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Philippine warty pigs (*Sus philippensis*). Photo: Brian T. Sanabal

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Table of Contents

EDITORIAL *by Thiemo Braasch* 4

Mobilizing action and partnerships to address African Swine Fever in Asia *by Matthew Linkie, Tiggy Grillo, Caitlin Holley, Eva Johanna Rode-Margono, Ferran Jori Massanas, Amanda Fine, Steven Unwin, Emily Denstedt, Yooni Oh* 5

Suspected African Swine Fever (ASF) mass die-offs of Philippine Warty Pigs (*Sus philippensis*) in Tagum City, Mindanao, Philippines *by Joselito B. Chavez, Harry D. Morris, Gia-Luvim Suan-Moring, Lief Erikson D. Gamalo and Emilia A. Lastica-Ternura* 8

Molar tooth emergence in *Babyrousa* spp. *by Alastair A. Macdonald* 12

A new record of Moluccan babirusa (*Babyrousa babyrussa*) in the Masbait Nature Reserve, Buru Island, Indonesia *by Ayu Diyah Setiyani and Tri H. Kuswoyo* 20

The sticky piggy: an alternative non-invasive method for fixing telemetry devices on wild boar (*Sus scrofa*) *by Jörg Beckmann, Horst Reinecke, Marcus Meißner, Sven Herzog and Helmuth Wölfel* 26

Sympatry between desert warthog *Phacochoerus aethiopicus* and common warthog *Phacochoerus africanus* in Kenya, with particular reference to Laikipia County by Thomas M. Butynski and Yvonne A. de Jong 33

Habitat occupation by peccary *Tayassu pecari* and *Pecari tajacu* (Artiodactyla: Tayassuidae) in the Calakmul region, Campeche, Mexico *by Marcos Briceño-Méndez, Eduardo J. Naranjo and Mariana Altrichter* 45

ARTICLES IN THE NEWS 55

NEW BOOKS ABOUT SUIFORMES 72

Editorial

Dear fellow readers,

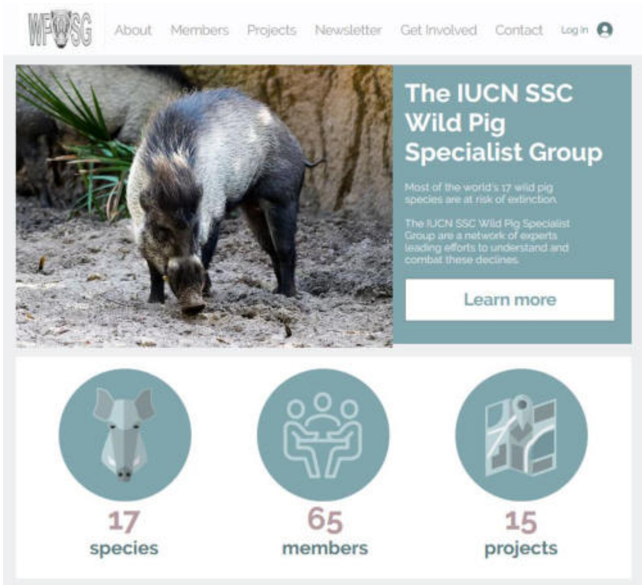
I am glad to present you this issue of Suiform Soundings. Again we present many interesting articles about African Swine Fever on the Philippines, babirusas on Buru, the emergence of teeth in babirusas, wild boar telemetry, warthogs in Kenya and habitat occupation of peccaries in Mexico.

We are also glad to present the new websites of the IUCN/SSC Wild Pig Specialist Group:

https://www.iucn-wpsg.org/

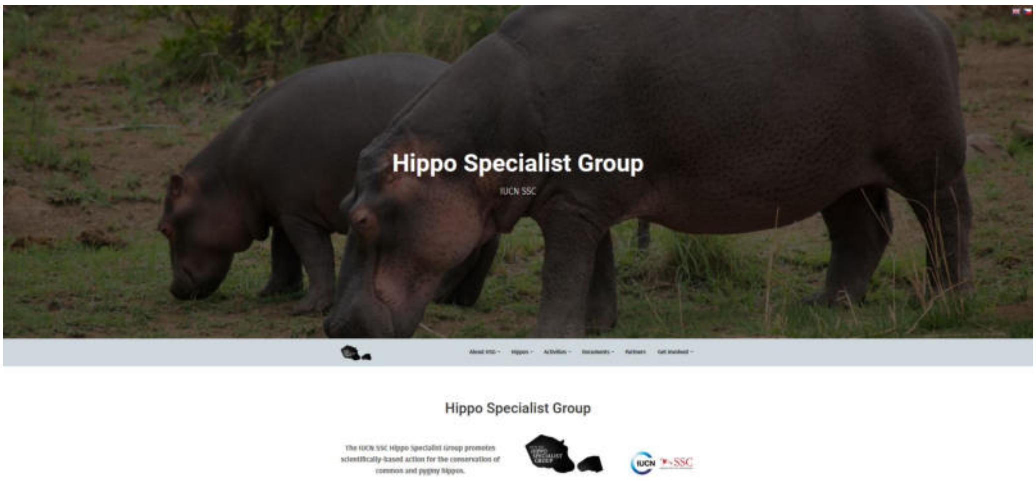
and of the Hippo Specialist Group:

https://www.hipposg.org/



These new websites offer updated information about the two specialist groups and their projects and will hopefully help to raise more public interest for wild pigs and hippos. The old WPSG website will be shut down soon.

The global Covid-19 pandemic still has a strong grip on many countries and regions around the world and the outcome for many nature and species conservation projects still remains an unanswered question. Unfortunately, African Swine Fever is posing a further dangerous threat to wild pig species across Asia and causing big concerns even for species like Bornean bearded pigs with new infections recorded in Sabah (see also in the section “In the news”). Let us all hope that the two pandemics will cease soon!



With warm regards,

Thiemo Braasch

Chief Editor Suiform Soundings

Mobilizing action and partnerships to address African Swine Fever in Asia

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Forests and biodiversity across Asia are under considerable pressure, be it through conversion of natural forests to exotic plantations for oil palm and rubber production or through poaching endangered species such as the Sunda (*Manis javanica*) and helmeted hornbill (*Rhinoplax vigil*) for the illegal wildlife trade. These pressures are synergistic and have greatly stressed ecosystems and wildlife populations, leaving them less resilient against stochastic events, such as climate change and disease outbreaks. Healthy forests and thriving wildlife populations provide essential ecosystem services, such as seed dispersal, pollination, sources of protein, regulation of water flow and much more. Depletion of these ecosystem services and the degradation of nature in general impacts human wellbeing, particularly that of the rural poor who live near forest areas and greatly depend on their services. The introduction of African Swine Fever (ASF) into the Asian region presents a significant risk to both food security and wildlife conservation. Since its first detection in August 2018, ASF has decimated livestock and infected wild pig populations across the region. By June 2021, ASF had rapidly spread to 15 Asian countries causing great alarm amongst a wide diversity of stakeholders (OIE, 2001).

The ASF virus is one of the most devastating infectious diseases of swine. It is highly contagious and although harmless to human and other species health, it is almost always fatal in wild boar and domestic pigs, both Sus scrofa. How it impacts other wild pig species is unknown and this uncertainty is the first cause for concern (Luskin et al., 2020).

In Asia, the Suidae family comprises 12 wild species (including wild boar, *S. scrofa*). Except for a Critically Endangered population of pygmy hog (*Porcula salvanius*) that is present in the Indian subcontinent, the eight other species of suidae (*Sus* spp.) and three species of *Babyrousa* are distributed across Indonesia, the Philippines, and Malaysia. These species are often endemic to islands, such as the Critically Endangered Visayan warty pig (*S. cebifrons*) on Negros and Panay in the Philippines or the Endangered Javan warty pig (*S. verrucosus*) on Java in Indonesia. Thus, the introduction of a novel lethal disease, such as the ASF virus, into a native wild pig population has the potential to wipe out these already threatened species. Furthermore, several of these pig species constitute an important prey species for large carnivores, such as tiger and leopard. The depletion of this key prey species would potentially increase predation of livestock and human-predator conflicts with detrimental consequences for farmers, these apex predators that are

already threatened with extinction, and the biosystem as a whole.
The ASF virus can be transmitted between pigs in multiple ways, through contact with infected animals, consumption of infected carcasses or pork products (raw, frozen, dried or under-cooked) or fomites. Depending on the ecosystem where the virus is introduced, it can adapt to survive in the wild and re-infect new individuals. In Africa, the common warthog (Phacochoerus africanus)-Ornithodoros tick cycle plays a major role in the maintenance of the virus in the environment and the introduction of new viral strains into this cycle (Jori & Bastos, 2009). In Europe, the introduction of Genotype II has particularly affected wild boar populations. In north eastern Europe, frozen wild boar carcasses allow the virus to survive in the environment for several months and perpetuate new infections in what has been described as the wild boar-habitat epidemiological cycle (Chenais et al., 2018).

This ease of viral transmission and occasional maintenance in the environment raises high concern since the disease has resulted in the death and culling of 100s of millions of domestic pigs. This has had a profound economic impact, with an estimated loss of USD50-120 billion in 2019 (Weaver & Habib, 2020), and resulted in the loss of livelihoods and an important protein source for millions of people.

There are also challenges with preventing the transmission of ASF between domestic and wild pig populations. For example, in Vietnam, Cambodia and Laos transmission from backyard domestic pigs to wild boar has been recorded (Denstedt et al., 2020). Less robust animal management practices that are commonplace in Asia present specific disease risks, thereby providing the opportunity to directly infect wild pig populations with ASF. This is of particular concern for the wide-ranging bearded pig that occurs in groups of tens to hundreds of individuals and also the Visayan warty pig that lives in proximity to free-ranging domestic or feral pigs. Scavengers, such as small carnivores, may spread ASF within wild pig populations by feeding on infected pig carcasses and then spreading infected carcass material (Probst et al., 2019).

In the face of such urgency, the Food and Agriculture Organization of the United Nations (FAO), International Union for Conservation of Nature Species Survival Commission (IUCN SSC) and the World Organisation for Animal Health (OIE) convened a series of online meetings from February to July 2021 to understand ASF impacts on different sectors in the region, identify the immediate actions required, and how best to coordinate future efforts to mitigate the threat of ASF to wild pig species and elicit a stronger response. The issues covered wild pig conservation, an FAO and OIE Initiative for the Global Control of ASF (FAO & OIE 2020), good animal husbandry practice of backyard pigs, updates on ASF spread in domestic and wild pigs, and more.

With this in mind, the three organizations developed a collective statement to describe their shared ASF concerns and outline an approach for preventing and controlling spillover at the domestic animal-wildlife interface, based on biosecurity, surveillance, monitoring, and response systems for all wild pig species in Asia. The three key recommendations presented in the Joint Communique on ‘Conservation impacts of African swine fever in the Asia-Pacific region’ are:
“Together, we call for increased dialogue between government ministries with responsibility for ASF and relevant experts to develop government policies that mitigate the impacts of the disease on wildlife, livestock health and rural livelihoods.

We encourage stronger biosecurity, surveillance, monitoring and response systems across all sectors, inclusive of all domestic and wild animal species.

Finally, we encourage collaborations between key sectors and government ministries and urge them to agree on policies that integrate responsibilities on ASF control."

Another important output has been the establishment of clear channels of communication on ASF issues amongst the three organizations in the Asia-Pacific region and the foundations for a growing partnership, both regionally and in wild pig range state countries, to support government agencies and other concerned parties in implementing the recommended actions.

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Suspected African Swine Fever (ASF) mass die-offs of Philippine Warty Pigs (*Sus philippensis*) in Tagum City, Mindanao, Philippines

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Abstract

African Swine Fever (ASF) is an economically important reemerging infectious disease (EID) that has spread phenomenally throughout the world. Although it does not pose direct health risks to humans, the disease can cause devastating losses in livestock production due to its almost 100% mortality rate in domestic pig populations. Trade and commerce has caused the virus to travel to different parts of the globe, infecting domestic and wild pigs in Europe and China. The recent outbreak has affected the Philippines, affecting food security and the economy. The disease is also a looming danger to the future of the Philippines four endemic pig species, a number of which are threatened with extinction. This paper reports a case of a mass die-off of an IUCN vulnerable Philippine warty pig (*Sus philippensis*) population in a privately-managed forest patch in Tagum City, Mindanao, Philippines. Tissue samples were collected, and were sent to the Regional Animal Disease Diagnostic Laboratory XII (RADDL-XII) tested positive for ASFV using Polymerase Chain Reaction (PCR). This is the first report of ASF affecting a wild pig population in the Philippines.

Keywords: African Swine Fever, conservation medicine, Mindanao, Philippine Warty Pig, wildlife

Introduction

African Swine Fever (ASF) is a contagious disease caused by African Swine Fever Virus (ASFV) that lethally affects commercial and wild pig species (Chenais et al., 2019; FAO 2020). Although the virus does not pose direct health risks to humans and other animals, it can cause devastating loss in livestock productions due to its almost 100% mortality rate in pig populations (Costard et al., 2013; FAO 2020). Apart from its known original hosts, warthogs (*Phacochoerus africanus*), the virus has already been reported to cause conservation risks to other species of wild pigs (Sánchez-Vizcaíno et al., 2012; Luskin et al., 2020; Jori & Bastos, 2019; Laddomada et al., 1994; Beltrán-Alcrudo et al., 2009; Mur et al., 2012; FAO 2020).

In the Philippines, the first ASF outbreak was recorded in July 2019, which has been documented in some islands in the Philippines, including parts of Mindanao. The disease has caused death and culling of thousands of domesticated pigs from different areas in the country (FAO, 2020). There has been no recorded case of ASFV infecting Philippine endemic wild pigs.

Fig. 1: Map of the Hijo Resources Corporation showing its protected forest and agricultural properties.

Case Presentation

On January 4, 2021, an unexplained death of nine wild pigs, morphologically identified as Philippine warty pigs *Sus philippensis*, was documented in the forests and agricultural areas of Hijo Resources Corporation (HRC) (7˚21'18"N; 125˚47'37"E). The 325-hectare area is surrounded by waterbodies; Libuganon River on the western side, Nabintad River on the northern portion and the southern side faces the Davao Gulf (Fig. 1). The area has a flat to nearly flat terrain based on its elevation that ranges from one to three meters above sea level (m asl) (Fig. 2 and 3).

On January 7, 2021, HRC management, together with the City Veterinary Office of Tagum, arrived at the area to do an ocular inspection and a post-mortem examination on two individuals showing unusual symptoms similar to ASF-infected domesticated pigs. The animals which were already lethargic and dying were very warm to the touch and had erythema seen as purplish to black spots on the dark integument of the ventral part of the wild pigs (Fig. 4). The animals were also seen to be weak and had difficulty standing. Blood samples from these two individuals were collected and sent to Regional Animal Disease Diagnostic Laboratory (RADDL) -XII in General Santos City for ASF testing, then carcasses were immediately buried (Fig. 5). On January 20, 2021, RADDL-XII declared the samples positive for ASF (RADDL-XII, 2021). As of February 1, 2021, there have been 141 deaths recorded. Though not all of these dead pigs were tested for ASFV, the virus may be the most likely culprit of this die-off.

In response to this incident, HRC implemented several measures to control the spread of the virus and to conserve the remaining population. These include disinfection of the resort premises; active surveillance of dead and dying individuals; and burying or incinerating carcasses. Capture of suspected uninfected pigs for isolation was also attempted, to no avail. Collaborations were initiated among HRC management, Local Government Unit of Tagum, Department of Environment and Natural Resources – XI, and Department of Agriculture - XI, and University of

Fig. 2: Aerial shot of the forest.

Fig. 3: Aerial shot of the coconut plantation.

the Philippines – Mindanao to come up recovery plans that can be implemented. One of the recommendations following these discussions is to sequence the positive samples to determine the viral origin, however, talks among concerned agencies are still on going.

Discussion

All Philippine endemic pigs, and in particular, *S. philippensis*, *S. ahoenobarbus*, *S. cebifrons*, and *S. oliveri* were assessed to be at a 'high' to 'very high' risk of ASF infection (Luskin et al., 2020). The authors believe that there is a serious risk of ASF on *S. philippensis* populations in contact with those from HRC, and this will pose a huge effect on the overall ecosystem functions in their habitats, as these species are considered ecosystem engineers (Luskin et al., 2020). Massive deaths of wild pigs will also affect locals who consider the species as an important resource (Tanalgo, 2017). Before ASF, the greatest threat to endemic wild pig populations in the Philippines has always been forest land conversion and genetic contamination (Meijaard et al., 2017) brought about by faulty management of backyard domestic pigs living in forest and around forest edges. ASF exacerbates the challenges faced by these species, particularly those that are already currently threatened, such as the ones mentioned above.

However, there might still be some light at the end of the tunnel, as the area of the HRC is not contiguous with any other forest reserve. Let this case remind us of the precarious position wild pigs are in, so that concerned agencies and stakeholders may carefully, but rapidly formulate integrated management strategies that can prepare for possible future outbreaks that threaten not just Philippine endemic suids, but all endemic species and wild habitats.

Fig. 4: Post mortem photos showing (A) hemorrhages on large and small intestine and (B) erythema on integument of ASF-infected wild pig.

Acknowledgment

The authors would like to thank the City Environment and Natural Resources Office of Tagum; Department of Agriculture-XI, and Department of Environment and Natural Resources-XI for the technical assistance and commitment to this mission; and to Dr. Jayson Ibañez, who facilitated the meeting of the response team. Many thanks Regional Animal Disease Diagnostic Laboratory (RADDL) -XII for analyzing the samples. Finally, we salute the staff of The Trinity Project who have devoted their time and energy implementing things on the ground.

Fig. 5: Disposal of dead pigs on a burial pit.

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Molar tooth emergence in *Babyrousa* spp.

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Abstract

The studies were carried out on 20 male and female babirusa (*Babyrousa* spp.) skulls, ranging in age from birth to approximately two years, curated by six international museum and private collections. The deciduous dentition of the babirusa is:

3i 1c 3p x 2 = 28
3i 1c 3p

Within about three months of birth the three deciduous cheek teeth were in place. The permanent M^1 and M_1 molar teeth had begun to erupt. These permanent teeth had fully erupted by 13 months of age. By about 16 months of age, the mandibular M_2 had appeared in place although the maxillary M^2 tooth had only partially emerged. By about 20 to 24 months of age the replacement, on each side of the maxilla and mandible, of the three deciduous premolar teeth by two permanent premolars had been achieved. The eruption of the third molar tooth in both maxilla and mandible was completed early in the third year of life.

Introduction

Despite the fact that many people have been greatly fascinated by the appearance and activities of new-born and juvenile babirusa (*Babyrousa* spp.), very little has been written about this important time in the lives of these interesting Indonesian suids (Ito and Melletti, 2018; Macdonald, 2018; Sheherazade et al, 2018). Stehlin (1899, 1900) drew attention to some aspects of neonatal babirusa dentition and Herring (1972) undertook some studies of the muscular anatomy of the head of a fetal babirusa. Various aspects of babirusa nursing behaviour have been described (Leus et al., 1992; Patry et al., 1995; MacLaughlin et al., 2000; Macdonald and Mitchell, 2019). Unsurprisingly, the development of the tissues inside the mouth of the young babirusa had been an area of relative neglect. Recent analyses of canine tooth development (Macdonald et al, 2016) drew attention to an absence of detailed examination of the deciduous teeth of babirusa. An overview of the research material required for such a study revealed that very few skulls of newly born and young juvenile babirusa have ever been placed in museum collections (Macdonald et al, 2016; Macdonald, 2021). The present investigation undertook to examine as much as possible of the available material and to present a synthesis of its findings.

Material and Methods

The studies were carried out on 18 male and 2 female babirusa skulls from six international museum and private collections (Table 1). Most skulls originated from Sulawesi (*Babyrousa celebensis*); one skull came from Buru (*B. babyrussa*); three skulls were from acute veterinary casualty cases in zoological collections (*B. celebensis*). This assembly of skulls represents the stages of babirusa tooth development from birth until the eruption of the third molar teeth.

Table 1: A summary list of all the specimens of Babyrousa spp. skeletal material examined in this study together with the study (AAM) identification number, museum name or private collection, registered specimen number, sex (M = male; F = female), age and molar tooth position, estimated order of dental development and origin of specimen.

AAM number	Museum or private collection	Registration	Sex	Age (Molar tooth position)	Age order	Origin
AAM0054	Naturhistorisches Museum Basel	C.2877	M	~22 months Sub-adult (M3 emerging)	17	North Sulawesi
AAM0055	Naturhistorisches Museum Basel	C.2878	M	Sub-adult (M3 emerging)	18	North Sulawesi
AAM0058	Naturhistorisches Museum Basel	C.2881	M	Sub-adult (M3 emerged)	19	North Sulawesi
AAM0065	Naturhistorisches Museum Basel	C.3036	F	Neonate (deciduous emerg)	1	North Sulawesi
AAM0247	National Museum of Scotland, Edinburgh	NMSZ. 1993.159.004	M	~13 months Juvenile (M2 emerging)	9	Zoo
AAM0268	National Museum of Scotland, Edinburgh	NMSZ. 2004.225.003	M	~16 months Juvenile (M2 emerging)	10	Zoo
AAM0269	National Museum of Scotland, Edinburgh	NMSZ. 2004.224.002	M	~6 months (both M1 emerging)	4	Zoo
AAM0310	Göteborgs naturhistoriska museum	4,73	M	Neonate (both M1 emerged)	5	North Sulawesi
AAM0316	Göteborgs naturhistoriska museum	17,937	M	Sub-adult (M3 emerged)	20	North Sulawesi
AAM0344	Göteborgs naturhistoriska museum	17,965	M	Sub-adult (M3 to emerge)	12	North Sulawesi
AAM0349	Göteborgs naturhistoriska museum	17,97	M	Juvenile (M2 emerging)	8	North Sulawesi
AAM0392	Naturalis, Leiden	28798	M	~ 3 months (both M1 to emerge)	3	North Sulawesi
AAM0393	Naturalis, Leiden	28799	M	Neonate (both M1 to emerge)	2	North Sulawesi
AAM0774	Private collection	(no number)	M	Subadult (M3 emerging)	14	South-east Sulawesi
AAM0775	Private collection	(no number)	M	Juvenile (M2 to emerge)	6	South-east Sulawesi
AAM0776	Private collection	(no number)	M	Juvenile (M2 to emerge)	7	South-east Sulawesi
AAM0400	Naturalis Leiden	28811	M	Sub-adult (M3 emerging)	16	Buru
AAM0453	British Museum (Natural History), London	19.11.23.6	M	Sub-adult (M3 emerging)	13	Sulawesi
AAM0640	Smithsonian National Museum of Natural History, Washington	199883	F	Sub-adult (M3 emerging)	15	North Sulawesi
AAM0655	Smithsonian National Museum of Natural History, Washington	199896	M	Sub-adult (M3 to emerge)	11	North Sulawesi

Results

The relative changes to be seen in the external appearance of the neonatal, juvenile and subadult babirusa during the first two years of life are illustrated in Figure 1. The oral region of the skull grows in length as the nose and mandible elongate. The maxillary canine tooth and its supporting alveolus change both in shape and in orientation. At birth the deciduous teeth had erupted or had begun to erupt (Figure 2). The cusps of the somewhat elongated mandibular p_3 were almost fully exposed. The shorter adjacent p^2 teeth had already penetrated into the oral cavity. The small p_1 teeth also appear to have erupted before birth. The maxillary deciduous premolar teeth seemed to be slightly later in erupting (Figure 2). The p^1 and p^2 in this specimen had entered the oral cavity. However, the p^3 appeared to be still partially covered by bony material.

The premolar deciduous teeth are illustrated in Figure 3. The deciduous dentition of the babirusa is:

3i 1c 3p x 2 = 28
3i 1c 3p

Within about three months of birth there were signs that the permanent M^1 and M_1 molar teeth had begun to erupt their way through their bony oral covering (Figure 3). The overlying bone had begun to be removed and some of the granular appearance of both upper and lower first molar teeth was visible. The narrow p^1 tooth was conical in lateral appearance and had prominent serrations down its distal slope (Figure 3A). There appeared to be smaller irregularities in the mesial slope of the tooth. It had two roots. The narrow p_1 tooth was also conical in lateral view and had a smooth mesial slope and a somewhat serrated distal slope (Figure 3A). It also had two roots. The similarly conical p_2 tooth was larger and appeared to have small serrations on both the mesial and distal slopes. The tooth had two roots. The maxillary p^2 tooth was broader distally, having one prominent mesial and two prominent distal cusps (Figure 3B). It had three roots, one mesially and two distally placed. The p_3 tooth had four prominent cusps, two mesially and two distally arranged, which gave the tooth's occlusal view a squarer appearance. Below each cusp was a main root. The p^3 tooth had six prominent cusps, three buccal and three lingual (Figure 3C). There was a root below each of the three buccal cusps (Figure 3C). Two roots were seen on the lingual side, one mesial and one distal (Figure 3C).

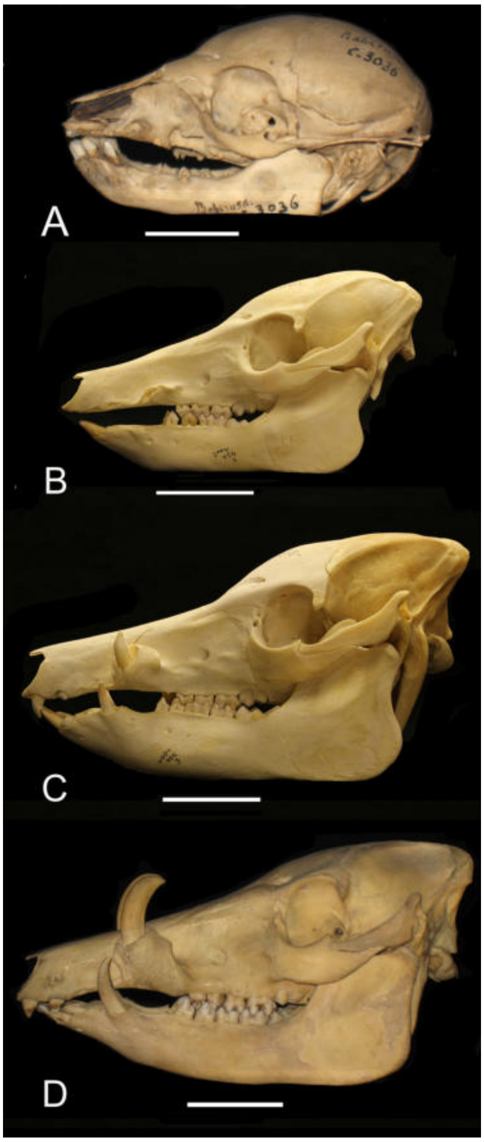

Fig. 1: Left lateral views of the skulls of neonatal, juvenile and sub-adult male babirusa (*Babyrousa celebensis*) Bars = 5cm. A. At birth (Basel C.3036); B. At about six months of age (NMSZ 2004.224.002); C. At about 16 months of age (NMSZ 2004.225.003); and D. At about 20-24 months of age (Basel C.2877).

By about six months of age (NMSZ 2004.224.002) the mandibular M^1 tooth was still erupting distal to the deciduous p_1, p_2 and p_3 (Figure 4). All the cusps of the mandibular M_1 teeth had largely become clear of the mandibular bony covering. The maxillary M^1 tooth was also in the process of erupting; the two rostral cusps were clear of the bony covering, but the distal cusps were still partially covered by bone. The three deciduous maxillary premolars were present and as described above. A narrow, longitudinal opening had appeared in both the maxilla and mandible distal to the emerging first molar teeth (Figure 4).

Fig. 2: Maxilla and mandible of a new-born male babirusa (*Babyrousa celebensis*) (Basel C.3036). Bar = 1cm.

The skull of a male babirusa (NMSZ 1993.159.004), aged about 13 months, showed that both the mandibular and

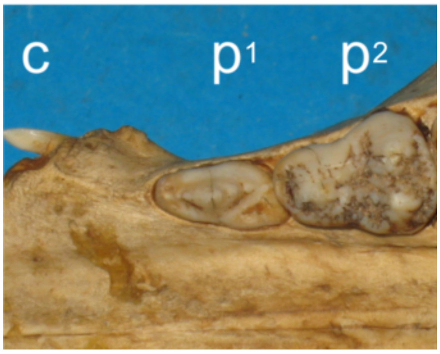

Fig. 3: The skull of a neonatal piglet (Naturalis, Leiden 28798) at about three months of age, illustrating the deciduous teeth. A Left lateral view of the skull showing the serrated edges of the deciduous premolar teeth, p^1, p_1 and p_2. Bar = 5cm. B. Oral view of the deciduous premolar teeth of the maxilla. The maxillary molar M^1 is beginning to erupt. C. Oral view of the deciduous premolar teeth of the mandible. The mandibular molar M_1 is beginning to erupt. c = deciduous canine tooth.

Fig. 4: Maxilla and mandible of a juvenile male babirusa (*Babyrousa celebensis*) aged about six months (NMSZ 2004.224.002). The deciduous cheek teeth remain, and the first molar teeth have almost emerged. Bar = 1cm.

maxillary first permanent molar teeth were established prior to the eruption of adjacent permanent premolar teeth (Figure 5). Indeed, the second molar teeth in both maxilla and mandible were evident but had not yet erupted into the oral cavity. Distal to these second molars, a narrow split in both the maxilla and the mandible was present. The deciduous premolar teeth remained in position in the maxilla and mandible.

Three months later, at about 16 months of age, the mandibular M_2 appeared to have fully emerged (Figure 6). However, the maxillary M^2 tooth had only partially emerged, the mesial cusps preceding the distal cusps. There was no change in the deciduous premolar teeth.

By about 20 to 24 months of age the replacement, on each side of the maxilla and mandible, of the three deciduous premolar teeth by two permanent premolars had been achieved (Figure 7). In this sub-adult babirusa, the process of eruption of the third molar tooth in both maxilla and mandible was not yet completed by that time; the mesial cusps had entered the oral cavity ahead of the distal cusps. (Figure 7). The completed eruption of M^3 was seen by the time of the first stage of maxillary canine tooth growth of adult babirusa (Macdonald and Shaw, 2018).

Fig. 5: Maxilla and mandible of a juvenile male babirusa (*Babyrousa celebensis*) (NMSZ 1993.159.004) aged about 13 months. The deciduous cheek teeth remain, the first molar teeth have emerged, and the second molar teeth are emerging. Bar = 1cm.

Fig. 6: Maxilla and mandible of a juvenile male babirusa (*Babyrousa celebensis*) (NMSZ 2004.225.003) aged about 16 months. The deciduous cheek teeth remain, the first molar teeth have emerged, as have the M_2 teeth. The M^2 teeth are still emerging. Bar = 1cm.

Fig. 7: Maxilla and mandible of a sub-adult male babirusa (*Babyrousa celebensis*) (Basel C.2877) aged about 20-24 months. The permanent premolar teeth have replaced their deciduous predecessors, the first and second molar teeth are in place, and the third permanent molar teeth are emerging. Bar = 1cm.

Discussion

This study has shown that the deciduous cheek teeth of the babirusa emerge before and shortly after birth and that they persist for approximately the first 18 months of its life. The morphology of these teeth suggests that the first maxillary premolar tooth and the first two mandibular premolar teeth have a cutting function (Figure 3). They also indicate that the second maxillary premolar tooth and both maxillary and mandibular third premolar teeth have more of a food crushing function. The eruption of the first molar tooth by about six months of age significantly increases the occlusal surface area of the juvenile tooth row available to perform this latter function (Figure 4). In this regard it is relevant to note that babirusa sows in zoological collections weaned their offspring between the 25th and the 32nd week after birth (MacLaughlin et al, 2000), a timing that appears to coincide with the eruption of the first molar teeth in the piglet.

Food selection by juvenile babirusa has not yet been systematically studied or described in any way. Several unpublished anecdotal observations, of young babirusa ‘cutting/tearing’ leaves off dangling plants in the forest as they pass by, is the extent of current knowledge from in the wild. Juvenile babirusa could be expected to have access to many of the plant leaves and fruits reportedly eaten by older babirusa (Leus, 1996; Macdonald and Pattikawa, 2017; Macdonald et al, 2018). This hypothesis requires investigation, modification and possible confirmation. There have also been no reports of older babirusa facilitating juvenile access to food plants in the wild. In zoological collections, juvenile babirusa are fed the same diets as older pen-mates. However, it is not yet known if these juvenile pigs make any specific selections from the wide range of fruits and vegetables offered to them (Leus et al, 2001). Studies of cheek tooth wear indicate that although the maxillary and mandibular first molar teeth were the first ones to receive significant wear, this was relatively slight in pre-adult babirusa (Macdonald, 2019).

There are similarities and differences in the development of cheek teeth in different suids. The pattern of appearance of the cheek teeth in *Sus scrof*a was reviewed by Briedermann (2009). The p^3 and p_4 deciduous teeth had erupted within two weeks of birth, the p_3 by about four weeks, and by the sixth week p^4 had followed. The second premolar teeth followed an irregular and slow path, erupting between two and four months after birth (Briedermann, 2009). The first permanent teeth molar teeth (M^1 & M_1) were evident at four months of age and had erupted in both mandible and maxilla by five months. The second molar teeth appeared during the second year, and the complete permanent dentition was established early in the third year of life.

In the *Sus domesticus* piglet the p^3 erupted at about 6 days after birth and the p_4 erupted about one day later. The p^4 erupted at about ten days and the p_3 about nine days later (Tucker and Widowski, 2009). The maxillary deciduous cheek teeth p^2 have two roots, p^3 have three roots and p^4 have four or six roots. The corresponding situation in the mandibular cheek teeth are p_2 and p_3 each have two roots and p_4 has five or six roots (Habermehl, 1957; Ide et al, 2013). The maxillary and mandibular first molar teeth were present before the replacement of the deciduous teeth by the permanent premolar teeth (Tongue and McCance, 1973).

In the African bushpig (*Potamochoerus porcus*) the third premolar deciduous tooth is the first cheek tooth to erupt in both jaws at about five weeks after birth (Sowls and Phelps, 1968). This is followed by p^4 and p_4 teeth at about 10 weeks. By about four months the deciduous dentition is complete. At about five to six months the first molar tooth M_1 erupts followed shortly thereafter by M^1. The second molar teeth erupt at between 14 and 17 months.

In the warthog (*Phacochoerus africanus*), deciduous premolar teeth were not replaced during the first year (Mason, 1984). Replacement of the deciduous premolars in the mandible tended to slightly precede that in the maxilla. The observed age range at commencement of eruption of the permanent premolars was about 12 to 14 months, and was completed by about 20-22 months. The eruption of M^1 was less advanced than M_1 at an estimated age of one to three months. The M_2 and M^2 teeth commence eruption between nine and eleven months of age. The third mandibular molar teeth start erupting at between 17 and 20 months of age (Mason, 1984).

Although behavioural signs of the sexual maturity of the male babirusa had been reported to occur between about five and ten months of age (National Research Council, 1983) it is much more likely that in the wild this occurs sometime after they are more than one year old (Macdonald, 1991). A clear indication of that probability is the report from zoological collections that male sexual maturity is achieved by about 18 months (Thomsen et al, 2010). It is also of interest that this is the timeframe for the eruption of the babirusa's third molar teeth (Figure 7) and is about the time of the more prominent presence of the maxillary canine teeth (Figure 1D; Macdonald and Shaw, 2018).

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A new record of Moluccan babirusa (*Babyrousa babyrussa*) in the Masbait Nature Reserve, Buru Island, Indonesia

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Introduction

The Moluccan babirusa (*Babyrousa babyrussa*) occurs on Buru and the Sula Islands of Taliabu and Mangole, and is probably extinct on Sulabesi Island (formerly Sanana) (MacKinnon, 1981; Macdonald, 1993; Verbelen, 1997). It is listed as a vulnerable species on the IUCN Red Lists of Threatened Species (Macdonald, Burton, & Leus, 2008) and as a protected species under Indonesian law. There are very few recent records of the presence of this species. Most of the scientific attention has focused on the Sulawesi babirusa (*Babyrousa celebensis*) (Macdonald, 2018) or on data derived from captive babirusa species in zoos (Leus, Bowles, Bell, & Macdonald, 1992).

Historical records of babirusa on Buru were presented by Tjiu & Macdonald in 2016, who stated that babirusa were reported on the eastern part of the island, in the region of Kayeli in 1726. Moreover, some studies were done based on community reports from 1990 that confirmed babirusa sightings all over Buru Island except in the northern coast (Tjiu & Macdonald, 2016). During four bird surveys on Buru lasting between two days and two weeks, Eaton & Hutchinson (2015) saw no sign of babirusa on Buru. However, two sightings of Moluccan babirusa had been made by Johan van Roy in November 1999 near Gunung Kapalat Mada (Verbelen, 2003).

Ever since the Ministry of Environment and Forestry (MoEF) released a babirusa conservation action plan, the Natural Resources Conservation Agency of Moluccas (BKSDA Maluku) has been monitoring Masbait Nature Reserve (MNR) on Buru Island (from 2011 to 2013). However, there was no significant sign of babirusa. A recent study by Macdonald, Kailuhu, & Pattikawa, (2018) showed a young female babirusa and a group consisting of an adult male, two young males, and two juveniles in east and south-east of Teluk Kayeli. Therefore, the aim of our research was to determine the existence of the Moluccan babirusa in MNR and, if recorded, use this to inform the MNR management plan for the conservation of this species.

Fig. 1: The complete skull and skeleton of an adult male babirusa in the floodplain of Waypoti river in MNR.

Method

Our studies were conducted over three different surveys and three years (2019-2021) in MNR, Buru Island, by a technical team from BKSDA Maluku. The MNR was established in 1985 and is located in eastern Buru Island. The MNR is a national protected area spanning 8,080 ha and covered by secondary forest ranging from 100 to 1,125 meters above sea level.

The first survey was done using exploration methods to provide a clear image of MNR, including land use/land cover (LULC) and physical parameters. The second study was a combination of a desk-based study and field work. The desk-based study estimated the possible habitat of Moluccan babirusa in MNR using previous studies of Sulawesi babirusa from several scientific articles. Some parameters like LULC, slope, and elevation (Rosidiy & Wibowo, 2020) were considered to predict suitable habitat. The study continued with camera trap surveys in the north and south of MNR and the resulting images were marked with location, date, time, and temperature. In 2020, 5 cameras were installed at heights of approximately 60-130 cm above the ground surface in secondary forest (total 6 points in north and south part) in certain areas based on the suitable habitat map created from the desk-based study.

According to the results and evaluation of the previous surveys, up to 10 cameras were located in 7 points in the northern part of MNR from 11 April to 19 June 2021. All 10 cameras were placed 140-225 meters above sea level. Suitable habitat was not the only consideration in placing cameras, but included other factors based on previous studies, such as the babirusa's home range size, estimated 'salt lick' presence, foraging areas, animal paths, animal tracks, and landscape. All of the cameras were assumed to cover an observation block with approximately 1.2 km radius according to babirusa home range size (Clayton, 1996) and the block was separated by a non-seasonal river called Waypoti. Most of the cameras were located some 20 to 210 meters away from the river and set approximately 40-120 cm above the ground. The cameras were set to photo mode to capture 3 pictures with a 10 second delay.

Results and Discussion

Based on the first survey, 85% of MNR is classified as montane rainforest and the rest (15%) as dryland forest. The montane rainforest is covered by secondary forest dominated by *Shorea* spp. which supplies food for babirusa (MacDonald, Kailuhu, & Pattikawa, 2018). The dryland forest is dominated by shrubs and *Melaleuca leucadendron*.

The results of the first survey, during the dry season in November 2019, revealed the presence of babirusa in MNR; a complete adult male skeleton was discovered, including its remarkable tusks

Fig. 2: Camera trap photos of an adult female babirusa taken in 2020 by the technical team of BKSDA Maluku.

Fig. 3: Camera trap photos of a young (left) and an older (right) adult male babirusa in two different locations. These photos were taken in 2021 by the technical team of BKSDA Maluku.

(Figure 1). The skeleton was found lying in the floodplain of the Waypoti River in the northern part of MNR. The local communities believe that babirusa kill themselves because the elongated tusks would wound them and the old babirusa would live close to the river near to their death in order to find food, water, and salt more easily. The next finding of three additional skeletons was reported by local community members who worked with the team in exploring MNR.

In 2020, the first camera trapping survey was conducted in suitable habitat based on parameters such as land cover (primary and secondary forest), slope (0-8%), and elevation (0-500 meters above sea level) (Rosidiy & Wibowo, 2020). From this, two cameras in the northern part of MNR captured images of a female babirusa, light brown in colour and with dark coloured piglets (Figure 2). These animals were confirmed as an adult female with piglet babirusa due to their colour, the size and shape of their ears, and the shape of the nose (Macdonald, personal communication, July 7, 2021).

This study led to another camera trapping survey in 2021 in selected locations of MNR for a longer survey period. The results indicated that nine of the cameras were able to capture images and one camera failed; it captured images without any objects non-stop until the batteries ran out. The number of recorded images was 4,284 from 9 cameras. They caught not only babirusa but also wild *Sus* sp., *Cervus timorensis*, *Varanus salvator*, *Megapodius freycinet*, *Eulipoa wallacei*, *Caloenas nicobarica*, *Gallicrex cinerea*, and *Viverricula tangalunga*. Approximately 48% of all the images captured were of babirusa or part of a babirusa, and some blurry images caught moving babirusa.
According to the images, there were two different adult male babirusa (Figure 3) in two different camera traps. The adult male babirusa was obvious due to its exceptional tusk with an upper canine crossed over the lower canine in lateral view (Meijaard & Groves, 2002; Meijaard, d'Huart, & Oliver, 2011). It is shown in Figure 3 that the upper canine of those two males babirusa were different from each other indicating two differently aged males. Both male babirusa were seen to be solitary (Patry, Leus, & Macdonald, 1995). The colour of the adult male babirusa was grey, and they had short hair similar to the finding of Macdonald, Kailuhu, & Pattikawa in 2018.

Beside the two solitary adult male babirusa images that were captured, there was another group consisting of an adult female with two piglets (Figure 4). Patry, Leus, & MacDonald (1995)

Fig. 4: Camera trap photos of a babirusa group comprising a grey coloured adult female with two black coloured piglets that were captured at two different camera trap locations. These photos were taken in 2021 by the technical team of BKSDA Maluku.

explained that an adult female babirusa was rarely seen without a companion, which was sometimes another adult, or that she was with young babirusa. A female and male adult pair, and a large group of babirusa with two adult females and four young babirusa is shown in Figure 5. The different size and structure group of babirusa can be vary depending on environmental factors, food supplies, and threats (Meijaard, d'Huart, & Oliver, 2011).

Threats

According to MacKinnon (1981), the only known predators of babirusa in Sulawesi are the python (*Phyton reticulatus*) and the Sulawesi civet (*Macrogalidia musschenbroekii*). However, in Sulawesi, another threat to the babirusa is from the massive trade of wild pig meat (Clayton, Millner-Gulland, Sinaga, and Mustari, 2000). There is no reported babirusa and other wild pig meat trade in MNR and its surrounding area due to the religion of the surrounding communities being mostly Islamic, which have prohibitions on pork meat consumption. Instead of hunting wild pigs, these communities hunt deer for their household needs. However, the traps set for deer may also lead to the accidental trapping and death of babirusa.

Meanwhile, there are nomadic traditional tribes who are called 'orang gunung' by the local communities. These tribes hunt and trap babirusa and other wild pigs for their subsistence use. They would kill the pig and cut the meat into small pieces then preserve it with smoke. The skulls of a female and a male babirusa were found close to one of their wooden houses during the survey.

This does not mean that there is no specific threat to babirusa in other places in Buru Island, such as in the south and west parts of the island because the babirusa population is in decline (Tjiu & Macdonald, 2016). The decrease in the babirusa population is also strongly related to the reduction of *Shorea* spp. (Macdonald, Kailuhu, & Pattikawa, 2018). Meanwhile, the babirusa's reproductive ecology means that they mainly give birth to a single piglet and twin piglets, and rarely triplets (Ziehmer, Ogle, Signorella, Knorr, & Macdonald, 2010), which makes population recovery harder.

Recommendation

We conclude that babirusa occurs in MNR, Buru Island, even though the size of the population, the species behavior in natural habitat, and habitat preferences remain unknown. It is therefore urgent to conduct further research to gain a better understanding of the basic science in managing and conserving this species. This would make a positive contribution to developing the MoEF babirusa action plan, particularly for Moluccan babirusa conservation. Moreover, similar studies that use a camera trapping method should be extended to the southern part of MNR, as well as other parts of Buru Island, including other protected areas such as Taliabu NR and Sehu NR. Social studies aiming to assess the relationship between babirusa and rural communities are needed to determine potential threats from people.

Conservation measurements, such as patrols and species monitoring, in the current study area should be undertaken to protect this species. Improving the management effectiveness of MNR by developing spatial and management plans and enhancing co-management with surrounding communities, local government, and research institutions should also be a priority action committed to by the MNR authority.

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Fig. 5: Camera trap photos of two groups of babirusa from the same location. A couple of adult females and an adult male.The photo was taken in 2021 by the technical team of BKSDA Maluku.

Fig. 5 cont.: Two adult females and four young babirusa of different ages. The photo was taken in 2021 by the technical team of BKSDA Maluku.

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The sticky piggy: an alternative non-invasive method for fixing telemetry devices on wild boar (*Sus scrofa*)

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Abstract

The Eurasian wild boar (*Sus scrofa*) is one of the profiteers of anthropogenic landscapes, demonstrated by increasing numbers and ranges. Especially the colonization of agricultural landscapes and urban areas causes the so-called “human-wildlife” conflicts. In addition, the current spread of African swine fever in Europe and Asia draws further attention to the species. Telemetry is an important tool in modern wildlife research and can provide data that help find solutions to the challenges of contemporary wild boar management. Nonetheless, telemetry studies in wild boars are rare. One reason might be that collars – the standard method for fixing telemetry devices on ungulates – are not as suitable for wild boars due to their morphology and behaviour. Therefore, we did a first test with a glue-on solution with promising results, which we present in this manuscript.

Introduction

The Eurasian wild boar (*Sus scrofa*) is the global player among all suids, inhabiting all continents except Antarctica in wild or feral form (Keuling and Leus, 2019). No other pig has a larger range and no other pig has a higher potential to cause huge economic loss, be it directly by crop damage (Jarolímek et al., 2014), indirectly by spreading diseases (Taylor et al., 2020), or as an invasive species (Barrios-Garcia and Ballari, 2012). Currently, scientists are focusing on wild boars due to the spread of African swine fever (Jori et al., 2020, O’Neill et al., 2020, Taylor et al., 2020), genetic questions (Drygala et al., 2020, Reiner et al., 2021), and in the context of climate change (Vetter et al., 2020), partly in combination with the current (re-)colonization of former and new habitats. Marked individuals have dispersed up to 500 km (Jerina et al., 2014). These current research matters in combination with its ecological impacts (Haaverstad et al., 2014, Sandom et al., 2012), makes the wild boar a high-relevance species for conservation, for example in the context of protection of other suid species (Khwaja et al., 2019). With this background and its potential for economic implications, the spatial behaviour of wild boars is of special scientific interest.

GPS-telemetry is a standard tool in wildlife research and is frequently used in studies related to mammal management and conservation. Various taxa have been equipped with GPS-tags; therefore, a broad spectrum of techniques can be used to fix telemetry devices. Today, collars (e.g. Podgórski et al., 2018), harnesses (e.g. Guimarães Rodrigues et al., 2003), ear-tags (e.g. Keiter et al., 2017), implantation (e.g. Horning et al., 2017), and glue-on (e.g. Voigt and Siebert, 2019) solutions are used for terrestrial mammals.

In contrast to the high scientific interest and its potential to deal with the actual problems in wild boar management, GPS-telemetry is rarely used for the species, compared to other ungulates of similar bodyweight, habitat, or management relevance like red deer (*Cervus elaphus*) (Morelle et al., 2014). Since capturing wild boars is relatively easy (e.g. Johann et al., 2020, Prévot and Licoppe, 2013, Stillfried et al., 2017), one reason might be that the technical standard solutions for fixing transmitters on ungulates do not fulfil the special needs of wild boar telemetry, resulting from the morphology, behaviour, and habitats of the species. According to animal welfare and best practice, techniques to fix transmitters must meet high requirements. They should not harm or handicap, effect the natural behaviour, or induce any other risk to the animal. Collars and harnesses are always associated with a certain risk that the animal gets caught in undergrowth or fences, especially in species living in dense vegetation like *S. scrofa*. Keiter et al. (2017) used harnesses to VHF-tag piglets, but all harnesses failed within one to three days after tagging. In the same study, VHF-transmitters were sewn-on between the scapulae with surgical dermal sutures and a small amount of epoxy was added to improve fixation. All ten sewn-on transmitters failed with a mean transmitter retention time of five days. Both methods of fixing transmitters, harnesses and sewn-on, were ceased by the authors of the study due to the high quantity of failures (Keiter et al., 2017). Implantation of tags might be an alternative method for wild boar telemetry, but implantation is complex and requires aseptic surgery, a proper anaesthesia, and ideally post-operative monitoring (Horning et al., 2017), and is therefore less suitable in the field. Nonetheless, implantation has been used in piglets without transmitter failures, but the authors recommend a holding period after the surgery to allow the animals to recover (Keiter et al., 2017). Collars, the standard telemetry method in ungulates, do not properly fit the wedge-shaped body and comparatively undefined neck of Eurasian wild boars. Nevertheless, they have been used for the telemetry of *S. scrofa* in different studies with varying results. In one study with 13 marked wild boars, eight collars had a runtime of less than six months (Broberg, 2008), in another study, seven out of 15 collars had the same short runtime (Peris et al., 2020). Lost collars were documented in two out of nine marked females within a few days after capture (Stillfried et al., 2017). Thus, a feasible and reliable solution in accordance with animal welfare to fix transmitters on wild boars continues to be missing. In addition, due to the documented high rates of accidently culled or road killed wild boars equipped with telemetry tags, especially in urban habitats (Jerina et al., 2014, Johann et al., 2020, Stillfried et al., 2017), an inexpensive method to mark a larger number of animals is needed.

In mammals, the glue-on method was originally developed for pinnipeds (Fedak et al., 1983), while today it is also used for bats (Duchamp et al., 2004) and small terrestrial mammals like juvenile European hares (*Lepus europaeus*) (Voigt and Siebert, 2019). Glued-on tags will fall off at the latest with the next change of coat, without harm or risk to the animal by getting caught in fences or dense vegetation or post-operative complications.

Therefore, we conducted a pre-test and a first trial with one wild boar individual under controlled conditions in an enclosure. We tested if glue-on tags are a practicable

Fig. 1: Plastic grid glued on a culled wild boar`s winter coat using epoxy as pre-test.

and alternative non-invasive method for temporarily fixing telemetry devices on wild boars and observed whether this causes any behaviour or social problems.

Material and methods

For the pre-test we used the winter coat of a culled wild boar. The coat was cleaned from dirt particles by brushing. Bristles were degreased by wiping with acetone to ensure good adhesion of the epoxy (Devcon 5-Minute Epoxy) – as it is done in pinnipeds (Fedak et al., 1983) – to attach a plastic grid (Marley Poly-Net 6 x 7 mm) as a platform for a GPS-tag dummy. The glue was applied with a spatula at a maximum thickness of approximately 5 mm. Once the glue was hardened (Fig. 1) and tested for adhesion, we deep-froze the coat and sawed up the test set-up (Fig. 2).

After the pre-test, an adult female wild boar with a body weight of approximately 60-70 kg kept in an enclosure was immobilized with a blowpipe via intramuscular injection of azaperone and ketamine. The animal was blindfolded, and the coat brushed and degreased as done in the pre-test. Due to rainy weather, a wireless hair dryer was used to dry the fur. Afterwards, a GPS-tag dummy of approximately 500 g fixed on a plastic grid (20 x 25 cm) was glued onto the wild boar's croup (Fig. 3, Fig. 4). Glue and plastic grid were the same as in the pre-test. Ambient temperature was 5 °C, the glue hardened within 10 minutes. Including brushing, degreasing, and drying, the whole procedure of fixing the dummy lasted less than 20 minutes.

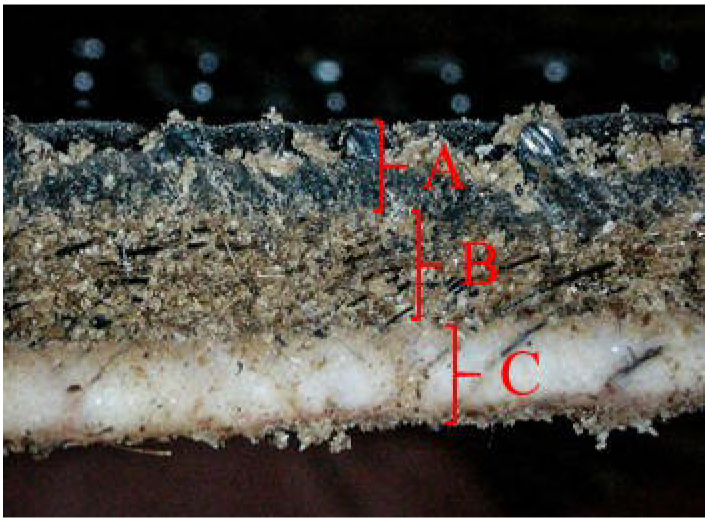

Fig. 2: Sawed up pre-test setup. The glue (A) was stopped by the undercoat (B) and did not get in touch with the skin (C).

Results

The pre-test showed that wild boar coat is generally suited to glue-on a grid as base for a GPS-transmitter, at least with the chosen epoxy. We observed strong adhesion once the glue was hardened, making it impossible to remove the grid and glue from the hair. Most importantly, due to the felted undercoat (Fig. 5), the viscous glue did not directly touch the skin (Fig. 2).

The dummy remained on the animal for 115 days (18th of December until 12th of April). We did not observe any changes in the behaviour of the female, neither rubbing nor wallowing to remove the foreign body. Other mature wild boars of both sexes in the same enclosure did not show any interest in or reaction to the dummy. As bristles and top layer of the undercoat were embedded in the epoxy, all hair fell off with the dummy resulting in a hairless area on the animal's croup (Fig. 6). Skin irritations were not seen, fur regrew within the next season.

Discussion

To our knowledge, this was the first attempt at using a pure technical glue-on solution for fixing telemetry devices in suids. Our tests have shown that it is possible to fix devices in the size of GPS-tags on Eurasian wild boars by gluing. As we started our test in the middle of December, the dummy dropped with the beginning of change of coat in spring, roughly after four months. Since

Fig. 3: Gluing the GPS-tag dummy on the croup of an immobilized adult female wild boar.

the winter coat in *S. scrofa* is fully grown at the latest in September or October, glued-on tags could last for six to eight months before dropping, covering the interesting time span of mating, highest hunting pressure, and time of increasing ranges (Frantz et al., 2020), as well as time of parturition.

The dummy did not seem to distract the animal in any way, since the female did not exhibit any behavioural reactions due to the dummy. From our point of view, three aspects seemed to be crucial for this: firstly, the large area of contact (approximately 500 cm²) of the plastic grid. Secondly, the felted undercoat that worked as padding reduced the perception of the dummy and thirdly, the low weight of the dummy including glue and grid (approximately 600 g) as it was just 0.85 to 1 % of the estimated body weight of the female. In addition, the thick undercoat prevented direct contact between the viscous glue and the skin and worked as insolation since the hardening of epoxy is a light exothermic reaction. In the same way, the placement on the croup seemed to be beneficial concerning the activity and habitat of wild boars in thick vegetation. The croup is at the sloping end of the body and therefore less exposed to mechanical stress from contact with obstacles and centrifugal forces if the animal shakes after swimming or wallowing.

Fig. 4: Female wild boar with glued-on GPS-tag dummy.

Our findings suggest that the glue-on method has several advantages: tags will drop automatically with the next change of coat. This reduces costs and weight of the tag as additional technical drop-off mechanisms, that sometimes fail (Baubet et al., 2004), become unnecessary. Furthermore, the automatic drop is beneficial in terms of animal welfare as it limits the dwell time on the individual and eliminates the risk of getting caught. Depending on technical solutions and terrain, dropped tags can be recovered and reused. To retrieve collars with stored data back, it might be necessary to recapture or cull the animals if the technical drop-off fails, which is undesirable for endangered or fully protected species, so collars and data may be lost altogether. In addition, the more closely to the body connected tags might be an advantage for the use of accelerometers.

Depending on tag weight, glued-on telemetry devices offer the chance to mark piglets and therefore whole family groups of wild boars with GPS-transmitters. This can offer new perspectives on investigating the spatial, social, and dispersal behaviour of the species. As piglets and yearlings gain weight rapidly and especially neck diameter increases quickly in the first months of life, the use of collars in young animals is problematic. Due to welfare reasons,

Fig. 5: Winter coat in wild boar is characterized by felted undercoat covered with thick and robust bristles.

tags should not exceed 5 % of the body weight of the animal (Hubrecht and Kirkwood, 2010). Johann et al. collared only wild boars with a minimum weight of 30 kg (Johann et al., 2020). As GPS-collars are placed around the neck of the animal, their weight has a certain lever action if the animal is lifting and lowering his head, for instance when foraging or feeding. In contrast to collars, the larger area of contact in combination with the placement on the animal`s croup of the tested glue-on solution and therefore directly above the powerful hind legs of the animal, makes tag weight less relevant. Modern GPS-tags developed for pinnipeds that are fixed by glue-on as well, weight approximately 300 g (Sea Mammal Research Unit, 2015), depending on battery capacity. Alike tags might work on wild boars as well, so even relatively young piglets could be marked. However, we did not check the performance of glue-on tags in young and fast-growing individuals so far and recommend tests with such and older individuals under controlled conditions before conducting fieldwork on a larger scale as our results are based on a single individual. In addition, a glue-on solution probably avoids problems associated with the massive variation of body weight between seasons due to fat deposition, which can lead to too loose or too tight collars and harnesses.

Fig. 6: Female wild boar after the GPS-tag dummy dropped. Note the hairless area at the croup.

The disadvantage of glue-on tags is the limited dwell time on the animal. The tags cannot remain on the animal for up to several years, which is possible with collars. This might be compensated by the generally high turnover in marked wild boars due to accidental culling and road kills (Jerina et al., 2014, Johann et al., 2020, Stillfried et al., 2017) and the fact that tag runtime in collared wild boars is often comparable to the assumptive runtime of glue-on tags (Broberg, 2008, Peris et al., 2020, Stillfried et al., 2017). A higher number and reuse of low-cost transmitters would also help to mitigate this.

The attempt was a first but promising test if glued-on tags could be an option for fixing GPS-transmitters on wild boars, be it as an alternative or a supplemental method. Glue-on could work for other hairy suids of genera *Sus*, *Porcula*, and *Potamochoerus* as well as for Peccaries. Depending on their morphology and behaviour, it might also be a feasible alternative for hirsute mammals that either inhabit dense vegetation, like mountain or woolly tapirs (*Tapirus pinchaque*) or animals that live in dens where is a certain risk of being caught in tree roots or that regularly climb in trees.

Legal note: The test was carried out with the necessary permissions of the public authorities; all handling procedures were compliant with the German Animal Protection Act.

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Sympatry between desert warthog *Phacochoerus aethiopicus* and common warthog *Phacochoerus africanus* in Kenya, with particular reference to Laikipia County

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Abstract

Desert warthog Phacochoerus aethiopicus delamerei and common warthog *Phacochoerus africanus* are widespread and locally common in the Horn of Africa and Kenya, east of the Eastern Rift Valley. It is of particular interest that these two taxa, the only two extant species in the genus *Phacochoerus*, occur in sympatry in some regions. Within Kenya, sympatry is known for the northern coast, Tsavo East National Park, Tsavo West National Park, and Meru National Park. This article presents information on a fifth region of sympatry, Laikipia County, central Kenya. Individuals that we judged to be atypical for either desert warthog or common warthog were encountered in Laikipia. New information on the distribution, abundance, population structure, ecology, and behaviour of desert warthog in Laikipia is presented. Laikipia offers considerable opportunity for comparative research on the morphology, molecular biology, ecology, and behaviour of desert warthog and common warthog.

Introduction

Desert warthog *Phacochoerus aethiopicus delamerei*, long over-looked by zoologists, is one of Africa's least studied and most poorly-known large mammals. Today, this species occupies parts of the Horn of Africa and Kenya, but it once occurred in South Africa and, perhaps, Namibia, where it was known as the 'Cape warthog' *P. a. aethiopicus*. Although this species was described in 1766, confusion concerning its taxonomy led to the recognition of only one species of warthog during much of the 20th century, the common warthog *Phacochoerus africanus*. As a result, the geographic range of the desert warthog remains poorly understood.

Desert warthog
-Ear tips bent backwards in all ages of both sexes.
-Adult male with hook-shaped infraorbital warts.
-Adult male with an obvious swollen pouch under the eyes.
-Relatively wide snout disk.
-Hindquarters relatively slender in adults.

Common warthog
-Ear tips erect in all ages of both sexes.
-Adult male with cone-shaped infraorbital warts.
-Adult male without an obvious swollen pouch under the eyes.
-Relatively narrow snout disk.
-Hindquarters relatively well-muscled in adults.

Fig. 1: Main traits for distinguishing desert warthog from common warthog in the field.

The history of warthog systematics was reviewed by Grubb and d'Huart (2010) and De Jong and Butynski (2018). The main external traits for distinguishing these two species in the field are presented in d'Huart and Grubb (2005) and De Jong and Butynski (2018). These are summarised here in Figure 1.

Grubb and Oliver (1991) described the ‘rediscovery’ of the desert warthog. Ten years later, the first distribution map for this species was produced by d'Huart and Grubb (2001). Four localities were shown on their map for Kenya, one in central Kenya, two in the northeast, and one on the north coast. They suspected that the two species of warthog were locally sympatric but were not able to confirm this.

A better understanding of the biogeography of the desert warthog is not only of considerable scientific interest, it is important to the development of effective conservation and management plans for this species. In 2005, together with Jean-Pierre d’Huart, we began studying the biogeography of the desert warthog. The results of this study will soon be published. Thirty years after the ‘rediscovery’ of the desert warthog we know that the species is widespread and locally common in the Horn of Africa and Kenya, east of the Eastern (Gregory) Rift Valley. Here we provide an overview of our findings for the distribution of the desert warthog in Kenya, sites of sympatry with common warthog, and some brief notes on population structure, ecology, and behaviour.

Results

Distribution and sympatry

In 2005, we found desert warthog 15 km and 80 km west of Garissa in central eastern Kenya (Fig. 2). These records extended the geographic range about 265 km northwestwards from Mkokoni on the northern coast of Kenya (De Jong et al., 2009).

Fig. 2: Adult male desert warthog west of Garissa, central eastern Kenya.

In 2007, desert warthog were recorded for the first time in Tsavo East National Park (13,747 km²) and Tsavo West National Park (7,067 km²; Fig. 3; Culverwell et al., 2008; De Jong et al., 2009). These records not only represent

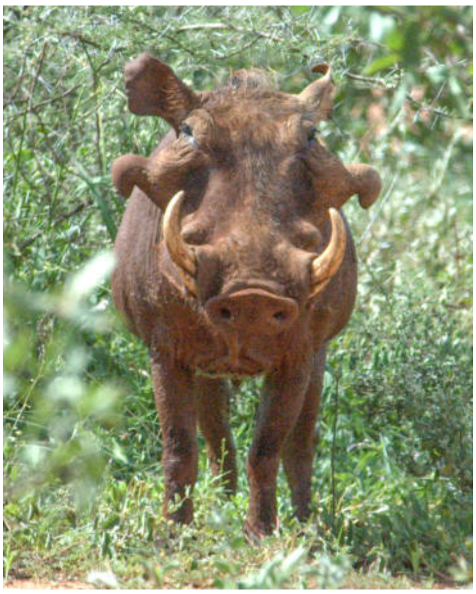

Fig. 3: Adult male desert warthog, Tsavo West National Park, southeastern Kenya.

Fig. 4: Adult female desert warthog, Meru National Park, central Kenya.

large range extensions to the southwest (up to 390 km from Mkokoni), but are also the first records of sympatry with common warthog. Since then, the two species of warthog have been found to be sympatric in Meru National Park (870 km²), central Kenya (Fig. 4), and on the northern coast of Kenya, as well as in northern Somalia and central eastern Ethiopia (De Jong & Butynski, 2018; De Jong et al., 2018, in prep.).

In 2013, we observed desert warthog on the southern foothills of Mount Forole, central northern Kenya. This site extends the known range 120 km to the west from Moyale Airfield (d'Huart & Grubb, 2001; De Jong & Butynski, 2014). Although warthog were reported to be widespread throughout the vast region between Lake Turkana and Uganda (Stewart & Stewart, 1963; Kingdon, 1979), it was not known which species occurred there. During our 2012 and 2013 surveys, we found common warthog in the Loima Hills, Nasalot National Reserve, and South Turkana National Reserve. This extended the known range for common warthog in Kenya at least 200 km to the north from Mount Elgon in central western Kenya (De Jong & Butynski, 2014). Within Kenya, there is no evidence for desert warthog west of the Eastern Rift Valley.

In November 2016, the first records of desert warthog for Laikipia County (9,700 km²), central Kenya, were obtained from Lekurruki Conservancy (120 km²) and the contiguous Il'Ngwesi Conservancy (165 km²) at 1,090–1,110 m asl (Figs. 5 & 6; De Jong & Butynski, 2016). This is the lowest part of Laikipia County (hereafter, referred to as 'Laikipia'). Overviews of the geography, environment, and biodiversity of Laikipia are presented in LWF (2011) and in Butynski and De Jong (2014). This is a region of *Acacia*-*Commiphora* bushland on red sandy soil and quartz gravel. *Acacia tortilis* and *Commiphora africana* are among the more common species of tree. Both species of warthog were common here, but desert warthog seemed to be the more

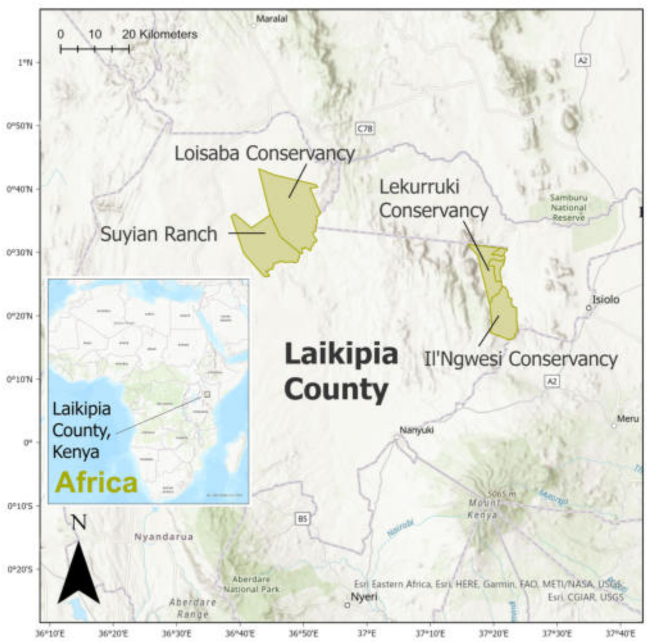

Fig. 5: Laikipia County, central Kenya, showing the four properties where desert warthog are known to occur. Desert warthog and common warthog are sympatric on all four of these properties. Map by the authors.

Fig. 6: Adult male desert warthog, Lekurruki Conservancy, northeastern Laikipia, central Kenya.

abundant. Here is a summary of the composition and size of three desert warthog sounders for which we believe we obtained complete counts: two adult females; three piglets + two adult females; five piglets + three adult females. In addition, four solitary adult males were encountered.

Fig. 7: Desert warthog and adult male savanna elephant *Loxodonta africana* on a glade, Suyian Ranch, northern Laikipia, central Kenya.

In January 2020, Anne Powys obtained the first record for desert warthog on the Laikipia Plateau (ca. 1,600–2,400 m asl; Figs. 5 & 7; Powys, 2020). This was at the headquarters of Suyian Ranch (180 km²), an active cattle ranch. Suyian Ranch represents both the western-most locality and highest site (1,890 m asl) known for desert warthog. This site is comprised of acacia woodland, short grass, several scattered buildings, and 'bomas' (= cattle enclosures/corrals).

We surveyed Suyian Ranch for 2.5 days in January 2021, and for 1 day in February 2021, and Loisaba Conservancy for 2.5 days in February 2021 (Fig. 5). Mean annual rainfall here is about 500 mm. With the exception of black rhinoceros *Diceros bicornis*, Suyian and Loisaba both have all of their original known mammalian fauna, including the larger predators (lion *Panthera leo*, leopard *Panthera pardus*, cheetah *Acinonyx jubatus*, spotted hyaena *Crocuta crocuta*, wild dog *Lycaon pictus*).

The more common trees and shrubs on plains and open woodlands of the highlands of Suyian Ranch and Loisaba Conservancy include *Acacia drepanolobium*, *Acacia mellifera*, *Boscia angustifolia*, *Croton dichogamus*, *Rhus natalensis*, and *Carissa spinarum*, while the more common grasses include *Themeda triandra*, *Pennisetum mezianum*, *Eragrostis superba*, *Cenchrus ciliaris*, and *Cymbopogon* spp. (A. Powys, pers. comm.). The common grass that both species of warthog appear to prefer on old boma sites is *Cynodon dactylon*. This species is one of the primary foods of common warthog in East Africa and southern Africa (Frädrich, 1965; Cumming, 1975; Butynski & De Jong, 2018b; Edossa et al., 2021).

We observed two desert warthog sounders (three and four individuals) at Suyian Headquarters. All individuals were at least somewhat habituated. Common warthog were present within about 400 m of this site. Anne Powys (pers. comm.) told us that common warthog were present at headquarters prior to the arrival of desert warthog. We encountered solitary individuals and sounders at several other sites on this ranch. A few sounders were comprised both of desert warthog and common warthog (Fig. 8). We also, for the first time, observed individuals with traits that appeared atypical for either desert warthog or common warthog, being outside of the intra-

Fig. 8: Adult female desert warthog (front left) and adult male desert warthog (front right) with an adult male common warthog on a glade, Suyian Ranch, northern Laikipia, central Kenya.

Fig. 9: Atypical adult male warthog (right) with adult male common warthog *Phacochoerus africanus*, Suyian Ranch, northern Laikipia, central Kenya. Note the shape of the ears and infraorbital warts of the atypical male and compare with the warthog in Figure 1.

Tab. 1: Age and sex of desert warthog and common warthog encountered on Suyian Ranch and Loisaba Conservancy during 6 days of surveys in January – 2021.

Species/age sounder February	**Desert warthog *Phacochoerus aethiopicus***			**Common warthog *Phacochoerus africanus***			**Atypical warthog**		
Ranch/conservancy	**Suyian**		**Loisaba**	**Suyian**		**Loisaba**	**Suyian**		**Loisaba**
Age/sex	Jan.	Feb.	Feb.	Jan.	Feb.	Feb.	Jan.	Feb.	Feb.
Adult males	4	3	0	8	1	4	1	0	0
Subadult males	1	0	0	2	0	0	0	0	0
Adult females	3	5	2	25	7	13	0	3	1
Subadult females	3	0	0	3	0	0	0	0	0
Adult sex unknown	0	0	0	1	1	3	0	0	0
Subadult sex unknown	0	0	0	3	4	2	0	0	1
Large juveniles	1	4	2	27	8	18	0	8	2
Age/sex unknown	0	2	0	20	17	35	0	0	1
Total	**12**	**14**	**4**	**89**	**38**	**75**	**1**	**11**	**5**

specific variation that we have observed elsewhere for these two species. In particular, the shape of the ears was atypical among these individuals. In the case of one adult male, the shape of the infraorbital wart was also atypical (Fig. 9). Twelve individuals with atypical characters were observed in two sounders on Suyian; one comprised of an adult male common warthog and an atypical adult male (Fig. 9), and one comprised of three atypical adult females and eight atypical large juveniles (Table 1).

In February 2021, we obtained the first record for desert warthog on Loisaba (230 km²; Figs. 5 & 10; Table 1). The two adult females and two large juveniles in the only sounder of desert warthog observed on Loisaba were on a glade about 7 km to the east of the eastern-most sounder of desert warthog on Suyian. One sounder of at least five individuals, all of which appeared to be

Fig. 10: Desert warthog and plains zebra *Equus quagga* on a glade, Loisaba Conservancy, northern Laikipia, central Kenya.

atypical, was briefly observed 5.5 km north of the one desert warthog sounder. Common warthog are abundant on Loisaba.

Population structure

During our 6-day survey on Suyian (3.5 days) and Loisaba (2.5 days), we drove slowly (ca. 15 km/h) along most of the main roads on both ranches. Total distance travelled was 442 km (264 km on Suyian and 178 km on Loisaba). Overall, 46 warthog sounders were encountered. The encounter rate was 0.02 sounders/km for desert warthog (0.03 sounders/km on Suyian and 0.01 sounders/km on Loisaba), 0.08 sounders/km for common warthog (0.08 sounders/km on Suyian and 0.10 sounders/km on Loisaba), and 0.01 sounders/km for sounders that included atypical individuals (both properties combined). Overall, we encountered about 30 desert warthog (13%), and about 202 (87%) common warthog (Table 1). Note (1) that some of the individuals counted in January were certainly counted again in February, and (2) that the 17 atypical individuals are not included in this calculation.

Desert warthog sounders averaged 4.0 individuals (range = 3–5; n = 4), common warthog sounders averaged 4.5 individuals (range = 2–17; n = 37), while sounders with at least some atypical individuals averaged 6.3 (range = 2–11; n= 5). In addition, 12 solitary common warthog were observed; one adult male in January and one in February, three adult females in January and one in February, and three adults (sex not determined) in January, and two adults (sex not determined) and one large juvenile in February. No solitary desert warthog were encountered.

In February 2021, for the 77 individuals whose age was determined, 62% of the 16 desert warthog were adults, while 48% of the 61 common warthog were adults (Table 1). Of the 10 adult desert warthog in February that we were able to sex, 30% were males. Of the 25 adult common warthogs in February that we were able to sex, 22% were males.

Ecology and behaviour

Like the common warthog, the desert warthog is a ‘hypergrazer’. At Suyian and Loisaba, both species of warthog appear to strongly prefer glades. These are sites of current or recent bomas, or sites that, at least several decades ago, supported the small settlements and bomas of traditional pastoralists. These glades are believed to be maintained through the heavy grazing of large mammals. The grasses here are relatively short, green, and nutritious (Young et al., 1995; LWF, 2011).

We have spent at least 20 hours, at several sites in Kenya, watching desert warthog foraging. Carpal kneeling is frequently seen in common warthog (Geigy, 1955; Frädrich, 1965; Cumming, 1975; Butynski & De Jong, 2018b). Although carpal callosities are present in desert warthog, we never observed them 'kneeling' while foraging. On Suyian, however, we saw at least five individuals kneeling while digging-up roots with their snouts. This behaviour was, nonetheless, far more frequent here among common warthog. The extent of carpal-kneeling appears to be a behavioral difference between these two species (De Jong & Butynski, 2018).

Desert warthog lack a heavy coat and fat layer. Like common warthog, they avoid hot afternoons, cold nights, and predators by sleeping in a burrow (Cumming, 1975; De Jong & Butynski, 2018). We suspect that, like common warthog, they also occupy erosion gullies and caves (Butynski & De Jong, 2018b). At West Gate Community Conservancy, central Kenya, we found a desert

Fig. 11: Consorting desert warthog. Adult male (foreground) examining an adult female, Suyian Ranch, northern Laikipia, central Kenya.

Fig. 12: Desert warthog. Adult male (middle) 'guarding' an adult female (left) from a young adult male, Suyian Ranch, northern Laikipia, central Kenya.

warthog burrow at the foot of a big *Commiphora* tree that had downward-growing branches. At Suyian Headquarters, at least one sounder slept regularly, perhaps nightly, under the wooden floor of an old sheep-shearing shed.

One sounder that included an adult male with distinctive infraorbital warts was encountered three times at two sites located 2.2 km apart; first observed at Site One, then 2.2. km away at Site Two 17.5 h later, then again at Site One 22.0 h later. This sounder comprised one adult male, two adult females, and three large subadults. The first time that we observed this sounder it comprised only the distinctive adult male and the adult female, although two adult male common warthog were within 10 m (Fig. 8) and a sounder of two adult female and two subadult common warthog was about 100 m away. The three large subadult desert warthog that we observed during our second and third encounters with the distinctive adult male were not in view during our first encounter.

In January 2021, we observed consortships between a big adult male and an adult female in two sounders. These consortships lasted for the 2 days and 3 days that we observed these desert warthog sounders. In both cases, the adult male remained close to the adult female, sometimes examining (sniffing?; Fig. 11) her urine and feces, and occasionally placing his chin on her rump, both while standing and lying. Both sounders had one small adult male that the big adult male kept away from the adult female in a manner suggestive of 'male guarding' (Fig. 12). No copulations were, however, observed.

There is little information on mating or birth seasonality for desert warthog. That this species lives where there are distinct dry and wet seasons suggests that these activities are highly seasonal, as is the case for common warthog (Butynski & De Jong, 2018b). In the Lolldaiga Hills, about 40 km to the southeast, where mean annual rainfall is about 700 mm, common warthog mate during November–January and give birth during April–June. We expect that, in Laikipia, desert warthog has similar mating and birth seasons. This is supported by the fact that no desert warthog or common warthog younger than large juveniles were observed during our January–February 2021 surveys, suggesting that few or no births occurred during the previous 6 months (i.e., since about June).

Discussion

Atypical warthog

Do desert warthog and common warthog interbreed under some circumstances? Prior to our surveys on Suyian and Loisaba, we never observed warthog that we suspected might be hybrids

Fig. 13: Eight members of a sounder of eleven individuals at Suyian Ranch Headquarters, northern Laikipia, central Kenya. All of the members of this sounder had atypical traits. Note, in particular, the shapes of the ears. Compare with the warthog in Figure 1.

(Butynski & De Jong, 2018b; De Jong & Butynski, 2018). Souron (2016), however, located three skulls out of a sample of more than 500 *Phacochoerus* skulls that he suspects represent hybrids. The fossil record does not yet indicate when desert warthog and common warthog diverged from their common ancestor, but it does indicate that the genus *Phacochoerus* originated 1–2 million years ago (Ma; Harris & Cerling, 2002; Pickford, 2012). If so, the divergence time for the two species of warthog would be, in a relative sense, recent. Two molecular studies, however, place the time of divergence of desert warthog and common warthog at 4.5 Ma (Randi et al., 2002) or 8.8–5.7 Ma (Gongora et al., 2011). In the case of some species of African monkey (even those in different genera) with divergence times much greater than 2 Ma (e.g., ca. 8.1 Ma; Tosi et al., 2005), viable hybrid offspring are produced in the wild (e.g., Struhsaker et al., 1988; De Jong & Butynski, 2010). This suggests that hybridization between the two species of warthog, with the production of viable offspring, might occur under some circumstances.

Natural hybridization appears to occur most often along the edges of the geographic ranges of one or both parental species where the population density of one or both species is likely to be low. One result may be a severe shortage of conspecific mates for one or both species. Under these circumstances, hybridization is seen as increasing the options to reproduce when conspecific mates are scarce or absent (e.g., Struhsaker et al., 1988; De Jong & Butynski, 2010). The situation observed for the two species of warthog on Suyian and Loisaba meets these criteria, as desert warthog is at the extreme edge of its known range and relatively uncommon. Of the 249 warthog observed during January–February 2021, 12% were desert warthog, 81% were common warthog, and 7% were judged to be atypical (Figs. 9 & 13). An alternative explanation for these atypical individuals must, however, be considered as this population of desert warthog might be both small and isolated with little or no gene-flow from the main population to the northeast. If so, what we may be observing are the results of inbreeding depression and genetic drift, not hybridization.

Conservation

Similar to common warthog, the desert warthog is probably vulnerable to climatic extremes (particularly drought, high rainfall, and low temperatures), predators and disease. The main threats to the long-term survival of this species are, however, human-caused habitat degradation, loss, and fragmentation, as well as hunting by people and competition with livestock for water and food. Although the desert warthog is listed as 'Least Concern' on the IUCN Red List of Threatened Species (De Jong et al., 2016), its abundance and geographic range are in decline. In Laikipia there are more than a dozen large ranches (e.g., Suyian), conservancies (e.g. Loisable), and government protected areas were large mammals, including both species of warthog, are relatively secure.

Other arid-adapted species (e.g., gerenuk *Litocranius walleri*, Grevy's zebra *Equus grevyi*, vulturine guineafowl *Acryllium vulturinum*) have moved southwards on the Laikipia Plateau in recent decades as the climate has become hotter and rainfall more variable, if not lower, with decreased river flow (LWF, 2011; Schmocker et al., 2015; Ogutu et al., 2016). At the same time, other mammals (e.g., eastern patas monkey *Erythrocebus patas pyrrhonotus*, mountain reedbuck *Redunca fulvorufula*, greater kudu *Tragelaphus strepsiceros*) have become rare in Laikipia, while several species of large bird appear to have been extirpated (southern ground hornbill *Bucorvus leadbeateri*, white-headed vulture *Trigonoceps occipitalis*; Butynski & De Jong, 2018a), perhaps due, in part, to climate change.

Research questions

Anne Powys, a botanist and naturalist who has lived on Suyian most of her life, has been on the look-out for desert warthog in central Kenya for the past several years. Only in January 2020 did she observe this species in Laikipia. These two authors have lived and undertaken research on the Laikipia Plateau for 18 years and did not encounter desert warthog there until January 2020 (on Suyian). It appears that desert warthog has moved onto the Laikipia Plateau in recent years from the lower-lying, hotter, and drier region to the north. What has caused this movement onto the Plateau, a region where the common warthog is widespread and locally abundant? What roles might climate change, changing land-use practices, and habitat degradation, loss, and fragmentation have played? Does the desert warthog occur in other parts of Laikipia? How large is the Laikipia Plateau population and is it isolated? Are the atypical individuals the products of hybridization or inbreeding, or both? How does the skeletal morphology of the atypical individuals compare with that of desert warthog and common warthog? These are among the many questions concerning the natural history and conservation of the desert warthog on the Laikipia Plateau, and beyond, that remain unanswered.

Conclusions

Desert warthog and common warthog are known to be sympatric in five regions in Kenya. All five regions are in southern and central Kenya, east of the Eastern Rift Valley. This article presents new information on the distribution, abundance, population structure, ecology, and behaviour of these two species in the most recently discovered region of sympatry, Laikipia County. Individuals that we judged to be atypical for either desert warthog or common warthog are also present here. Laikipia offers considerable opportunity for comparative research on the morphology, molecular biology, population ecology, and behavioural ecology of desert warthog and common warthog.

More warthog photographs are available on the Warthog Photographic Map at:
https://wildsolutions.nl/photomaps/phacochoerus/

All photographs by Yvonne de Jong and Tom Butynski.

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Habitat occupation by peccary *Tayassu pecari* and *Pecari tajacu* (Artiodactyla: Tayassuidae) in the Calakmul region, Campeche, Mexico

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Abstract

The white lipped peccary (*Tayassu pecari*) and the collared peccary (Pecari tajacu) are social ungulates of huge ecological and economic importance. To estimate habitat occupancy in a community forest bordering the Calakmul Biosphere Reserve, twenty-eight sampling points were settled in the study area. In each point, the presence of both peccary species was measured taking into account three ecological variables (habitat type, presence natural predators, and water availability) and an anthropogenic one (hunting). In order to relate both species of peccaries to the selected variables, models of habitat occupancy were constructed using a binary matrix of detection (1)/ no detection (0) through the PRESENCE program. For white-lipped peccaries, estimated occupancy was 30% and 88% during the rainy and the dry seasons, respectively. For collared peccaries, occupancy was 40% and 44% during the rainy and the dry seasons, respectively. Our results preliminary suggest that human activity and presence negatively affect how peccaries occupy specific habitats, particularly during periods of water scarcity.

Introduction

Knowledge of the factors intervening in habitat occupancy by wildlife species is of utmost 74 importance for their effective monitoring and management (MacKenzie et al, 2006). In most species, the availability of food and water can determine their presence, movements, and population size. Faced with a growing habitat disturbance due to anthropic activities, ungulates have been particularly identified as vulnerable to local extinction because of their habitat requirements hunting pressure on them (Peres, 2000; Escamilla et al, 2000; Fa et al, 2002; Peres and Palacios, 2007; Di Bitetti et al, 2008).

The Collared Peccary (CP) (*Pecari tajacu*) and the White-lipped Peccary (WLP) (*Tayassu pecari*) are social ungulates. In places with hunting pressure such as the Calakmul region, it has been shown that the former prefers habitats with secondary vegetation and the latter prefers low-lying rainforests (Briceño-Méndez et al, 2016; Reyna-Hurtado, 2007). Their ecological importance lies in their function as seed dispersers and seed predators of numerous plant species (Altrichter et al, 1999; Keuroghlian and Eaton, 2009; Beck et al, 2010) and as important prey for large natural predators (Aranda, 1994; Sowls, 1997).

Peccaries represent an important source of animal protein for rural communities throughout their distribution (Montiel et al, 1999; Escamilla et al, 2000; Altrichter and Almeida, 2002; Altrichter, 2006; Reyna-Hurtado and Tanner, 2007; Fang et al, 2008). Approximately 60% of the distribution of WLP is found in humid tropical forests whereas PC has a wider distribution including tropical dry forests and semi-arid areas (Sowls, 1997). According to the International Union for Conservation of Nature (IUCN), the CP is in a state of least concern throughout its distribution range (Góngora et al, 2011), while the WLP is considered in a vulnerable position (Keuroghlian et al, 2013). This last species is endangered in Mexico, where its population size has been drastically reduced (SEMARNAT 2010). It has recently been documented that WLP populations present a decline in isolated areas of Mesoamerica, with a reduction of 87% of its historical distribution range (Altrichter et al, 2012, Thornton et al, 2020). For the CP, there is concern about the social ecology of some local populations being affected by intense hunting pressure (Briceño-Méndez et al, 2016).

Hunting pressure exists in heterogeneous environments such as those that occur in much of southern Mexico and in ejidos surrounding protected areas. Therefore, monitoring of wild populations must prevail to ensure their survival. Since conservation of hunted species cannot be achieved only within protected areas, it is essential to assess occupancy parameters and species occurrence to infer the effect of hunting on peccary populations in rural communities.
An important tool allowing the evaluation of the presence and distribution of species is the use of occupancy models explaining the occurrence of species through certain variables. These models estimate the probability of occurrence (ψ) and detection (ρ), allowing the incorporation of the detection probability given that a site could be used by a species but its use could have not been detected (MacKenzie et al, 2002; MacKenzie et al, 2005; Meredith and Floyd, 2005; MacKenzie et al, 2006). These models also include the effects of the variables on the occurrence of the species and allow maintaining a constant detection probability (e.g., ψ covariate, ρ constant) (Bailey et al, 2004; Pellet and Schmidt, 2005; Fredriksson et al, 2006).

The monitoring of species that are strongly under pressure and that are distributed in environments with anthropic activity is fundamental for management and conservation plans. Therefore, to model and project the variation in habitat occupancy and focus conservation and management efforts in the areas of greatest biological importance, this study aimed to determine through habitat occupancy models the anthropic and ecological factors conditioning the presence and occurrence of peccaries in the Calakmul region of Campeche, Mexico.

Methods

Study sites:

Ejido Nuevo Becal is located in the southeastern part of the state of Campeche, Mexico (18°40'07" N and 89°12'34" W). Mainly medium subdeciduous forest with trees between 18 and 25 m. high. Some common tree species are Brosimum alicastrum, Manilkara zapota, Pouteria campechiana, Ampelocera hottlei, Cratavea tapia, Citrullus vulgaris, and Metopimu brownie (Pennington and Sarukhán, 1998).
Elevation vary between 100 and 380 meters above sea level. The predominant climate is warm subhumid with an average annual temperature of 25°C, with rains in summer and 599 mm of mean annual precipitation (García-Gil, 2003). Nuevo Becal neighbors the Calakmul Biosphere Reserve (RBC), the largest tropical forest protected in Mexico with an area of 7,231 km^2. (Morales and Magaña, 2001). Land tenure is predominantly community-based, and agriculture, beekeeping, cattle ranching, and coal extraction stand out among the economic activities. In addition, subsistence hunting is practiced and to a lesser extent, sport hunting (Escamilla et al,

2000; Weber, 2000; Reyna-Hurtado and Tanner, 2007; Santos-Fita et al, 2012; Briceño-Méndez, 2012). It has been documented that in Nuevo Becal, the Collared Peccary is one of the most hunted prey (Weber, 2000; Santos-Fita et al, 2012) and entire groups of White-lipped peccaries have been exterminated by hunters in a single dry season (Reyna- Hurtado and Tanner, 2007).
In the region, the presence of numerous species of large-sized mammals such as Baird's Tapir (*Tapirus bairdii*), Brocket Deer (*Mazama temama* and *Mazama pandora*), White-tailed Deer (*Odocoileus virginianus*) and large predators such as the Jaguar (*Panthera onca*) and Puma (*Puma concolor*) have been highlighted (Escamilla et al, 2000; Reyna- Hurtado and Tanner, 2007; Amador et al, 2013; Sandoval-Seres et al, 2016).

Selection of sampling sites:
To analyze the presence and habitat occupancy by both species of peccaries, 28 sampling points were established within ejido Nuevo Becal. The presence of peccaries was verified through direct sightings and photo-trapping in two stations: dry season (February-May) and rainy season (June-September). The sampling points included trails in the tropical forest, farming areas, and streams to include the landscape variability. At each point, an approximate area of 20 m^2 was marked to detect peccary tracks or feces once a month (Meredith and Floyd, 2005) to determine the presence or absence of both species. Based on these records, a detection (1) and no-detection (0) matrix was built (Meredith and Floyd, 2005). The sampling points were separated by a minimum distance of 1.5 km from each other (Meredith and Floyd, 2005).

Occupancy probability ( ):
To generate the occupancy models, we elaborated detection histories in binary arrays using the records of both peccary species at each sampling point considered as an independent site. To relate the presence and occupations of peccaries at the sampling points, these were characterized from predictive ecological variables (habitat type and water availability) that could influence the presence of both species based on previous studies (Reyna-Hurtado, 2002; Reyna-Hurtado, 2007; Briceño-Méndez, 2012; Briceño-Méndez et al, 2014; Briceño-Méndez et al, 2016). The characterization of habitat types was carried out as follows: Percentage of records obtained in each of the four habitat types present in the study area; floodplain forest, medium subdeciduous forest, tropical deciduous forest, and secondary vegetation. The water availability variable was coded as presence (1) or absence (0) for each sampling point.

Detection probability (ρ):
To model the probability of detection (ρ) we selected 3 covariates: 1) presence of hunters (% of hunter records in camera-traps, direct observations, tracks, and cartridges on the ground); 2) presence of jaguars (% of records in camera-traps, and footprints); and 3) presence of pumas (% of records in camera traps, and footprints).

Statistical analyses:
The constant detection (ψ; ρ), the occupancy (ψ), and the detection (ρ) models were combined to produce a total of 12 candidate models generated from the detection arrays built in the dry and rainy seasons for each species. We used the Akaike information criterion (AIC) to obtain the range of the models and calculate the Akaike weights (w) (Burnham and Anderson, 2002; Burnham et al, 2011), which allowed to select from among various models the one that best

explained the data set. This in turn facilitated to infer which variables were associated with the presence and occupancy of peccaries in the study area. The modeling analyses were performed with the PRESENCE program (v. 9.9; USGS-PWRC, Laurel, MD, EEUU).

Results

For White-lipped peccaries, an occupancy probability during the rainy season of 30% (psi=0.30) and a detection probability of p=0.21 were estimated. During the dry season, an occupancy probability of 88% (psi=0.88) and a detection probability of p=0.79 were obtained. Their occupation was low in the rainy season and high in the dry season (Models 1.8 and 2.6, respectively) (Table 1). According to the Akaike weights (w), in the rainy season the best model that explained the presence and occupancy of White-lipped peccaries was determined by the presence of the floodplain forest habitat type (Model 1.1, w=0.353; Table 1). In the dry season, the occupation of peccaries was negatively correlated to the detection probabilities in presence of hunters (Model 2.1 w=0.228; Table 2).

For Collared peccaries, the occupancy probability during the rainy season was 40% (psi=0.32), with a detection probability of p=0.39. During the dry season, an occupancy probability of 44% (psi=0.42) and a detection probability of p=0.31 were obtained. The simplest models of occupancy and constant detection probabilities suggested that Collared peccaries occupied the sites similarly during the two seasons of the year (Models 1.8 and 2.8, respectively; Table 2). According to the estimated weights of Akaike (w), in the rainy season occupancy was determined primarily by water availability, and the detection probabilities were influenced by hunting pressure (Model 1.1, w=0.2928; Table 2). In the dry season, model 2.1 (w=0.1905) indicated that occupancy was determined by the presence of the floodplain forest habitat type. The occupancy estimates defined by the number of records where both species were detected at the occupied points suggest that there is a variation among the proportion of occupied sites

Table 1. Habitat occupancy estimation (ψ) and detection probabilities (p) of the White-lipped Peccary (*Tayassu pecari*) during the rainy and dry seasons in ejido Nuevo Becal, Calakmul, Campeche, Mexico.

I.D.	Models	ΔAIC	*w*	K	ψ (SD)	p
First season (rainy) (Simple model ψ=0.300)						
1.1	ψ(Habitat+floopla)p(.)	0.00	0.353	2	0.4562 (0.3219)	0.2192
1.2	ψ(Habitat+medsubeve) p(Pumas)	0.61	0.261	3	0.5717 (0.4556)	0.1166
1.3	ψ(Habitat+acahual) p(Jaguars)	2.00	0.130	3	0.3179 (0.1537)	0.1333
1.4	ψ(Water availability) p (Hunters)	3.53	0.061	3	0.3075 (0.1485)	0.0270
1.5	ψ(Water availability)p(.)	3.89	0.051	2	0.3061 (0.1479)	0.0136
1.6	ψ(Water availability) p (Pumas)	4.51	0.038	3	0.4267 (0.4072)	0.1367
1.7	ψ(Water availability) p (Jaguars)	5.17	0.027	3	0.4460 (0.4367)	0.1367
1.8	ψ(.)p(.)	7.09	0.010	7	0.3998 (0.3769)	0.2725
1.9	ψ(Habitat+lowdryfor) p (Jaguars)	7.74	0.007	2	0.3188 (0.0769)	0.4442
1.10	ψ(Habitat+acahual +lowdryfor)p(Pumas)	7.77	0.007	2	0.0667 (0.0322)	0.5170
1.11	ψ(Habitat+medsubeve) p(Hunters)	9.58	0.003	3	0.3129 (0.1516)	0.1168
1.12	ψ(.)p(Jaguars)	10.52	0.002	2	0.5278 (0.4039)	0.1895
1.13	*Model average*				0.3275 (0.2258)	
Second season (dry) (Simple model ψ=0.883)						
2.1	ψ(.)p(Hunters)	0.00	0.228	3	0.4231 (0.1933)	0.7940
2.2	ψ(Water availability)p(.)	0.89	0.146	3	0.9378 (0.1143)	0.3060
2.3	ψ(Habitat +floopla) p(Hunters)	1.69	0.098	3	0.5556 (0.3936)	0.3189
2.4	ψ(Water availability)p(Hunters)	1.97	0.085	3	0.6683 (0.2469)	0.3162
2.5	ψ(Water availability)p(Jaguars)	1.99	0.084	4	0.8733 (0.1290)	0.3184
2.6	ψ(.)p(.)	2.02	0.083	7	0.9190 (0.1089)	0.1813
2.7	ψ(Water availability)p(Pumas)	2.88	0.054	3	0.8733 (0.1304)	0.3184
2.8	ψ(Habitat+medsubeve)p(.)	2.90	0.053	3	0.7996 (0.1956)	0.3113
2.9	ψ(.)p(Hunters)	2.92	0.052	3	0.9993 (0.1176)	0.3196
2.10	ψ(Habitat+medsubeve) p(Pumas)	2.92	0.052	3	0.9993 (0.1176)	0.3196
2.11	ψ(.)p(Jaguars)	3.22	0.046	4	0.9416 (0.1116)	0.2972
2.12	ψ(.)p(Pumas)	5.38	0.016	2	0.5263 (0.1984)	0.7940
2.13	*Model average*				0.7930 (0.1714)	

Note: ΔAIC is the difference between the AIC of the models where *w* represents the model weights, K is the number of model parameters, ψ is the estimate of the occupation sites, SD is the standard error and p is the probability of estimated detection.

Table 2. Habitat occupancy estimation (ψ) and detection probabilities (p) in the Collared Peccary (*Pecari tajacu*) during the rainy and dry seasons in ejido Nuevo Becal, Calakmul, Campeche, Mexico.

I.D.	Models	ΔAIC	*w*	k	ψ (SD)	p
First season (rainy) (Simple model ψ=0.400)						
1.1	ψ(Water availability) p(Hunters)	0.00	0.2928	3	0.4203 (0.1644)	0.3965
1.2	ψ(.)p(Hunters)	0.02	0.2899	2	0.4185 (0.1621)	0.1166
1.3	ψ(Habitat+floopla) p(Hunters)	2.22	0.0965	3	0.4063 (0.1574)	0.0106
1.4	ψ(Habitat+medsubeve) p(.)	3.00	0.0653	2	0.4085 (0.1585)	0.0211
1.5	ψ(Habitat+medsubeve)p (pumas)	3.70	0.0460	3	0.2625 (0.2277)	0.3982
1.6	ψ(Water availability)p(.)	3.79	0.0440	2	0.4036 (0.1052)	0.0430
1.7	ψ(.)p(Jaguars)	3.93	0.0410	2	0.0454 (0.0464)	0.3982
1.8	ψ(.)p(.)	4.42	0.0321	2	0.2618 (0.2271)	0.4032
1.9	ψ(Water availability) p(Pumas)	4.49	0.0310	3	0.2095 (0.1876)	0.4032
1.10	ψ(Habitat+floopla) p(Jaguars)	5.00	0.0240	3	0.4032 (0.0439)	0.0118
1.11	ψ(.)p(Pumas)	5.27	0.0210	2	0.4032 (0.1056)	0.0432
1.12	ψ(Water availability)p(Jaguars)	5.79	0.0162	3	0.2090 (0.1872)	0.4079
1.13	*Model average*				0.3201(0.1478)	
Second season (dry) (Simple model ψ=0.444)						
2.1	ψ(Habitat+floopla)p(.)	0.00	0.1905	2	0.5245 (0.1506)	0.3177
2.2	ψ(Habitat+medsubeve) p(Pumas)	0.01	0.1895	2	0.5301 (0.1532)	0.2620
2.3	ψ(Habitat+acahuales) p(Jaguars)	0.04	0.1867	2	0.2620 (0.1240)	0.3017
2.4	ψ(Water availability) p(Hunters)	1.96	0.0715	3	0.4536 (0.1195)	0.0253
2.5	ψ(Water availability)p(.)	2.00	0.0701	3	0.4536 (0.1195)	0.0258
2.6	ψ(Water availability)p(Pumas)	2.00	0.0701	3	0.5075 (0.1664)	0.2667
2.7	ψ(Water availability)p(Jaguars)	2.02	0.0694	3	0.4736 (0.2647)	0.1473
2.8	ψ(.)p(.)	2.04	0.0687	3	0.1381 (0.1236)	0.1346
2.9	ψ(.)p(Hunters)	2.04	0.0687	3	0.5075 (0.1664)	0.2667
2.10	ψ(.)p(Pumas)	6.71	0.0066	2	0.5413 (0.1891)	0.2630
2.11	ψ(Habitat+acahuales) p(Hunters)	7.87	0.0037	7	0.4443 (0.2820)	0.2645
2.12	ψ(.)p(Jaguars)	8.80	0.0023	2	0.2630 (0.0730)	0.1382
2.13	*Model average*				0.42501610)	

Note: ΔAIC is the difference between the AIC of the models where *w* represents the model weights, K is the number of model parameters, ψ is the estimate of the occupation sites, SD is the standard error and p is the probability of estimated detection.

and between seasons for the two peccary species in the study area.

Discussion

Water availability, floodplain forest and hunting pressure have been strongly related to habitat occupancy by both peccary species in the study area. These results are consistent with what has been observed in previous research suggesting that factors such as surface water availability in bodies known locally as "aguadas" are to a great extent essential for the occupancy by both species in critical times of scarcity (Briceño-Méndez et al, 2016). Therefore, these sites should be considered a priority for the conservation of peccaries in the Calakmul region.

It has been evidenced that WLP group sizes are bigger in sites with higher rainfall and in sites far from human settlements (Reyna-Hurtado et al, 2015). In this sense, the analyses of our final models indicated that occupancy in the rainy season was determined by the presence of floodplain forest and in times of water scarcity the probability of detection is influenced by hunting pressure. Additionally, it has been reported that this species prefers floodplain forests in places whitout constant hunting pressure (Reyna-Hurtado and Tanner, 2005; Briceño-Méndez et al, 2012, Briceño-Méndez et al, 2014), possibly because this is a habitat difficult for hunters to access. Considering the above, it can be assumed that habitat type, water availability and human presence are factors potentially explaining why WLP groups in Calakmul may show seasonal and unpredictable movements, as well as "disappearances" during long periods of time without apparent cause, and that requires extensive areas of habitat in good condition (Fragoso, 1998, 2004; Altrichter and Almeida, 2002; Reyna-Hurtado, 2009; Reyna-Hurtado et al, 2012, Morera-Martinez et al, 2019).

Collared peccaries can withstand major transformations of their natural habitat and even resist considerable levels of hunting (Bodmer and Puertas, 2000; Fang et al, 2008. However, it has been determined that this species in the Calakmul region is being strongly pressured by hunting and therefore its populations have been affected according to estimates of their relative abundance found well below those recorded at sites without hunting (Briceño-Méndez et al, 2016). As like WLP, our analyses suggested that occupancy by PC depend on habitat type (floodplain forests) during the dry season. Consequently, in areas with hunting pressure it tends to occupy sites with floodplain forests contrary to what was documented in a previous study where Collared peccaries preferred secondary vegetation in areas with hunting pressure (Reyna-Hurtado and Tanner, 2005). This fact may be attributable to the current strong hunting pressure to which this species is object of, which means that it may be preferring sites difficult to access for humans such as floodplain forests. However, these characteristics about the preferred habitat of CP should be addressed in future research. Although it has been shown that this is a species that can be hunted in a sustainable way in some areas of its distribution (Bodmer and Puertas, 2000, Altrichter, 2005; Fang et al, 2008; Hernández, 2013), our results suggest that at least for the Calakmul region, CP requires a conservation plan focused on the control of hunting and monitoring of its habitat in the dry season. In addition, more extensive studies of its ecology and population dynamics are required to reassess its conservation status in the region.

Considering that both peccary species are among the main prey of large predators in the Calakmul region, it is likely that our results were also influenced by natural predation by jaguars and pumas (Briceño-Méndez et al, 2017). However, it will be necessary to carry out specific studies on the ecology of these big felines to estimate their densities and evaluate their effects on the peccary populations in the region. In this sense, the presence of jaguars and pumas in the study site (Briceño-Méndez et al, 2017), would be influencing the occurrence and probability of detection for the two species of peccaries, although not significantly according to the models generated.

This study has shown the viability of monitoring to estimate habitat occupancy and the detection probability of peccary populations in the Calakmul region. Photo-trapping and direct sightings have provided important information about the presence and absence of peccaries to infer their detection probabilities which in turn allowed the construction of occupancy models with greater precision. Expanding the monitoring sites and sampling effort for both peccary species in the Calakmul region is essential to obtain estimates of vital parameters such as local colonization and extinction probabilities. The detection and non-detection method applied in this study constitutes a tool with great potential for monitoring tropical species in a vulnerable state, which would contribute to managing the improvement of their conservation status.

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Borneo's bearded pigs and traditional hunters adapted to oil palms. Then came swine fever

https://news.mongabay.com/2021/09/borneos-bearded-pigs-and-traditional-hunters-adapted-to-oil-palms-then-came-swine-fever/
by Sheryl Lee Tian Tong, Mongabey, 8th September 2021

Oil palm expansion and urbanization have altered the traditional hunting of bearded pigs by the Indigenous Kadazandusun-Murut (KDM) community in Sabah, Malaysia, a new study has found.
Researchers interviewed 38 hunters on changes in pig behavior and hunting practices before the African swine fever (ASF) epidemic hit Sabah in 2021.
They found that even though pig hunting patterns have changed dramatically, the activity remains a cornerstone of KDM communal culture for food, sport, gift-giving, festivals and celebrations.
As ASF devastates wild pig populations, the researchers' findings highlight a need for long-term hunting management that conserves both the bearded pig and Indigenous cultural traditions.
It's easier to spot the bristly, gray-brown hide of a Bornean bearded pig (*Sus barbatus*) ambling through orderly rows of oil palm trees, than amid a dense tropical forest. But modern-day pig hunting in plantations brings its own challenges. The animals are more skittish. They are sensitive to the sound of gunshots and the smell of gunpowder. Once aware of a human presence, they bolt.
It wasn't always this way. Indigenous Kadazandusun-Murut (KDM) hunters, who have for centuries tracked wild pigs through the forests of Sabah, Malaysia, reported that their prey never used to be so fearful of humans. In the past, pigs that encountered hunters "wouldn't run," but "only looked."
Today's pigs, however, are smarter: quicker to flee and harder to catch. "Now the pig has got a high school certificate," hunters told researchers, in a new study published August in People and Nature. The study, which investigates how KDM bearded pig hunting practices have changed in recent decades with oil palm expansion and urbanization, found it wasn't just the pigs' behavior that was different: hunting patterns had adapted in response, too.
Previously, hunters mainly headed to forests or mangroves to hunt pigs in traditional ways: with dogs and a spear, on foot with a gun, or using snares. But as industrial and smallholder oil palm plantations steadily replace forests, pigs and hunters are increasingly altering their behavior and practices to fit this new landscape.
According to hunters, waiting for pigs to appear in plantations is often more fruitful than actively searching for them in forests. "In the plantation you know the pig will come eventually — it's only a matter of time," one said. In the forest, "it's not as certain even if you hunt all day long."
Not only are the pigs easier to spot in plantations, their arrival and location are more predictable. Drawn to the abundant palm fruits in plantations, pigs have been known to time their appearances for the hours when oil palm workers are not around, in the early evenings or at night.
But predictable behavior doesn't always translate to a successful hunt, according to the study. Pigs foraging in palm fruit-rich plantations employ a "high-risk, high-reward" strategy and therefore tend to be more skittish, with elevated flight responses, the researchers wrote — making them harder to catch.
Because bearded pigs have for centuries been so common in Sabah, the hunting and consumption of their meat is a cornerstone of traditional KDM culture. Even as oil palm expansion

and urbanization changed cultural traditions, researchers witnessed bearded pig hunting practices enduring in “powerful ways.”

“A lot of the hunters we interviewed still hunt for the same reasons — food, sport, gift-giving and pest control,” David Kurz, first author of the study and a wildlife ecologist at Trinity College, Hartford, in the U.S., told Mongabay. “Many of their same customs still take place, with bearded pig meat shared at cultural celebrations and feasts, and other community events. There is a very strong attachment between KDM people and bearded pigs that continues today.”

But as oil palm plantations spring up in places where their forest habitats once were, and as wild pig populations slump under the African swine fever (ASF) epidemic, a creature once so ubiquitous could be lost.

From 1990 to 2010, the encroachment of oil palm and rubber plantations across the forests of Peninsular Malaysia, Sumatra and Borneo deforested and fragmented more than 20% of key bearded pig habitat. With wild populations falling more than 30% in the past two decades, the species was categorized as vulnerable in 2017.

Today, the ASF epidemic is lending fresh urgency to conservation efforts. Previously unknown to the immune systems of pigs in Southeast Asia, the virus has spread rapidly through Sabah’s numerous forests and districts since the start of this year. While harmless to humans, ASF is deadly to wild and domestic pigs alike, with fatality rates ranging from 48% to 100%.

“[The emergence of] African swine fever is a massive development. It came to Sabah after our study,” Kurz said. “Our study talks about how important the pigs are to local people, but now most of the pigs in Sabah have perished because of this virus.

“It’s a really big deal,” he added. “It means people can’t eat it at nearly the same rate anymore. It may mean they can’t preserve and pass on their cultural traditions.”

But bearded pigs are a “very resilient” species with high reproductive rates, says Benoît Goossens, director of the Danau Girang Field Centre in Sabah and a co-author of the study. A female can birth between three and 10 piglets per litter, two litters a year.

“We have evidence collected from camera traps in several protected areas that some bearded pig individuals have survived, although the numbers are extremely sporadic,” Goossens said in a statement. “[If] some individuals survived the outbreak, the population could bounce back in a few years.”

In the meantime, it’s “important for people to not hunt them if they have that option,” Kurz said. “We need to give the pigs a chance to recover.”

In Sabah, it’s legal to hunt bearded pigs for both sport and commercial reasons with the appropriate licenses. To mitigate the spread of ASF, and due to COVID-19 movement restrictions in force, the local government froze the issuance of hunting licenses in February.

Kurz called such actions “helpful” in the short term. “In the long run, depending on how the pigs are doing in different places, we might have to think about translocation or additional protection,” he said, adding that any new conservation measures should be discussed with Indigenous communities beforehand to “preserve culturally important practices and ensure food security.”

Before the ASF outbreak, Kurz and his colleagues had recommended local authorities and conservation managers consider location-specific management approaches to bearded pig hunting, such as regulating subsistence wild meat consumption by a separate standard from commercial sale.

Interviews with dozens of hunters highlight the importance of pig hunting in KDM communal culture for food, sport, gift-giving, festivals and celebrations.

"If you take the pig away, you lose a lot of different threads in these Indigenous culture groups in Borneo," Kurz said. "We need to think carefully about bearded pig conservation, but also sustainable hunting to preserve cultural traditions."

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Kurz, D. J., Saikim, F. H., Justine, V. T., Bloem, J., Libassi, M., Luskin, M. S., … Potts, M. D. (2021) Transformation and endurance of Indigenous hunting: Kadazandusun-Murut bearded pig hunting practices amidst oil palm expansion and urbanization in Sabah, Malaysia. People and Nature. doi:10.1002/pan3.10250
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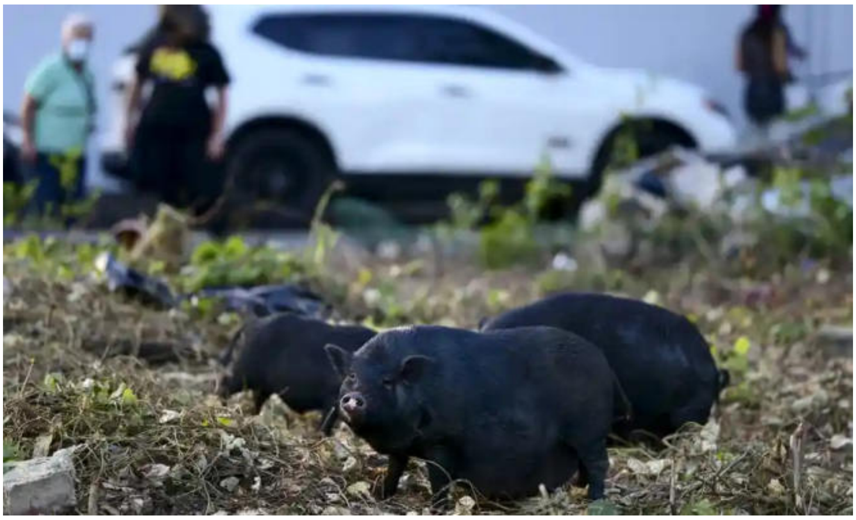
African swine fever caused collapse of bearded pig population in Sabah

https://www.nst.com.my/news/nation/2021/08/722359/african-swine-fever-caused-collapse-bearded-pig-population-sabah
by Olivia Miwil, New Strait Times, 29th August 2021

KINABATANGAN: African Swine Fever (ASF) has not only caused the collapse of the wild bearded pig population in the state but also harmed indigenous communities.
For the past nine months, the lethal virus caused the mass death of domestic and wild pigs in the state.
As a result, the lack of pigs threatened the health of the forest, as well as food security and cultural traditions in some parts of the state.Despite the situation, Danau Girang Field Centre director, Professor Benoit Goossens said there was still hope for a recovery of bearded pigs. "We have evidence collected from camera traps in several protected areas that some bearded pigs have survived, although the numbers are extremely sporadic. "The species is very resilient, and its reproductive rate is high with a female able to produce between 3 and 10 piglets. "We can therefore expect that if some survived the outbreak, the population could bounce back in a few years," he said in a statement.
Goossens was one of the co-authors of newly published research in the journal, People and Nature which revealed ways bearded pigs played important cultural and dietary roles in Indigenous Kadazandusun-Murut (KDM) communities in Sabah. An international research team from Malaysia, the UK, and the US came together to study ways oil palm expansion has affected the millennia-old hunting practices of the KDM people, the largest Indigenous group in Sabah. The team was also made up of researchers from Universiti Malaysia Sabah (UMS), Sabah Parks, Sabah Wildlife Department, Cardiff University, the University of Queensland, and UC Berkeley.Based on interviews conducted for the study, apart from food security, some hunters emphasised the importance of the bearded pig for cultural traditions. Bearded pig meat is frequently shared at festivals, birthday parties, and other celebratory events. UMS researcher Dr Fiffy Hanisdah Saikim said if the pigs could make a comeback, it would be great news for bearded pig conservation and KDM cultural traditions.
"This animal is much more than simply a game for the people of Borneo. "The bearded pig is a unique creature that bears witness to both ecological and cultural keystone species."

World's feral pigs produce as much CO_2 as 1.1m cars each year, study finds
Researchers estimate the invasive species releases 4.9m metric tonnes of greenhouse gas annually by uprooting soil

https://www.theguardian.com/environment/2021/jul/19/worlds-feral-pigs-produce-as-much-co2-as-11m-cars-each-year-study-finds
by Donna Lu, The Guardian, 19th July 2021


Feral Vietnamese pot-bellied pigs roam in Puerto Rico, where they reproduced at such a rate the government declared a health emergency. Photo: Carlos Giusti/AP

The climate impact of wild pigs around the world is equivalent to the greenhouse gas emissions of 1.1m cars annually, according to new research.
Modelling by an international team of researchers estimates that feral pigs release 4.9m metric tonnes of carbon dioxide each year globally by uprooting soil.
Researcher Dr Christopher O'Bryan of the University of Queensland said feral pigs were one of the most widespread vertebrate invasive species on the planet.
"Pigs are native to Europe and parts of Asia, but they've been introduced to every continent except Antarctica," he said.
"When we think of climate change, we tend to think of the classic fossil fuel problem. This is one of the additional threats to carbon, and to climate change potentially, that hasn't really been explored in any global sense."
Feral hogs uproot soil while searching for food, in a process O'Bryan likens to "mini tractors that are ploughing soil". Doing so exposes microbes in the soil to oxygen. The microbes "reproduce at a rapid rate and then that can produce carbon emissions [in the form of] CO_2."
"Any form of land-use change can have an effect on carbon emissions from the soil," O'Bryan said. "The same thing happens when you put a tractor through a field or you deforest land."
The researchers estimate that wild pigs are uprooting an area upwards of 36,000 sq km (14,000 sq miles) in regions where they are not native.
Oceania had the largest area of land disturbed by wild pigs – roughly 22,000 sq km – followed by North America. The pigs in Oceania accounted for more than 60% of the animal's estimated yearly emissions, emitting nearly 3m metric tonnes of CO_2, equivalent to about 643,000 cars.
The findings of the study, published in the journal Global Change Biology, were drawn from three models. One model predicted wild pig density globally across 10,000 simulations, based on existing information about wild pig populations and locations.
A second model converted pig density into an area of disturbed land, and a third estimated the amount of CO_2 emitted when soil is disturbed.
Nicholas Patton, a PhD student at the University of Canterbury, said there was some uncertainty

in the modelling as a result of the variability of the carbon content in soils and the densities of wild pigs in different areas.
"Areas that are peat bogs or black soils … especially ones that have a lot of moisture, they're a sink for carbon," said Patton. "When pigs get in there and root around, they have a lot more potential for that carbon to be released [than from other soils]."
In addition to their climate impacts, the destructive impact of wild hogs has been well documented. O'Bryan said managing the animals was a challenge that would involve prioritising whichever of their impacts was deemed most significant.
"If all we care about is agriculture, then the cost and the benefits of managing pigs will be different than if all we cared about was carbon emissions, than if all we cared about was biodiversity.
"At the end of the day, feral pigs are a human problem. We've spread them around the world. This is another human-mediated climate impact."

China mourns passing of acclaimed pig that survived 2008 quake
Pig that became Chinese national icon after surviving 36 days under rubble has died.

https://www.theguardian.com/world/2021/jun/17/china-mourns-passing-of-heroic-pig-that-survived-2008-quake
by AFP, 17th June 2021


Zhu Jianqiang, or 'strong-willed pig', in January 2021. Photo: Rex/Shutterstock

A pig that became an unlikely national icon in China after surviving 36 days under rubble following an earthquake in 2008 has died at the age of 14.
Zhu Jianqiang, meaning "strong-willed pig", shot to fame after being discovered alive after the magnitude-7.9 earthquake in south-western Sichuan province on 12 May 2008.
The earthquake left nearly 90,000 people dead or missing, and the pig's miraculous story – it subsisted on a bag of charcoal and rainwater – was hailed as an inspiring symbol of the will to survive. Witnesses said the young Zhu Jianqiang had lost so much weight by the time it was pulled from the rubble that it looked more like a goat. A museum near the city of Chengdu bought the pig for 3,008 yuan (about £335) and kept it as a tourist attraction while it lived out its days. It succumbed to "old age and exhaustion" on Wednesday night, the museum said on China's Weibo platform. In human terms, Zhu Jianqiang was 100 years old, the Global Times said, citing its breeder. It was named China's animal of the year in 2008 because it "vividly illustrated the spirit of never giving up". By midday on Thursday the Weibo hashtag "strong pig died" had drawn nearly 300m views. Weibo users hailed it as "the most famous pig in history". "It is indeed a strong animal, not just for surviving the earthquake but also for the 13 years of life afterwards," said one Weibo post.

Italian farmers have protested in recent years about soaring wild boar population wreaking havoc on crops

https://www.theguardian.com/world/2021/may/14/wild-boar-corner-woman-in-rome-and-steal-food-shopping
by Lorenzo Tondo, The Guardian, 14th May 2021

A herd of wild boar surrounded a woman who had just come out of a supermarket near Rome and stole her shopping, rekindling a debate about the presence of the animal in Italian towns and cities. A video posted on social media on Thursday shows the boars approaching and cornering the woman in a supermarket car park in the village of Le Rughe.

The animals, four adults and two young boars, pursue the woman as she backs away, attempting in vain to keep them at bay. The angry woman is then forced to drop the shopping bag on the ground, which is immediately raided by the animals. The little ones start eating the contents of the bag in the car park, others take what they can and run away.

“I don’t believe my eyes,” said the author of the video.

Last October, the mayor of Rome ordered an investigation after a family of wild boars, commonplace in the city, were shot and killed by police in a children’s playground near the Vatican. The event sparked protests by animal rights activists and some locals. In recent years, Italian farmers have protested about wild boar wreaking havoc on their land and causing fatal road accidents. Wild boar are believed to be responsible for an average of 10,000 road accidents a year in Italy.

There have been cases of people being injured or killed in attacks and an increase in sightings of boar rummaging through rubbish in urban areas.

Last month, Coldiretti, the country’s largest farmers’ association, described the increase in the number of the animals in some Italian regions as unsustainable and asked the authorities to intervene.“We must act as soon as possible and involve the army if necessary,” Coldiretti said in a statement, citing the situation in Piedmont.

Two million boar are estimated to roam Italy and hunting them is a popular pastime. Boar meat is a staple of Tuscan and Umbrian cuisine.

They are not only an Italian affliction. In Greece, sightings of swine in urban centres have become commonplace, with one spotted taking a late-night stroll through Thessaloniki’s central square only last week.

Since the start of the pandemic villagers have increasingly complained of packs of wild boar descending from nearby forests to raid gardens around homes in the quest for food.

As in Italy, Greek farmers have voiced concern about the damage wrought on crops as a result of galloping reproduction rates. The explosion has been attributed to climate change but also the ban on hunting imposed by Covid. On Wednesday, Prof Christos Vlachos at Thessaloniki University’s department of forestry and natural environment described the appearance of the animals in urban areas as especially worrisome. “It is serious and is going to get more serious,” he told the country’s state news agency. “Their reproduction cycles have got smaller because with climate change we have milder winters and, as a result, they give birth to six to ten little ones three times every two years.”

The curb on hunting had also contributed to the population explosion. “Hunting is a regulatory mechanism that ultimately contains the population because it puts a break on reproduction [rates]," he said. While hunting policies needed to be adjusted it was vital that wild boar populations were more closely monitored, the academic told the agency.

African swine fever rips through parts of southern Indonesia

https://news.mongabay.com/2021/03/african-swine-fever-rips-through-parts-of-southern-indonesia/?utm_medium=Social&utm_source=Facebook#Echobox=1617032324
by Ebed de Rosary, Mongabey, 29*th* March 2021

An outbreak of African swine fever has flared up in the Indonesian province of East Nusa Tenggara, officials say, killing tens of thousands of pigs.
The island of Flores, famous for its Komodo dragons, is particularly hard hit, with a single district there losing up to 40% of its pigs.
An official with a local nonprofit working with farmers and fishers says the death toll may be far higher because many pig farmers aren't reporting the deaths of their animals to authorities.
The swine flu outbreak also threatens Southeast Asia's various wild pig species, many of which are rare and endangered. African swine fever is seeing a resurgence in Indonesia's southern East Nusa Tenggara province, government officials say, undermining food security and fueling fears that the viral disease could jump to other species.
The disease has done the most damage in China, where tens of millions of pigs have either died from it or been culled since 2018. But it is increasingly wreaking havoc in Southeast Asia after jumping to the region from its northern neighbor. Since July 2020, tens, or perhaps hundreds, of thousands of pigs in East Nusa Tenggara are said to have died from ASF. The disease seemed to have disappeared from the region in late 2020, before returning in 2021.
Flores, famous for its Komodo dragons, is one of the islands that has been hard hit. Simon Nani, the head of the livestock department in East Flores district, said in mid-March that ASF had killed 35,000 pigs there, up to 40% of the population. His counterpart in nearby Nagekeo district, Klementina Dawo, said her office had recorded 6,048 deaths from the disease. Albert Moang, from the agricultural office in Sikka, another Flores district, said 11,919 pigs there had died since February 2020.
Atong Gomez, a pig farmer in Sikka, said that when the virus began to spread, he sold nearly half of his pigs at a low price. "I panicked," he told Mongabay, adding, "I cleaned their pen twice a day, sprayed disinfectant and fumigated the pen so that flies" — thought to be one vector of the disease — "wouldn't come." Carolus Winfridus Keupung, the director of Wahana Tani Mandiri, a local nonprofit that works with farmers and fishers, said he believes the death toll is far higher because many pig farmers weren't reporting the deaths of their animals to authorities. The government, he added, needed to more to prevent the virus from spreading further.
"There must be real action to restrict trade," he said. "Pigs are dying everywhere, and the community is suffering great losses … If a pig costs 3 million rupiah [$207], tens of billions of rupiah of income are being lost. The government is talking about the Food Estate" — a central government plan to establish large-scale plantations in several provinces — "but people's food security has been destroyed."

The battle to control America's 'most destructive' species: feral pigs
These "ecological zombies" will eat almost anything and can live almost anywhere.

https://www.nationalgeographic.com/animals/article/battle-to-control-america-most-destructive-invasive-species-feral-pigs
by Stephen Robert Miller, National Geographic, 26th March 2021

COLUMBIA, SOUTH CAROLINAA layer of frost clings to the grass on the morning Tony DeNicola sets out to check his trap. It's late January in South Carolina. The sun is rising, the fog is lifting, and the frogs are croaking from somewhere in the dark loblolly pines. In a whisper, DeNicola explains what will happen.
"I wait for them to tire themselves out and then start tipping them over," he says, shifting a loaded rifle from his shoulder and cautiously approaching a clearing in the forest beside a small cattle ranch.
DeNicola is a Yale-educated ecologist with the build of a wrestler, the jawline of a G.I. Joe, and a talent for making destructive species disappear. Most of the time, he runs a small nonprofit that does the dirty work of curtailing overabundant wildlife in national parks and quiet East Coast neighborhoods. But he came south from Connecticut to tackle America's most destructive and seemingly unsolvable wildlife problem: the invasive feral hog.
Over centuries, this adaptable, omnivorous creature has rooted its way from Florida to Kansas, inundated Texas and California, and recently has been banging for entry at the northern border of Montana. Today, there are between six and nine million hogs running wild across at least 42 states and three territories. The exact number is difficult to pin down, and the estimated cost of the damage they cause—probably about $2.5 billion annually, according to the U.S. Department of Agriculture—is likely an underestimate.
In their relentless march across the country, pigs plow through crops, tear up roads and infrastructure, spread disease, and elbow native species out of fragile marshes, riversides, grasslands, and forests. Many researchers consider them the most destructive invasive species on the planet. Stacked against other invasive species, DeNicola says, "Hogs are like a neutron bomb compared to a conventional bomb."
Landowners, sport hunters, and wildlife managers have deployed all manner of technology and weaponry to keep feral hogs from wreaking havoc. Despite grenade launchers and airborne assault rifles, remote-controlled snares, and illegal poisons, the pig has persisted.
To DeNicola, their success is proof that the old ways of managing wildlife are out of step with the modern world. A professional who kills with icy efficiency in the name of conservation, he's caught between animal rights activists who abhor the killing of any animal and recreational hunters who don't want to lose a favorite quarry.
His trap is a novel design that's so simple he can't believe it took 20 years for him to invent. "This trap is going to blow everything else away," he says. "It would cost billions to hire people to manage hogs, but this model will help people manage it themselves."
As he comes within earshot of the muddy clearing this chilly morning, there are no panicked squeals or agitated grunts. The bait corn is mostly gone, and there are hundreds of hoof prints frozen in the mud, but they belong only to deer.
He's frustrated, but not flustered. He has spent more time studying hogs—their feeding, mating, social behavior, and the way different-size bullets pass through them—than he'd like to admit. He

knows they'll come.

Pigs in America

No pig or any other member of the swine family, Suidae—which includes warthogs, Russian boar, and domestic pigs—is native to the Western Hemisphere. Those found here today trace their lineage back to a wild boar that likely evolved in Southeast Asia and was imported to the Americas over centuries.

Their arrival on the North American continent involved a who's who of early colonization. Christopher Columbus stocked the West Indies with domestic pigs to feed his Grand Fleet in 1493. They reproduced so quickly that the Spanish crown ordered their population reduced just 12 years later. In 1539, Hernando de Soto brought more than 300 swine along on his murderous 3,000-mile march around North America. Along the way, his pigs escaped into the countryside and were traded to Native people. Later, colonists raised their hogs free-range, letting them loose on the land to fend for themselves.

In the mid-19th century, millionaire hunting aficionados imported purebred Eurasian wild boar to hunting reserves in New Hampshire, North Carolina, California, and Texas. These large and aggressive pigs were favored, like largemouth bass, for the fight they put up. By the 1980s, many state game departments were stocking hogs to create a public hunting resource. As domestic pigs escaped captivity and interbred with wild animals over the centuries, America's feral swine developed into the motley bunch we know today.

They have few natural predators and move in familial groups called sounders that range in size from a handful to a few dozen members. Like domestic pigs, they learn quickly, maintain complex social relationships, can choose to resolve conflicts without violence, and seem to understand what they see in a mirror. (Related: This species of wild pig knows how to use tools.)

Generally stout and barrel-chested, most weigh less than 300 pounds and are covered in coarse hair. Both males and females grow tusks, which can reach over 19 inches and can loop around to puncture the jaw—if they're not worn down by rooting.

Rooting is also their most destructive behavior: Pigs drive their snouts and tusks into the ground and, like stubby-legged bulldozers, plow through crops, soil, forest floor, and golf green. They do it in search of grubs or acorns to eat, to cool off on summer days, to communicate, and, as far as scientists can tell, for the sheer joy of it. In the wake of a sounder, a newly planted field can resemble no man's land on the Eastern Front, gutted in a network of trenches and craters several feet deep.

Damage and destruction

The afternoon after finding his trap empty, DeNicola drives south to the sloping coastal plain of the Low Country to share a prototype with Corrin Bowers, the 37-year-old mayor of Estill, population 3,282. Bowers' family arrived in what are now the Carolinas about a century after the pigs, and, like his father, he grows peanuts, corn, and cotton on 2,500 acres. He estimates that wild hogs cost him around $10,000 in damages each year.

More than a million acres of South Carolina are tilled for field crops, and while farmers here have long battled drought, flood, and deer, they now find they're fattening hordes of pigs as well. To slow the animal's advance, DeNicola aims to put as many of his traps as possible into their hands.

"We don't get to plant this anymore because hogs will completely devastate this ground," Bowers says, pointing to a barren field. At one time this 25-acre plot was thick with peanuts, but sitting less than 10 miles from the Savannah River, it's vulnerable. When the river floods, hogs escape

uphill into crops, and when it dries to a trickle, they come to wallow in the puddles left by irrigation.
Ruts caused by their rooting can sink a tractor and destroy expensive equipment, including the long sprayers that irrigate wide fields. “Your sprayer will be riding along, and next thing you know you can’t see it because it’s hit a hole,” Bowers says. New equipment can cost $350,000, and repeated repairs account for most of his annual pig-related expenses.
Wild hogs stick close to river valleys, but South Carolina farmers noticed an uptick in activity on their fields following a government program that boosted peanut production. In response, many have switched to other crops, but the pigs keep coming. “On peanuts they’re terrible. On corn they’re terrible. They won’t nip the tips off of cotton like deer do,” Bowers says, but they’ll plow over rows of four-foot cotton plants in search of the salt in fertilizer.
“We haven’t been able to find a crop that feral swine won’t eat,” says Stephanie Shwiff, a research economist with National Wildlife Research Center.
For many growers who are kept up at night by the grunts of a sounder descending on their property, the physical damage accounts for only part of their exhaustion. “We control everything we can and thank the Lord when we get rain on our dry land,” Bowers says, “but you can only do so much before you’re just deep down to where you can’t even go anymore.”
In South Carolina alone, feral swine inflict some $115 million in damages on agricultural industries, according to a recent Clemson University study. Aside from destroying fields, they can introduce harmful bacteria to water supplies through their feces, chew through the roots of timber seedlings, and have been known to hunt lambs and calves.
What worries Shwiff most, though, is their potential to transmit diseases like African swine fever and rabies to farm animals. If that happens, she says, “the implications for our economy immediately go into the billions of dollars.”
As a conservation ecologist, DeNicola is most concerned with how unsparingly feral swine ravage native wildlife. They prey on fawns and endangered salamanders. They raid the clutches of ground-nesting birds and threatened sea turtles. They outcompete deer and wild turkey for resources and often beat coyotes to the scene of a kill. Wild hogs are linked to the decline of 22 species of plants and four species of amphibians, and research shows that a habitat where they’re present is more than a quarter less biologically diverse than one where they’re not.
This unparalleled toll has earned invasive hogs the moniker “ecological zombies.”
“Porkchoppering,” tracking dogs, and the Pig Brig
In turn, Americans kill pigs at an astonishingly vicious pace. After white-tailed deer, feral pigs are the most popular big game animal in North America, though existing patchy data hardly bear out the true extent. In 2019, South Carolina hunters reported killing 31,508 hogs while pursuing deer. There is no record of the scads of others that were hunted and trapped deliberately.
In many states, wildlife agencies have declared open season: There are no designated hunting periods, no limits to the number of pigs a hunter can shoot, and few restrictions on the means used to kill them.
Wildlife managers depend on recreational hunters to help keep animal populations in balance, and state agencies are funded primarily by hunting taxes and fees. Hunters spend millions on weapons, ammunition, clothing, optics, and permits, as well as travel and hospitality. They set traps and poison bait (illegally), and fire everything from pistols to grenade launchers.
It’s not surprising that pigs have responded by becoming largely nocturnal, and so hunters now also invest in night vision optics and thermal-scoped rifles. In Texas, which harbors some 2.6

million wild hogs—more than any other state—shooting from helicopters has become a popular activity called “porkchoppering.” Hunters pay more than $1,000 for an hour of aerial gunning, then shell out another $100 for a video of the experience.

At his torn-up peanut farm, Bowers walks past the gutted carcasses of two dead hogs, shot last night and left for scavengers. “Almost every farmer has somebody who’s trying to shoot” their pigs, he says. “I have three crews of guys that run dogs. They come once a week, at least.” Using trained dogs to corner wild hogs is one of the most effective ways to ensure a clean—and therefore more humane—shot, but hogs are smart, and hunters who repeat tactics see diminishing returns.

“We were cleaning up out there, taking over a thousand pigs a year off the site using dogs,” recounts research scientist Jack Mayer, who has spent the better part of 30 years looking for a solution to the hog problem at the Savannah River National Laboratory in South Carolina. “I thought this was the answer.” But over time the hogs stopped turning to face the dogs and took to outrunning them instead. “I wonder if we haven’t just created a population of runners that we can’t kill,” he says.

Mayer doubts invasive hogs will ever be wiped from the Southeast; they’re too smart, and hunters simply can’t kill enough of them. To eradicate hogs, their population must drop 60 to 80 percent each year. In a busy year, recreational hunters kill only about 24 percent. Meanwhile, healthy sows can birth three litters of 10 piglets every year.

Images of the violence hunters inflict while trying to keep pace—panicked pigs fleeing airborne gunners, lifeless sounders heaped haphazardly in traps—invariably draw concerns about animal welfare, but not to the extent DeNicola has experienced when managing other more charismatic and less destructive species, like deer.

Dave Pauli, wildlife conflict resolution program manager for the Humane Society of the United States, says lethal control will always be part of the solution, but he notes that “there are very few modern-day examples of ‘killing your way to controlling a wildlife species.’”

Success will require a task-force approach of nonlethal means used in concert with trapping and shooting carried out by trained experts, he says. Over time, state agencies and private landowners “need a cultural shift from ineffective pig hunting revenue to pig control income streams” that view the killing as long-term management, not sport.

Across the country, landowners and wildlife managers have experimented with everything from noisemakers to sturdier fences and sterilization. They tend to be no easier and certainly no cheaper than firearms. Several poisons are in development, and one has been approved by the Environmental Protection Agency. These can kill a pig in anywhere from a few hours to 15 days. So far, though, no state has approved them out of concern that toxins will linger in the ecosystem, harming scavengers and hunters who may unknowingly feed a poisoned pig to their families.

With a trap 20 feet in diameter, landowners can round up all the animals in an area so they can be easily and humanely shot. As long as they snare the entire sounder, traps are the most effective option, Mayer says. Hogs left outside become smart to the tactic and unlikely to enter another metal cage. That’s where DeNicola’s design is unique.

The Pig Brig, as he calls it, is a circular corral like most pig traps, but it’s made out of netting instead of heavy metal panels. Rather than relying on an expensive remote-operated trap door that requires a cellular signal, his trap takes advantage of a pig’s natural tendency to root. The animals push under the net, which is draped in an unbroken circle from a ring of rebar posts, then find themselves in a lobster trap. The hem of the net drapes a few feet toward the corral’s center and becomes an impenetrable barrier once boars stand upon it. Importantly—for both the scale of the problem and DeNicola's intent to put these traps in the hands of multitudes—the Pig Brig is lightweight, simple to set up, and relatively cheap (a basic model costs $1,500).

As DeNicola finishes setting a prototype on Bowers' land, the farmer, who is no stranger to pig traps, looks it over. "This is pretty ingenious," he says, and it may be. Still, DeNicola's trap shares one weakness with every other design on the crowded hog-management market: It requires that someone actually wants to eradicate invasive pigs.

"People hate hogs," he explains, "but they love their guns and they love having something to shoot."

A region at odds

The Low Country is sopping, steaming, and teeming with huntable life. Not only white-tailed deer, black bear, and coyote, but also alien armadillo and alligators. Locals are proud of their rebounding wild turkey, but most everyone agrees that, more than any other target, hogs are a hoot to shoot. The chance of bagging the next Hogzilla draws eager sportsmen to hundreds of hunting plantations across the South and funds a simmering culture war between plantation owners and neighboring farmers.

"If you're a farmer and losing crop, you want to get rid of them. Plantation owners making money off them don't," Mayer explains flatly. Farmers with hog problems often point to nearby game resorts as the root of their trouble. Pigs are notorious escape artists, and broken fences are common on 10,000-acre properties. Adding insult to injury, wealthy landowners looking to start or add to a hunting resort can often outbid farmers for cropland real estate.

Acknowledging that the cultural and economic popularity of killing hogs is driving their growth, eight states have banned wild hog hunting. That will never happen in South Carolina, Mayer says. "In the 1990s the state and USDA questioned landowners in the Low Country about cooperating with getting rid of pigs. They got death threats."

Today, illegally transporting hogs to establish new hunting opportunities is driving expansion beyond the South. In Colorado, wild hogs began appearing for the first time in small pockets of farm country around 2000. Their limited numbers were Colorado's "saving grace," says Travis Black, a wildlife manager with Colorado Parks and Wildlife. Small groups are easier to eliminate than large, dug-in populations, and agents immediately set about tracking many of the disparate sounders to shoddy fencing on nearby plantations while intercepting U-Haul trucks packed with smuggled pigs.

The state's early piecemeal resistance became a larger effort after outbreaks of Porcine Reproductive and Respiratory Syndrome, a highly infectious disease carried by feral swine, hit pig farms in 2005. "That got the attention of the USDA," Black says.

In 2014, with livestock producers clamoring for help, Congress appropriated $20 million toward the creation of a national feral swine task force. Four years later, it set aside another $75 million in the 2018 Farm Bill to fund pig trapping, monitoring, research, and restoration, and to offer financial assistance to affected farmers in a dozen states. The money has paid for everything from aerial gunning to the development of techniques that detect pig DNA in stream water.

Buoyed by that support, Colorado last February declared itself the first state to eradicate invasive feral hogs. Black says they were fortunate to have had a head start. In South Carolina, where hogs predate statehood by two centuries, wildlife officials say they'll be happy just to limit the damage.

Like brown trout and Asian ring-necked pheasant, feral swine are foreigners that have rooted into

American land and culture, blurring the line between the native and the invasive. Their unmatched destructiveness, however, easily overshadows their finer traits, like their exceptional faculty for survival. “They are truly remarkable creatures,” the economist Shwiff says, noting that few other species can eke out a living in almost every environment and in the face of undaunted hostility.

To DeNicola, the situation is straightforward: People brought them here and now people have to deal with them. He maintains that with discipline and scientific understanding, pigs can be solved. “Human complacency, that’s the ultimate problem,” he says.

At the end

More than a week after DeNicola set his trap and a motion-detecting camera in the muddy clearing, the hogs finally show up. It’s 6:14 in the morning and raining. They scrape at the mud and nibble on the teasing bits of bait spread meagerly around the trap’s edge, but the real prize is at the center: a 50-pound pyramid of golden corn kernels. By 6:50, an entire sounder of 14 pigs is shouldering for a mouthful inside the enclosure, unaware of what’s to come.

DeNicola reaches the clearing just after 9 a.m. By then, the rain has stopped, the sun is rising over the pines, and the hogs are in a frenzy. They throw themselves at the net, biting, gnawing, and tearing with their tusks. Adults clamber over screeching piglets. A 200-pound boar launches itself at the enclosure and springs back onto the others. Some, exhausted, writhe hopelessly in the mud.

DeNicola stands about 10 yards away and waits for them to settle. Then he raises his rifle.

Fourteen cracks, and the forest is silent.

Pig nest-building promotes tree diversity in tropical forest: Study

https://news.mongabay.com/2021/03/pig-nest-building-promotes-tree-diversity-in-tropical-forest-study/
by John C. Cannon, Mongabey, 15th March 2021

New research from a tropical forest in Malaysia reveals that wild pigs, better known for their destructive tendencies on farms and in ecosystems, may actually help encourage tree diversity in forests. Expectant mother pigs will build nests amid clumps of saplings, which are usually from a set of tree species common to the forest.

When the sow kills these saplings for the nest, she’s effectively providing a check on any one species becoming dominant in the forest.

The research demonstrates the benefits that pigs can bring to forest health, but they also note that pig populations that grow too numerous could — and do, in places — keep the forest from regenerating.

Wild pigs have reputation as a destructive lot. Farmers and scientists alike know that, when they’re too numerous, their constant rooting and wallowing can run roughshod over crops and regenerating ecosystems. The predators that hunt them may have disappeared, or logging or agriculture may have degraded the forest, allowing pig populations to mushroom.

But such destructive tendencies also might be a boon to the overall health of forests in the right circumstances, according to recent research. A study, published in the journal Proceedings of the Royal Society B: Biological Sciences on March 3, reveals that when sows build nests on the rainforest floor, they help maintain the balance of tree species diversity in the forest. Mother pigs in the forests of Southeast Asia typically look for beds of seedlings that have sprouted on flat, dry areas of the forest. They then clip these shoots or pluck them from the ground to form a protective nest for their young's first weeks of life.

Lead author and wildlife ecologist Matthew Luskin of Australia's University of Queensland said that pigs are "efficient" builders. "They don't shop at many different stores, each selling one plank, and then carry all the materials to build the house in a different location," Luskin said in an email. "They go to lumber yard to get all the materials needed to build a house, and then build the house right there in the lumber yard!" The origins of the team's research stretch back decades in the Pasoh Forest Reserve in Peninsular Malaysia. Tapirs, civets and sun bears haunt Pasoh's primary forest, along with a lot of native wild pigs (*Sus scrofa*) — a "hyper-abundance," in fact, according to 2001 research by ecologist Kalan Ickes.

In 1995, a team from the Smithsonian's Forest Global Earth Observatory (ForestGEO) had tagged more than 30,000 saplings in the Pasoh plot as part of their global network of tree censuses. Then, in 1996, Ickes's doctoral research led him to begin scouring the forest for pig nests. When he found tagged saplings in a nest, he made a note of it. In the end, he had compiled a list of around 1,800 tags from more than 200 nests.

Around two decades later, Luskin teamed up with Ickes, currently based at Clemson University in South Carolina, to match up those tags with the tree census data from ForestGEO, down to the species of tree and the sapling's original location. Luskin found that the patches preferred by expectant sows were full of seedlings from a relatively narrow set of species, especially considering that Peninsular Malaysia is home to more than 700. He also discovered that the seedlings tended to be from more common species in the forest, while rare tree species weren't typically present in the clumps of seedlings where pigs chose to build their nests.

"This provides a rare species advantage that can maintain diversity," Luskin said. When a pig kills those seedlings for her nest, she's effectively providing a check on a small group of prevalent trees becoming too dominant and helping to cultivate the wonderous array of species dwelling in the region's forests.

Still, Luskin and his co-authors are quick to caution that too many pigs in an area can throw off the delicate equilibrium of the forest ecosystem.

"While pigs may contribute to diversity, these findings must be viewed in context," said Stuart Davies, director of the ForestGEO program and a co-author of the study, in an email. "One has to remember, the hyper-abundance of wild boar in a number of Asian forests is dramatically reducing tree regeneration and perhaps even the functional composition of these forests. This may have long-term deleterious consequences for Asian rainforests."

Luskin said pigs could also "magnify" the loss of tree regeneration in forests that have been logged for timber or turned into oil palm plantations.

On the other hand, other research has shown that the complete disappearance of pigs could also damage the health of the forest.

"This is exactly the finding from a nearby site where pigs were hunted out: tree seeds and seedling survived, total understory growth increased, and tree diversity decline," Luskin said.

He said a disease like African swine fever, which is almost universally deadly to pigs and recently took hold in Southeast Asia, could touch off dramatic changes in the makeup of the forest.

"This new paper underscores the delicate balance between wildlife and environmental processes: human-influenced overabundance or underabundance of wildlife can have far-reaching effects on the whole ecosystem," said David Kurz, a wildlife ecologist and doctoral candidate at the University of California, Berkeley, in an email. "We can throw ecological communities out of

whack either way."
Kurz studies wild pigs in tropical forests and is a former lab mate of Luskin's, but was not involved in this study.
"As conservationist Gerald Durrell once said," Kurz added, "the world is like a spider's web — by tearing one thread, we send shivers running through all the others."
The study provides further evidence of pigs' role as ecosystem engineers because of the outsize influence they have over their surroundings. But to Luskin, the fact that these animals, maligned in so many contexts for the damage they can cause, can provide benefits is "a little positive silver lining to the overall negative storyline," he said — or as, he likes to call it, a "silver swining."
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Hippos and anthrax

Studying hippo movement provides insights into anthrax outbreaks in Tanzania.

https://www.sciencedaily.com/releases/2021/06/210615132311.htm
University of California - Santa Barbara, 15th June 2021

Summary: Hippopotamus aren't the first thing that come to mind when considering epidemiology and disease ecology. And yet these amphibious megafauna offered ecologists a window into the progression of an anthrax outbreak that struck Ruaha National Park, Tanzania, in the dry season of 2017.

Hippopotamus aren't the first thing that come to mind when considering epidemiology and disease ecology. And yet these amphibious megafauna offered UC Santa Barbara ecologist Keenan Stears a window into the progression of an anthrax outbreak that struck Ruaha National Park, Tanzania, in the dry season of 2017.
Through surveys and GPS monitoring, Stears and his colleagues, Wendy Turner, Doug McCauley and Melissa Schmitt, revealed that reduced dry-season flows in the Great Ruaha River indirectly spread the disease by affecting hippo movement. The results, which appear in the journal Ecosphere, present a unique perspective on disease ecology and illustrate how anthropogenic changes can impact wildlife and human health. The ecology of wildlife disease was far out of mind during the dry season in 2016, when Stears and his team outfitted 10 male hippos with GPS collars. The researchers sought to track the animals' movements to better understand their behavior and ecology, especially in light of reduced flows along many of Africa's major rivers. The resulting study was the first to track hippo movement and land use, and finally uncovered some of the basic facts about hippos' spatial ecology.

Then the anthrax came.
"This wasn't something I actually set out to study," said Stears, a postdoctoral researcher in the Department of Ecology, Evolution and Marine Biology. "You can't plan for an outbreak to occur; it just happens."
Stears was in the field from 2016 to 2017 conducting hippo counts and maintaining equipment. The GPS tracking collars had been on the animals for about a year, roughly as long as they're supposed to last before dropping off. Noticing one of the collars hadn't moved for a couple of days, he figured it had fallen off. It appeared to be in a nearby pool, so Stears hiked out to retrieve it. "I turned around a bend in the river, and there was a hippo pool with about six or so hippo carcasses," he recalled. Stears had stumbled upon an anthrax outbreak.
Anthrax is an infection caused by the bacterium Bacillus anthracis, which can manifest in a variety of ways depending on how it's contracted. The bacterium is notable for its ability to produce spores that can lie dormant in the soil for years. Notably, in outbreaks like the one in this study, animals can only spread the disease once they die.
Although he isn't a disease ecologist, Stears quickly realized his GPS data could illuminate aspects of the outbreak. There didn't seem to be any existing studies that combined a spatio-temporal account of an active anthrax outbreak with wildlife movement, he explained. "So this was really a unique opportunity to answer some questions that hadn't really been answered before."
"We can't predict when an anthrax outbreak will occur, so it's impossible to plan such a study," added co-author Wendy Turner of the U.S. Geological Survey and the University of Wisconsin-Madison. "This project is in part a fantastic bit of luck (for understanding disease transmission, not for the hippos), and in part very clever and quick thinking by Keenan and Melissa at UCSB, to capitalize on such a unique opportunity.
"I have been studying anthrax for years in Namibia, with many more GPS-collared hosts monitored than the 10 in this study," she continued, "and I still haven't had any of our individuals succumb to the disease."
The team first had to determine how many hippos in this population had interacted with potentially infected pools. That meant identifying which of the many disconnected pools along this stretch of the Great Ruaha River were infected. Stears' colleagues at Ruaha National Park conducted sampling for the pathology to confirm the anthrax outbreak.
Stears and his team conducted daily counts of both live and dead hippos in these pools. The surveys enabled them to track the disease's spread, its rate and direction. The scientists were also curious where the hippos were coming from, where they were going and whether the outbreak was influencing their behavior.
The researchers linked this information with the hippo movement data they had from the GPS collars. Four of the 10 hippos they had tracked could have caught the disease, Stears said, and of those, three died.
The team found that infection had no noticeable effect on a hippo's movement. Infected individuals roamed just as much as healthy hippos. "This has important implications for how far a single individual could potentially vector the disease before its death and create new infectious reservoirs," Stears said. Under certain conditions, wildlife can succumb to infection within a few days. Even if this is the case, a hippo can walk about seven kilometers over the course of a night in search of water. Thus, hippos can quickly move the disease over large distances.
What's more, the animals didn't appear to actively avoid carcasses. Why? Well, dry times are not

good times to be a hippo. Normally, species avoid the bodies of their own kind. But with suitable ponds so scarce, the amphibious animals were forced to remain in pools alongside the dead.

"The drying of rivers is one of the major reasons why these outbreaks have gotten so bad over the years," Stears explained. "As the river dries, hippos are forced to congregate in the remaining river pools. Now this paper's showing that their movements spread the disease as well."

Anthrax outbreaks are a natural occurrence, but drying rivers are making them worse. As pools dry up, hippos either pack into those that remain or move to find new ones. Increased crowding and social interactions can drive up physiological stress, which scientists have linked to a greater susceptibility to infection.

Additionally, altered hippo movements as they search for new pools raise the risk of exposure to anthrax reservoirs as well as the duration that they interact with these reservoirs. Aggressive interactions around the remaining pools mean that hippos frequently visit several in a given night. All these factors have exacerbated anthrax outbreaks in hippo populations.

Stears noted that hippos also appear particularly susceptible to these outbreaks, aggregating as they do in small, dirty pools during the dry season. Other animals avoid drinking from hippo pools during these times because of all the dung that has accumulated due to the lack of river flow. Instead, they seek out shallower puddles that are cleaner, which potentially protects them from contracting lethal doses of the disease.

"Understanding disease outbreaks in hippos is especially important," said co-author Doug McCauley, an associate professor of ecology, evolution, and marine biology (EEMB) at UC Santa Barbara. "People don't often realize that hippos are a vulnerable species that has declined in many areas. There are far less hippos, for example, than African elephants. Their outlook is further complicated by potential impacts that climate change may have on rivers and how this change might amplify disease outbreak risk."

Stears plans to start looking at historical records of river flow across Africa and linking changes in hydrology to past anthrax outbreak timing and severity. There hasn't been much research on anthrax and river flow, he said; most of the work has been terrestrial. The historical records could be a treasure chest of information.

Shedding light on the factors that influence disease dynamics helps scientists predict how disturbances might affect future outbreaks. With this information, they can begin to assess how future circumstances could affect the extent and severity of an anthrax outbreak, as well as the probability that it jumps to other species of wildlife, livestock and even humans.

"Hippos can be considered the canary in the coal mine," added co-author Melissa Schmitt, an EEMB postdoctoral researcher. "Their sensitivity to adverse conditions makes them a good indicator of how global change may influence disease dynamics and overall wildlife health.

In all, the paper represents a confluence of events that offered an unparalleled opportunity to explore novel disease dynamics. "You can only get this kind of information from having an animal that is collared and actually infected," Stears said. "So this unique situation allowed us to answer questions that you just can't normally answer without having everything lined up."

Journal Reference:

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Understanding and combatting African Swine Fever – A European perspective

African Swine Fever (ASF) has become one of, if not the most, important threat to wild pig species in Asia and to the Eurasian wild boar populations across Europe and Asia (see also two articles about ASF in this issue of Suiform Soundings). To fight this disease and stop its spread among countries and different wild pig species and domestic pigs a multi- and interdisciplinary approach is needed. We therefore welcome the timely arrival of a book entitled, "Understanding and combatting African Swine Fever – A European perspective" by Laura Iacolina, Mary-Louise Penrith, Silvia Bellini, Erika Chenais, WPSG member Ferran Jori, Maria Montoya, Karl Ståhl and Dolores Gavier-Widén. The aim of the book is to share and spread all available scientific information about ASF to avoid its spread in Europe for the protection of wild pigs and the European pig industry.

The book has twelve chapters and eleven of them are written like a scientific article. The different chapters deal with ASF as a major challenge for pig health during this century, cellular and molecular aspects of ASF, immune responses against ASF virus infection, the pathology of ASF, diagnosis of ASF and environmental samples, ASF vaccines, the pig sector in the European Union, management of wild boar populations before and during the ASF crisis, epidemiology, surveillance and control of ASV, biosecurity measures against ASF in domestic pigs, cleaning and disinfection in the domestic pig sector and, finally, a chapter summarising the main conclusions of each advancing chapter. It would be far beyond the scope of this review to discuss each chapter in detail. However, this is THE most up-to-date multi- and interdisciplinary book dealing scientifically with ASF. The lessons learned from this book should help to prevent the spread of ASF further in Europe and will also help scientists and veterinarians in Asian countries to get now ideas how to fight against the virus.

Understanding and combatting African Swine Fever – A European perspective
by Laura Iacolina, Mary-Louise Penrith, Silvia Bellini, Erika Chenais, Ferran Jori, Maria Montoya, Karl Ståhl and Dolores Gavier-Widén (editors)
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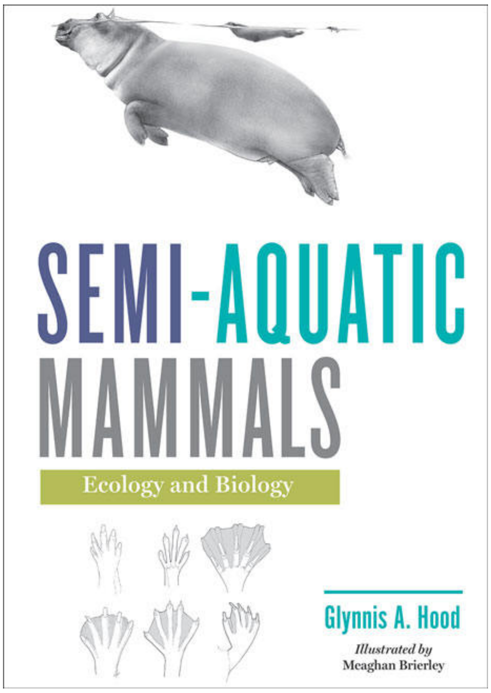
Reviewed by Thiemo Braasch

Semi-aquatic Mammals – Ecology and Biology



There are only few mammal species that have adapted to two worlds: land and water. Therefore, they are called semi-aquatic. About 140 mammal species can be considered to have a semi-aquatic lifestyle. The book described here closes a gap because it is the first comprehensive examination of the natural history of semi-aquatic species all around the world. Most of these semi-aquatic mammal species are rodents, followed by carnivores, Eulipotyphla (shrews and desmans), hoofed mammals, and also other groups like otter-shrews, hares and rabbits, water opposums and the famous platypus. Regarding Suiformes, the two hippo species and the three babirusa species are semi-aquatic species.

In the introductory chapter semi-aquatic mammals are defined and all of the 140 semi-aquatic mammal species are mentioned. The author Glynnis A. Hood explains that all three babirusa species are classified as terrestrial-freshwater specialists because of their clear dependence on wetlands and seasonal flooded plants. It is obvious that due to their traits and life history both hippo species are also included in this book.

The following part of the book is divided into five parts. The first part deals with geographical distribution and habitats. The chapters of this part are about paleobiology (including a short description of ancient hippo species), the distribution of semi-aquatic mammal species among continents and in zoogeographic realms and ecological niches. The second part on physiology describes the morphology, physiological adaptations as well as locomotion and buoyancy of these semi-aquatic mammals. The third part is on foraging strategies and niches of predatory semi-aquatic mammals, including a section on predator-prey interactions. Part four of the book deals with reproduction and part five is on the conservation challenges and management approaches and also the status and threats to semi-aquatic mammals and also introductions and reintroductions strategies. This part is especially interesting because the challenges of conserving species living in the water and on the land are discussed using different examples from around the world. The Sulawesi babirusa is mentioned here.
Overall, this book is well written and in an entertaining style. A glossary is helpful for readers not familiar with some terms. The marvellous illustrations by Meaghan Brierley throughout the book and also the helpful maps and tables complete this compendium about the ecology and biology of semi-aquatic mammals.

Semi-aquatic Mammals – Ecology and Biology
by Glynnis A. Hood, illustrated by Meaghan Brierley
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These groups consist of technical experts focusing on the conservation and management of wild pigs, peccaries and hippos.
The broad aim of the these groups is to promote the longterm conservation of wild pigs, peccaries and hippos and, where possible, the recovery of their populations to viable levels.

Pigs, peccaries and hippopotamuses are nonruminant ungulates belonging to the Suborder Suiformes of the Order Artiodactyla (the eventoed ungulates). Within the Suborder Suiformes, pigs belong to the Family Suidae, peccaries to the Family Dicotylidae and hippopotamuses to the Family Hippopotamidae.