal of Action Indonesia, the Anoa GSMP has put in much work to facilitate connections of *ex situ* and *in situ* practitioners, skill sharing opportunities and capacity building of zoo management in Indonesia. Connecting *ex situ* populations with *in situ* conservation can demonstrate the importance of responsible population management of species like Anoa in zoos around the world.

For the Anoa GSMP, there are currently three zoo regions participating and managing *ex situ* populations, including the American Association of Zoos & Aquariums (AZA), European Association of Zoos & Aquariums (EAZA) and the Indonesian Zoological Parks Association (PKBSI). With some additional holdings in some other Asian countries, like Japan or Singapore, the global *ex situ* population of Anoa currently consists of approximately 185 anoa among 42 differ-

ent zoos and aquariums around the world (Fig. 1A).

The first animal recorded being brought into a zoo from the wild was as early as 1844 with the importation of an anoa into a zoo in Paris, France (Burton et al., 2018). The more modern populations in the other zoo regions are from exports occurring in the late 1960's and mid 1970's. Eleven animals were brought into zoos and aquariums and nine of these make up the genetic founders from which all the AZA and EAZA animals currently descend. Cooperative breeding programs and population management have been present in both EAZA and AZA regions since the 1980's (Faust et al., 2019). These programs focus on managing *ex situ* populations for particular goals among member institutions, sharing data, exchanging animals and being genetically and demographically minded about how to manage animals for long term sustainability. Each region manages their populations regionally, but with the global population in mind.

The *ex situ* population in EAZA consists of 41 anoa across 20 member facilities and is managed in a cooperative program called an EAZA

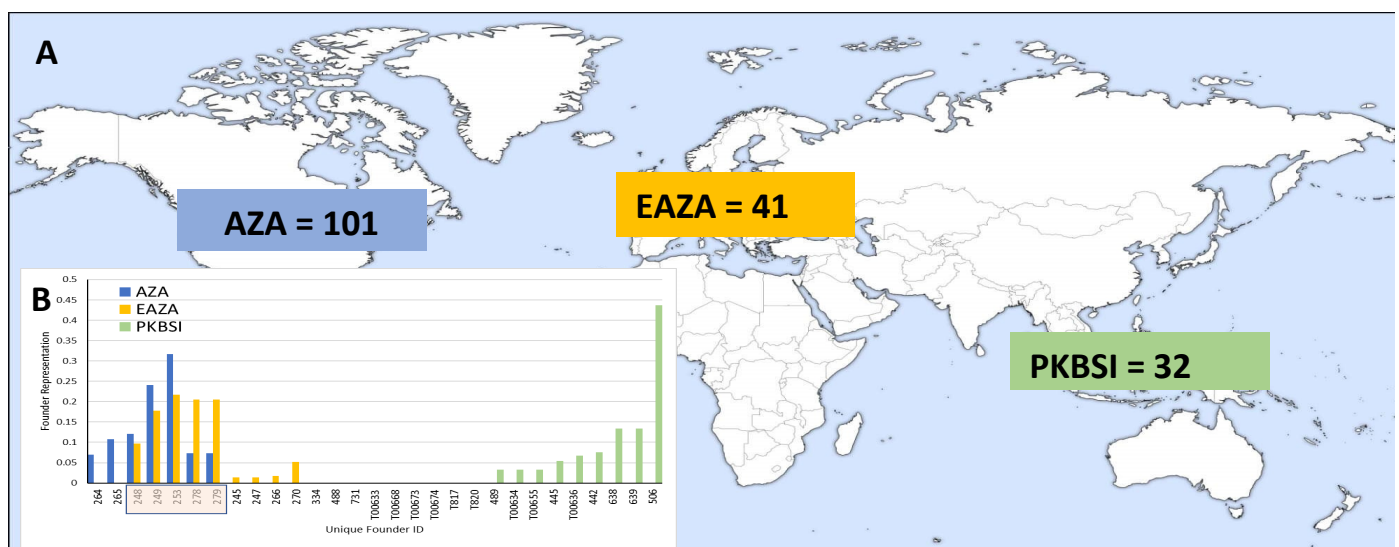


Figure 1: (A) Global depiction with zoo regions labeled in colored boxes and the current size of each regions *ex situ* population. (B) Inset in the global map, is a representation graph showing how all currently living animals among these three zoo regions are related. In Blue, AZA founder representation overlaps with several EAZA founders in orange, indicating that these two population share many common ancestors. In Green, the PKBSI population founders are noted. For all those founder ID's on the x-axis with no representation represent unique genetics among the global population.

Ex-Situ Program (EEP). With the small size of this population, successful breeding and demographic stability is vital to sustaining anoa long term in European zoos. Recently, this population has been challenged with few births and loss of some breeding aged females (Fig. 2).

To combat recent challenges, the population managers have recommended more transfers than usual to set up new breeding pairs and recruit new zoos to breed and exhibit anoa. Genetically, anoa in this region may be closely related and inbreeding may be difficult to avoid. In cases like this, keeping the population productive and reproducing maintains demographically stable populations. For long term sustainability, this *ex situ* population will need to continue consistent breeding to maintain demographic numbers and then must incorporate new animals with unrelated genetics.

In AZA, anoa are managed in a similar cooperative program called Species Survival Plans (SSPs). Most animals in AZA are related to those in Europe because of historic exchanges of animals between regions. In AZA, the population size is even smaller. Only ten anoa are held at seven AZA facilities currently (Fig. 2). Without

more holders, that small population alone is not viable by itself. Interest and support for exhibiting this species is waning in AZA. With increased successes in the global efforts, population managers are hoping to reverse this trend. Interestingly, one private North American facility, specifically for ungulate conservation, holds over 150 anoa. Including this facility, North America contains the largest *ex situ* population of any anoa globally. Gene diversity is still a challenge in all North American anoa as they are all from the same sources as European animals. The North American population needs more zoos to exhibit and promote the species and make space for the population to grow. Like Europe, new unrelated animals from the range country would genetically benefit the population greatly and improve sustainability.

In Indonesia, the zoo population is also small but being closer to the native range of the species, may be more genetically diverse and more distantly related to other regional populations (Fig. 1B). According to the international studbook of Anoa, the zoo population in Indonesia currently consists of 37 anoa across seven zoos and breeding centers. The current *ex situ* population started around 1970 and grew from breeding and

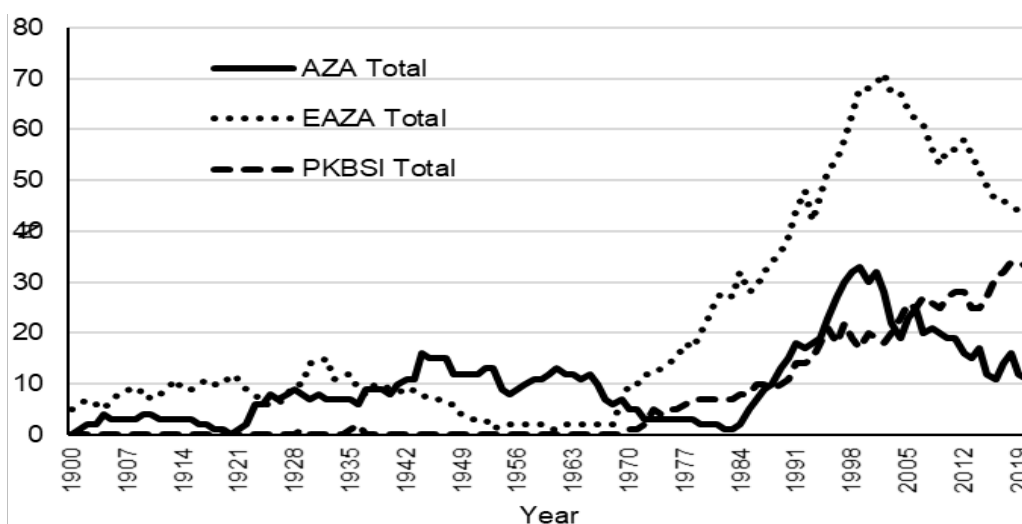


Figure 2: Census of the global *ex situ* anoa population by zoological region; AZA, EAZA and PKBSI regions from 1 Jan 1900 to 31 Dec 2020

confiscations of animals from the wild to the current size (Fig. 1). The Indonesian Zoo Association (PKBSI) is in the process of building their own version of a cooperative breeding program with anoa and various other species, with the support of Action Indonesia (Burton et al., 2020). Early steps of this process involve data sharing among member zoos and managing data in a national studbook. Data are provided from zoos that hold anoa to a central zoo professional that works at a facility that is a member of PKBSI. For Anoa, Dr. Yohana Tri Hastuti from Taman Safari Indonesia, Bogor is the National Studbook Keeper and is responsible for keeping accurate data to facilitate population management and communicating with Indonesian zoos that hold the species they are managing. While small, the Indonesian *ex situ* population is important because they are potentially the most important source of unique genetic founders in zoos (Fig. 1B). Not only will it be vital for growing the *ex situ* population there to represent different genetic lines more, but exchanges to other regions would infuse much needed diversity in the future. Some facilities in Indonesia are unique and meant for breeding the species or as a rehabilitation facility for confiscated animals. Current challenges for the anoa *ex situ* population in Indonesia are largely space constraints and need for transferring animals. Moving animals around Indonesia is difficult logistically and physically, but mixing up animals to cross blood lines and avoid inbreeding is vital to long term sustainability.

Breeding and transfer recommendations between zoos is a key tenant of cooperative breeding programs in zoos. These recommendations guide which animals should breed to avoid inbreeding and increase gene diversity as well as how to mix animals among zoos so that

bloodlines are not overrepresented, zoo needs for exhibit animals or moving offspring are met and demographic stability can be maintained.

The Anoa GSMP group has been working hard to collaboratively build breeding programs among Indonesian zoos since 2016 and has achieved several successes. The first formal analysis was completed of the Anoa National Studbook in 2016. Following this analysis, and workshops held in Indonesia with zoo official attendees from across Indonesia, the first formal written report sharing the *ex situ* population status and breeding and transfer recommendations was produced. This document contained the current gene diversity, demographic status and future recommendations for the population in Indonesia, including a national Indonesian target of increasing the *ex situ* population to 75 anoa individuals. It was then shared with all zoo officials holding anoa, as well as government officials and used to guide breeding in the *ex situ* population. In 2018, a second document was created with updates after changes in the population and following the 2nd Action Indonesia Global Species Management Plan Workshop. In this workshop, 91 participants from 20 Indonesian zoos attended as well as 30 other Indonesian and International institutions. For anoa holders, 17 attendees from 7 zoos who hold anoa were able to attend, discuss and share their experiences and needs at the workshop helping to create better recommendations for everyone. Engaging with such a wide group of people has been key to building cooperation and success in population management. Four births were produced from recommended pairings and one recommended transfer was accomplished following recommendations since 2018. This is a massive success for *ex situ* population management of anoa in Indonesia, but

there is more to learn. As we continue to move forward and prepare for the next workshop and next set of recommendations, we continue to learn from the past, and change or build this process with partners in the GSMP.

In addition to these *ex situ* population successes in Indonesia, the Anoa GSMP also develops strategies for maintaining the global population. Each zoological region faces different challenges related to zoo space for new animals, relatedness among populations or need for demographic support. Previous strategies to address these challenges center on the idea of inter-regional transfers of animals. AZA and EAZA would benefit from more interest and space to increase population numbers in their respective regions, but they would also benefit from new genetic unrelated lines from Indonesia. Conversely, Indonesia could also use more space to grow, but capacity building is needed to build a system of cooperation, and partner with government, zoo and PKBSI officials to make transfers easier in Indonesia.

In addition to building up genetically viable *ex situ* populations to strengthen the genetic diver-

sity of the global metapopulations, the Action Indonesia GSMPs work holistically to raise awareness about the species and their threats, and to support in situ conservation efforts through population monitoring. Conservation education can increase knowledge of species and conservation efforts where they are implemented (Nekaris et al., 2017) and can influence public behavior and connection to nature (Ancrenaz et al., 2018). Educators in the GSMP have been integral to spreading the word and messaging among member zoos around the world, which would intern bolster *in situ* support for rescued animals. Education groups have developed a web platform to focus information for Action Indonesia, implemented the first annual Action Indonesia Day in August 2019, and started Facebook groups to connect educators across the globe. GSMP educators also successfully delivered workshops to Indonesian zoo officials to encourage more education programs, signage and started short term community education outreach projects in partnership with NGOs with communities living with these species (Burton et al., 2020). In the next three years, awareness raising will also occur directly



A female anoa and her calf from Leipzig Zoo in Germany. Credit: Leipzig Zoo

to address threats to populations in the wild in Sulawesi and Java.

The Anoa GSMP continues to implement strategies for cooperative breeding and managing the global population sustainably, but *in situ* populations have benefited from zoo, government and *in situ* experts. Experts from Indonesia (and international) zoo staff and government representatives have shared their experience through training Sulawesi protected area rangers on handle and transport of rescued anoa.

Technical support from Indonesia and international zoo experts is ongoing to develop an island wide coordination of the management of rescued anoa by local government offices. Currently, monitoring of anoa populations trends over time in the wild is not consistent between sites and absent for some important populations. So work is in development by Indonesian and international experts to achieve greater consistency and start new monitoring to fill knowledge gaps, funded by zoo partners. In the future, it is likely that anoa in the wild may need to be managed as a metapopulation (regional group of connected populations of a species with movement of animals among sub populations) to maintain gene diversity as much as possible. Different *ex situ* populations and the wild populations are likely to become too small to maintain gene diversity. Action Indonesia partners will continue to be vital, even if partners are not zoos exhibiting species in the GSMPs.

Fundraisers, conservation supporters, keepers and educators from zoos, non-profit, academic and government agencies are all active participants with Action Indonesia initiatives for anoa and other species. These partnerships can provide input on future holistic strategies to manage a metapopulation of anoa successfully.

Maintaining gene diversity is vital for sustaining populations of anoa, whether in the wild or in zoos. Wild anoa especially have recently been found to have lost a significant amount of gene diversity in the past few hundred years (Frantz et al. 2018). In zoo populations that are often closed (i.e. no imports or exports), gene diversity will always decline via genetic drift (Lacy, 1997). Population management is what we use to slow loss of gene diversity as much as possible for sustainability and ensure animals are as diverse as possible if ever needed for reintroductions. Understanding the genetic status of assurance wild and zoo populations then becomes more vital for long term conservation. Research is underway to evaluate the level of relatedness among *ex situ* anoa, determine individual geographic origins of animals compared to wild anoa and determine true genetic variability of the zoo population compared to the wild.

Ex situ and *in situ* experts in the Anoa GSMP collaborated with geneticists to help prioritize which zoo anoa to sample for these research questions. Samples will be processed in Indonesia, in partnership with Indonesian scientists. Results from this multidisciplinary study will help give more resolution to the relatedness of zoo anoa and can feed into management recommendations. Zoo populations are highly valuable as assurance populations for future conservation needs and incorporating genetic results can strengthen the sustainability of anoa in zoos.

While much has been accomplished in the first five years of Action Indonesia, the Anoa GSMP has a strong vision of the future. All three regions aspire to grow their regional sub populations and increase the interest of zoos in their regions to house anoa. The GSMP continues to work with *in situ* partners and the donor community around the world to strengthen population monitoring

efforts across multiple sites in Sulawesi to inform future management. International zoo donors provide a great deal of support to the Anoa GSMP, especially in development of future *in situ* projects.

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